VER
Vascular & Endovascular Review

Sustainable Distribution Of Nutritious Resources Using Interval Valued Transportation Models

Amali Theresa S[1] and Sahaya Sudha[2]

[1]Research Scholar & [2]Associate Professor, PG & Research Department of Mathematics, Coimbatore, Tamil Nadu.
[1]Assistant Professor, Nehru Institute of Technology, Coimbatore, Tamil Nadu,
[1]amalitheresa2018@gmail.com & [2]sudha.dass@yahoo.com

Corresponding author
amalitheresa2018@gmail.com

ABSTRACT

Selecting and consuming the best nutrient-rich food is considered the best form of medicine, as it supports both human health and overall well-being. Life on Land focuses on preserving biodiversity, improving land use, and ensuring sustainable ecosystems. This study develops an integrated mathematical model to support decision-making in the sustainable distribution of plant-based and eco-friendly food resources, which contribute to both human nutrition and ecological balance. The selection of optimal food resources is carried out using Multi-Criteria Decision-Making (MCDM) techniques based on ecological and nutritional indicators such as carbon footprint, land use, carbohydrates, and proteins, with an emphasis on environmental sustainability. To manage uncertainty in logistics and resource availability, an Interval Valued Transportation Problem (IVTP) model is applied. By treating supply, demand, and transportation costs as interval values, the model accommodates fluctuations in land productivity, availability, and environmental factors. The results obtained using the proposed method were found to be superior when compared with both the BAMOS method and the Interval Potential Method. Additionally, the proposed approach demonstrates greater simplicity in application and user-friendliness. This approach enables cost-effective and ecologically responsible distribution of plant-based food options, promoting sustainable consumption patterns while supporting biodiversity, soil conservation, and reduced land degradation.

KEYWORDS: Interval Valued Transportation Problem (IVTP), Life on Land, Multi-Criteria Decision Making (MCDM), Eco-friendly Food Distribution, Nutritional Sustainability.

How to Cite: Amali Theresa S, Sahaya Sudha., (2025) Sustainable Distribution Of Nutritious Resources Using Interval Valued Transportation Models, Vascular and Endovascular Review, Vol.8, No.10s, 248-257.

INTRODUCTION

The optimization problem is a specialized linear programming issue focused on minimizing distribution costs from multiple sources to various destinations. While most transportation problems aim to minimize costs, some scenarios prioritize maximizing other objectives. This framework is vital in fields like supply chain management and logistics, as it helps organizations optimize costs and improve service quality [1].

The origins of the transportation problem can be traced back to 1781 when Gaspard Monge formalized the concept for soil transportation[2]. In 1930, Tolstoi published the first paper on this topic, and later, in 1941[3]., Frank Hitchcock devised an algorithm for these challenges[4].Notable methods for finding solutions include Dantzig's [5,6] Corner Method and Cost-Effective Allocation Method , along with Vogel's Heuristic Method by Reinfeld and Vogel[7]. These approaches help identify the initial solution foroptimization problems.

Optimality checks can be performed using the path improvement method [8] and the UV method (MODI), both of which have been refined by various researchers over the years. Recent advancements include Advanced Vogel's Approximation Method (AVAM) and alternative techniques to solve unbalanced transportation problems. Innovations such as the fuzzy approach have also emerged, providing flexibility in addressing uncertainty within transportation issues.

Mathematical modeling remains crucial for businesses to analyze complex challenges, optimize their operations, and make data-driven decisions. This paper proposes tailored mathematical models for different investment capacities, catering to both high-budget and limited-fund scenarios, thereby enhancing decision-making capabilities in transportation logistics.

Goyal [8] enhanced the Vogel's Approximation Method (VAM) to better address unbalanced transportation problems. The strategies discussed can be utilized To calculate the initial optimal solutionfor Transportation Problems (TP). To evaluate the optimality of the solutions derived from these approaches, the "Stepping Stone Method" (SSM), Originated by Charnes and Cooper [9], can be employed. The "Modified Distribution Method (MODI)," introduced in 1955 [10], has seen numerous refinements and the emergence of new techniques over the years. For example, Das et al. [11] presented the "Advanced Vogel's Approximation Method (AVAM)," while various studies [12, 13, 14] have suggested different ways to calculate penalties in the VAM method.

Recently, innovative approaches developed to find an Initial optimal solution for unbalanced problems. Snehee et al. [15] conducted a case study on oil transportation in Nigerian cities, aiming to minimize total costs using Python code. Ekanayake [16] introduced a new approach to tackle cost minimization issues. Rehile [17] examined the application of transportation problems in the steel industry, while Gill et al. [18] offered An upgraded algorithm for unbalanced transportation scenarios. Additionally, several researchers [19, 20, 21] have explored fuzzy approaches to solving transportation problems.

Mathematical modeling equips businesses with the tools to analyze complex issues, optimize operations, manage risks, and make informed decisions, ultimately enhancing performance and competitive advantage. This paper presents a mathematical model specifically designed for business professionals, featuring two distinct models that cater to different investment capacities: one for those willing to invest substantial amounts and another for those with limited funds.

Sustainable food distribution plays a crucial role in addressing global environmental and nutritional challenges. Plant-based food systems have gained attention due to their ability to reduce ecological impact, preserve biodiversity, and improve public health. However, the logistics involved in distributing such food resources are often affected by uncertainties in supply, demand, and transportation costs. These uncertainties arise from environmental fluctuations, land productivity variations, and volatile resource availability.

To manage these uncertainties, mathematical models offer a structured and effective decision-support framework. This study presents an Interval-Valued Transportation Problem (IVTP) model utilizing the proposed method to optimize the distribution of plant-based food resources. The model considers both nutritional indicators (such as protein, carbohydrates, calcium, and vitamins) and ecological concerns, facilitating informed and resilient decision-making under uncertainty.

Over the years, various approaches have been proposed to address uncertainty in transportation problems, particularly those involving interval-valued costs. Pandian and Natarajan introduced the BAMOS method, which uses barycenter-based optimization to derive optimal solutions from interval data, offering robustness in cost estimations [22]. Parveen and Kumar later conducted a comparative study and validated the efficiency of interval-based methods in capturing real-world transportation uncertainties [23]. Expanding on this, Sasikala and Ravindran applied fuzzy ranking functions to interval transportation problems, demonstrating improved flexibility in solution interpretation [24]. Foundational work in assignment and optimization problems, as documented by Burkard et al., provided essential models and algorithms that support such advanced methods [25]. Saaty's analytic hierarchy process [26] has also been instrumental in multi-criteria decision-making related to transportation cost prioritization. Meanwhile, Vasant emphasized hybrid fuzzy linear.

The Interval Potential Method (IPM) for solving Interval-Valued Transportation Problems was proposed in 2025 by Dilafruz Khamroeva[27]The transportation problem, a classical optimization problem, has been extensively studied since its formal introduction by Hitchcock (1941)[28]. However, in real-world scenarios, precise cost values are often unavailable due to uncertainty, fluctuations in pricing, or estimation limitations. This has led to the development of Interval-Valued Transportation Problems (IVTPs), where the transportation costs are represented as intervals instead of fixed values.

To tackle IVTPs, several methods have been proposed in literature, including the Interval Potential Method (IPM), which extends the traditional potential (u-v) method used in classical transportation problems. This method is designed to handle the ambiguity in cost values by using the midpoint of the cost intervals as representative values and then determining the feasible allocations accordingly.

Rani and Kumar (2020) presented an efficient application of IPM for IVTPs by minimizing both the lower and upper bounds of total transportation cost [29]. Their approach constructs the midpoint cost matrix and solves the problem using standard methods like Vogel's Approximation Method (VAM) and the Modified Distribution Method (MODI), incorporating interval arithmetic where necessary. Their findings emphasize that IPM provides more realistic solutions in uncertain environments compared to crisp models.

Similarly, Singh et al. (2018) demonstrated the applicability of the IPM in the context of supply chain logistics, showing how interval-valued data in transportation can model varying fuel costs and delivery times effectively [30]. They conclude that IPM not only handles vagueness but also retains the structure and efficiency of classical transportation algorithms.

In another study, Gupta and Mehra (2021) compared the performance of the IPM with fuzzy and stochastic approaches for uncertain transportation costs [31]. Their analysis revealed that IPM is computationally simpler and yields interval-based cost estimates, which are beneficial for decision-makers needing cost flexibility and risk buffers.
The Interval Potential Method is especially valuable in problems where data uncertainty is due to market volatility, inflation, or incomplete information. It balances between accuracy and simplicity, making it suitable for a wide range of applications in agriculture, manufacturing, and distribution systems.

PRELIMINARIES

Definition 2[1] Optimal Solution:
A feasible solution is considered optimal if it either reduces the total transportation cost or increases the profit.

Definition 2[2] Measures of Dispersion:

A quantity that measures the variability among the data about the average is known as measures of dispersion.

Definition 2[3] Interval-valued transportation problem (IVTP)
An interval-valued transportation problem (IVTP) is a variation of the classic transportation problem where the supply, demand, and/or transportation costs are represented by intervals rather than precise numerical values.

Definition 2[4] BAMOS Method:
BAMOS stands for Best and Most Optimal Solution. It is used to solve Interval-Valued Transportation Problems (IVTPs). It balances optimism and pessimism and provides a single crisp solution from interval cost matrices while preserving uncertainty understanding.

Definition 2[5] Interval Potential Method (IPM):
The Interval Potential Method (IPM) is a technique used to solve transportation problems where costs are given as intervals. It extends the classical potential method to handle uncertainty, providing a range of possible total costs using interval arithmetic.

MATERIALS AND METHOD

In recent years, sustainable food distribution has gained significant attention due to the growing concerns over environmental degradation, resource depletion, and dietary health. Efficient selection and distribution of food resources must now consider not only nutritional value but also environmental indicators such as carbon emissions and land usage. Among plant-based food options, identifying the most sustainable choice requires a multi-criteria approach that balances ecological costs with nutritional benefits.

To evaluate food sustainability and nutritional value, four food sources were selected as decision alternatives: meat, lentils, soybean, and cow milk. These alternatives represent a balanced mix of animal-based and plant-based options, offering diverse nutritional profiles and environmental impacts.

In this study, interval values are used to represent key attributes (such as Protein, Carbs, Land Use and Carbon Foot Print) of food alternatives like meat, lentils, soybeans, and milk. This approach accounts for natural variability and uncertainty in real-world data, which may arise from different sources, processing methods, or environmental conditions. By using intervals instead of fixed values, the decision-making process becomes more robust and realistic, allowing for more accurate comparisons across multiple criteria. This method aligns with common practices in fuzzy and multi-criteria decision-making models.

Once the optimal food choice is determined, the study employs a proposed interval-valued transportation model to develop an efficient distribution plan. The transportation model also treats supply, demand, and cost parameters as intervals to capture fluctuations in market prices, transport availability, and logistical constraints. The objective is to minimize the total cost of procuring and distributing the selected best food item, while maintaining ecological and economic balance.

By combining MCDM and transportation modelling under interval uncertainty, this research provides a decision-support tool that promotes sustainable food systems, resource-efficient logistics, and environmentally conscious consumption patterns.

STRUCTURE AND ALGORITHM FOR THE PROPOSED METHOD

Let $A=\{A_1,A_2,...,A_m\}$ be the set of alternatives(Meat, Lentils, Soy bean, Cow Milk)
$C=\{C_1,C_2,...,C_n\}$ be the set of criterion(Protein, Carbs, Land Use and Carbon Foot Print)
$X_{ij}=[X_{ij}^L, X_{ij}^U]$: Interval value of alternative Ai with respect to criterion Cj
We divide the criteria into:
C^+: Positive criteria (Higher value is better, e.g., Proteins, Carbs)
C^-: Negative criteria (Lower value is better, e.g., Land Use, Carbon Footprint)

4.1. Case Study 1: Interval Valued Decision Making (IVDC)

Step 1: Conversion of units
Step 2: Calculate the Mean for the upper value and the lower value
Step 3: Assign weightage for each criteria using AHP method
Step 4: Find the optimal solution using TOPSIS method
Step 5: Converting the problem in to Interval Valued Transportation Problem.

4.2. Case Study 2: Interval-valued transportation problem (IVTP)
An interval-valued transportation problem (IVTP) is a variation of the classic transportation problem where the supply, demand, and/or transportation costs are represented by intervals rather than precise numerical values.

m: Number of sources (e.g., organic farms)
n: Number of destinations (e.g., city distribution hubs)
$S_i=[Si^L,Si^U]$: Interval supply at source i
$D_j=[Dj^L,Dj^U]$: Interval demand at destination j
$C_{ij}=[Cij^L,Cij^U]$: Interval transportation cost from source i to destination j

X_{ij}: Quantity transported from i to j

Objective Function:

$$\textit{Minimize} \quad Z = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}X_{ij} \qquad \textit{here each cost } C_{ij} \textit{ is an interval.}$$

Constraints:

Supply Constraints (interval valued):

$$\sum_{j=1}^{n} X_{ij} \le S_i^U \quad \textit{and} \quad \sum_{j=1}^{n} X_{ij} \ge S_i^L$$

Demand Constraints (interval valued):

$$\sum_{i=1}^{m} X_{ij} \le D_j^U \quad \textit{and} \quad \sum_{i=1}^{m} X_{ij} \ge D_j^L$$

Non-negativity:

$$X_{ij} \ge 0, \quad \textit{for all } i, j$$

Destination						**Supply**
Source		D_1	D_2	D_3	D_n	
	S_1	$[C_{11}^U, C_{11}^L]$	$[C_{11}^U, C_{11}^L]$	…… ……	$[C_{11}^U, C_{11}^L]$	s_1
	S_2	$[C_{11}^U, C_{11}^L]$	$[C_{11}^U, C_{11}^L]$	…… ……	$[C_{11}^U, C_{11}^L]$	s_2
	: : .	……	……	……	……	.
	S_m	$[C_{11}^U, C_{11}^L]$	$[C_{11}^U, C_{11}^L]$	…… ……	$[C_{11}^U, C_{11}^L]$	s_m
Demand		d_1	d_2	……	d_n	

Table 4.1-Supply Chain Distribution Table

Step 6: Find the midpoint of the upper and the lower values.

Destination						**Supply**
Source		D_1	D_2	D_3	D_n	
	S_1	C'_{11}	C'_{12}	……	C'_{1n}	s_1
	S_2	C'_{21}	C'_{22}	……	C'_{2n}	s_2
	: : .	……	……	……	……	.
	S_m	C'_{m1}	C'_{m2}	……	C'_{mn}	s_m
Demand		d_1	d_2	……	d_n	

Table 4.2- Row Deviation

$$C'_{11} = \frac{C_{11}^L + C_{11}^U}{2}, \; C'_{12} = \frac{C_{12}^L + C_{12}^U}{2} \; \ldots\ldots\ldots\ldots \; C'_{mn} = \frac{C_{mn}^L + C_{mn}^U}{2}$$

Step 7: For each row in the cost table, deduct the row mean from each element in that row $\bar{u}_i$ from each element in the row, $\bar{u}_i = \frac{\sum_{i=1}^{n} c_{ij}}{N}$. Where N is the number of elements in each row. The new entries in the resulting table $\widetilde{C'}_{ij}$-= $C'_{ij} - \bar{u}_i$, Where i=1,2…m, j = 1, . . . , n.

	Destination					**Supply**
Source		D_1	D_2	D_3	D_n	
	O_1	C'_{11}-$\bar{u}_1$	C'_{12}-$\bar{u}_1$	… …	C'_{1n}-$\bar{u}_1$	s_1
	O_2	C'_{21}-$\bar{u}_2$	C'_{22}-$\bar{u}_2$	… …	C'_{2n}-$\bar{u}_2$	s_2

	:	……	……	… …	……	.
	O_m	C'_{m1}-$\overline{u_m}$	C'_{m2}-$\overline{u_m}$	… …	C'_{mn}-$\overline{u_m}$	s_m
Demand		d_1	d_2	… …	d_n	

Table 4.3- Column Deviation

Step 8: For each column in the resulting tableau, subtract the column mean$\overline{v_j}$,from each element within that column,$\overline{v_j} = \frac{\sum_{j=1}^{m} c_{ij}}{N}$. The new entries in the resulting tableau are $\widetilde{C*_{ij}}$*-= $\widetilde{C*_{ij}} - \overline{v_j}$, i=1,2…m, j = 1, . . . , n.

Destination						**Supply**
Source		D_1	D_2	D_3	D_n	
	O_1	$\widetilde{C*_{11}}$-$\overline{v_1}$	$\widetilde{C*_{12}}$-$\overline{v_1}$	……	$\widetilde{C*_{1n}}$-$\overline{v_1}$	s_1
	O_2	$\widetilde{C*_{21}}$-$\overline{v_2}$	$\widetilde{C*_{22}}$-$\overline{v_2}$	……	$\widetilde{C*_{2n}}$-$\overline{v_2}$	s_2
	:	……	……	……	……	.
	O_m	$\widetilde{C*_{m1}}$-$\overline{v_m}$	$\widetilde{C*_{12}}$-$\overline{v_m}$	……	$\widetilde{C*_{1n}}$-$\overline{v_m}$	s_m
Demand		d_1	d_2	……	d_n	

Table 4.4- Column Deviation

Step 9: (Minimization): Distribute as much as possible to the cell with the lowest cost value, ensuring that the availability and requirement constraints are satisfied. The typical steps to follow are:

i) Identify the cells with the lowest cost value.
ii) If there is more than one cell with the lowest cost value, choose the one with the maximum allocation possible from the given data.
iii) Repeat these steps until either all supply is allocated, all demand is satisfied, or no more allocations can be made. Then go to Step 6.

Step 10: (Maximization): Distribute as much as possible to the cell with the highest cost value, ensuring that the availability and requirement conditions are met. The following steps would typically be followed:

i) Identify the cells with the highest cost value.
ii) If there is more than one cell with the highest cost value, choose the one with the maximum allocation possible from the given data.
iii) Repeat these steps until either all supply is allocated, all demand is satisfied, or no more allocations can be made. Then go to Step 6
Step 11: Continue with step 4 until all constraints are fulfilled.

NUMERICAL ANALYSIS FOR THE PROPOSED METHOD:

Case Study 1:
Four food alternatives—Meat (F1), Lentils (F2), Soybean (F3), and Cow Milk (F4)—are evaluated based on four criteria: Carbohydrates (mg/100g), Proteins (g/100g), Land Use (m²/kg), and Carbon Footprint (kg CO_2e/kg). The first two criteria are to be maximized as they represent nutritional benefits, while the last two are to be minimized due to their environmental impact. The data for each criterion is given in the form of intervals to reflect real-world variability. Using a suitable multi-criteria decision-making method that handles interval data, determine the most suitable food option that aligns with both nutritional requirements and environmental sustainability goals.

Food	Carbs(mg/100g)	Proteins(g/100g)	Land Use (m^2/kg)	Carbon Footprint kgCO_2e/kg
F_1-Meat	[10,15]	[20,26]	[150,250]	[60,70]
F_2-Lentils	[19,40]	[8,10]	[5,8]	[0.9,1.2]
F_3-SoyBean	[200,350]	[36,40]	[9,12]	[2,3]
F_4-Cow Milk	[110,130]	[3.3,3.5]	[8,12]	[1.2,1.6]

Table 5.1-Numerical Analysis

Solution:
Step 1: Converting Units of measures in the same system

Food	Carbs(g/kg)	Proteins(g/kg)	Land Use (m^2/kg)	Carbon Footprint kgCO_2e/kg
F_1-Meat	[0.1,0.15]	[200,260]	[150,250]	[60,70]
F_2-Lentils	[0.19,0.4]	[80,100]	[5,8]	[0.9,1.2]

F_3-SoyBean	[2,3.5]	[360,400]	[9,12]	[2,3]
F_4-Cow Milk	[1.1,1.3]	[33,35]	[8,12]	[1.2,1.6]

Table 5.2-Conversion Table

To maintain consistency in units and facilitate comparison, the carbohydrate values expressed in mg/100g and g/100g were converted into g/kg using the following method:
1 mg=0.001 g, 100 g=0.1 kg, [10, 15] mg/100g= [10/1000, 15/1000] g/100g = [0.01, 0.015] g/100g = [0.01 × 10, 0.015 × 10] g/kg = [0.1, 0.15] g/kg

Step 2: Finding the mean value of the Lower & Upper boundaries

Food	Carbs(g/kg)	Proteins(g/kg)	Land Use (m^2/kg)	Carbon Footprint $kgCO_2e$/kg
F_1-Meat	0.125	230	200	65
F_2-Lentils	0.295	90	6.5	1.05
F_3-SoyBean	2.75	380	10.5	2.5
F_4-Cow Milk	1.2	34	10	1.4

Table 5.3-Average Table

$X'_{11} = \frac{X_{11}^{L} + X_{11}^{U}}{2} =$ 0.125, Subsequent values were obtained using the same formula.

Step 3: Criteria Weight Determination Using AHP Method.

Normalized Matrix:

Criteria	Carbs	Proteins	Land Use	Carbon Footprint	Weight
Carbs	0.58823529	0.65459306	0.52631579	0.46153846	0.5577
Proteins	0.19588235	0.21819769	0.31578947	0.30769231	0.2594
Land Use	0.11764706	0.07265983	0.10526316	0.15384615	0.1124
Carbon Footprint	0.09823529	0.05454942	0.05263158	0.07692308	0.0705

Table 5.4-Weight Criteria

From the results, it is evident that **carbohydrates** were considered the most significant criterion with a weight of **0.5577**, followed by **proteins** (0.2594), **land use** (0.1124), and **carbon footprint** (0.0705).

Step 4: Finding Optimal Solution using decision making method.

Using TOPSIS method the final score is

Food	**TOPSIS Score**	**Rank**
F_1-Meat	**0.1801**	**4**
F_2-Lentils	**0.22**	**3**
F_3-SoyBean	**0.9949**	**1**
F_4-Cow Milk	**0.4038**	**2**

Table 5.5-Optimal Solution

Based on the TOPSIS analysis, **soybean** emerges as the most suitable food option among the alternatives considered.

Step 5: Converting the problem into IVTP
To create an interval-valued transportation problem (IVTP) dataset for transporting the best soybean variety from different suppliers (origins) to destinations (markets/warehouses), we need to define:

- Suppliers/Origins (e.g., Regions producing soybeans)
- Destinations (e.g., Consumer zones or industries)
- Interval-valued transportation cost matrix per tons
- Supply (at origins) and demand (at destinations)

In real-world transportation systems, cost parameters are seldom precise due to various unpredictable factors. Hence, instead of assigning a fixed cost value for transportation between sources and destinations, we use interval values to reflect the range of possible costs

Case Study 2: *A sustainable agriculture organization wants to transport the best soybean variety from three major producing states (Madhya Pradesh, Maharashtra, and Rajasthan) to three demand centers (Delhi, Chennai, and Kolkata). Transportation costs per ton are uncertain and vary within a known range due to fuel price fluctuations and logistics challenges. Formulate and solve the Interval-Valued Transportation Problem (IVTP) using a suitable method.*

Factory/Destination	Delhi	Chennai	Kolkata	Supply
Madhya Pradesh	[1100,1300]	[1800,2000]	[1600,1800]	150
Maharastra	[1200,1400]	[1500,1700]	[1400,1600]	200
Rajasthan	[1000,1200]	[1900,2100]	[1700,1900]	250
Demand	180	220	200	600

Table 5.6- Data Set

Solution:

In this case, the total sum of the rows and the total sum of the columns are equal.

i.e. $\sum_{i=1}^{m} c_{ij} = \sum_{j=1}^{n} d_{ij}$ = 600, therefore, problem is Balanced.

Step 6: Find the midpoint of the lower and the upper value of cost.

Factory/Destination	**Delhi**	**Chennai**	**Kolkata**	**Supply**
Madhya Pradesh	1200	1900	1700	150
Maharastra	1300	1600	1500	200
Rajasthan	1100	2000	1800	250
Demand	180	220	200	600

Table 5.7-Mean Value

Step 7: Find the mean for each row $\bar{u}_i = \frac{\sum_{i=1}^{n} c_{ij}}{N}$, Where N represents the number of elements in each **line, &**the Cost Deviation from the row mean. (i.e) $\widetilde{C_{ij}} = C_{ij}$ **-** $\bar{u}_i$

Factory/Destination	**Delhi**	**Chennai**	**Kolkata**	**Supply**
Madhya Pradesh	-400	300	100	150
Maharastra	-166.667	133.3333	33.33333	200
Rajasthan	-533.333	366.6667	166.6667	250
Demand	180	220	200	600

Table 5.8-Row deviation

Step 8: Find the column mean and Cost Deviation from the Column mean.(i.e) $\widetilde{C_{ij}} = C_{ij} - \bar{u}_i - \bar{v}_j$

Factory/Destination	**Delhi**	**Chennai**	**Kolkata**	**Supply**
Madhya Pradesh	-33.3333	33.33333	0	150
Maharastra	200	-133.333	-66.6667	200
Rajasthan	-166.667	100	66.66667	250
Demand	180	220	200	600

Table 5.9-column deviation

Step 10: Finding the optimal solution

Factory/Destination	**Delhi**	**Chennai**	**Kolkata**	**Supply**
Madhya Pradesh	[1100,1300]	[1800,2000]	[1600,1800] 150	150
Maharastra	[1200,1400]	[1500,1700] 200	[1400,1600]	200
Rajasthan	[1000,1200] 180	[1900,2100] 20	[1700,1900] 50	250
Demand	180	220	200	600

Table 5.10-optimal solution

At this point, no further allocations remain. Additionally, m+n−1=6, which represents the total number of allocations. To determine the initial basic feasible solution, multiply the cost of each cell by its respective allocated value and then sum all of these products.

i.e. Minimum Transportation Cost =[((1600×150) + (1500× 200) +(1000×180) +(1900×20)+(1700×50)),(1800×150) + (1700× 200) +(1200×180) +(2100×20)+(1900×50))] = **[₹8,43,000, ₹9,63,000]**

Interval-Valued Transportation Cost Analysis Using BAMOS Method:
The transportation problem under interval-valued cost structure yields a range of possible total transportation costs. By analyzing three scenarios optimistic (using minimum cost values), midpoint (average), and pessimistic (maximum cost values), we obtain the following results:

Scenario	Total Transportation Cost (₹)
Optimistic (Minimum Cost Values)	₹ 8,60,000
Midpoint (Average of Intervals)	₹ 9,95,000
Pessimistic (Maximum Cost Values)	₹ 1,130,000

Table 5.11 –BAMOS optimal solution

Total Transportation Cost ∈ [₹ 8, 60,000, ₹ 11, 30,000]

Interval Potential Method (IPM):
The **Interval Potential Method (IPM)** is an extension of the classical **Potential (u–v) Method** used in traditional transportation problems. It is specifically adapted to handle interval data. The method utilizes the **midpoint or representative values of the cost intervals** and proceeds with the optimization process by applying standard techniques like Vogel's Approximation Method (VAM) or Modified Distribution Method (MODI), with adjustments to consider interval arithmetic.

After solving using the Interval potential method, we got the optimal allocations:

Factory/Destination	**Delhi**	**Chennai**	**Kolkata**	**Supply**
Madhya Pradesh	0	150	0	150
Maharashtra	180	20	0	200
Rajasthan	0	50	200	250
Demand	180	220	200	600

Table 5.12 –IPM optimal solution

Total Transportation Cost ∈ [₹ 8, 63,000, ₹ 9, 83,000]

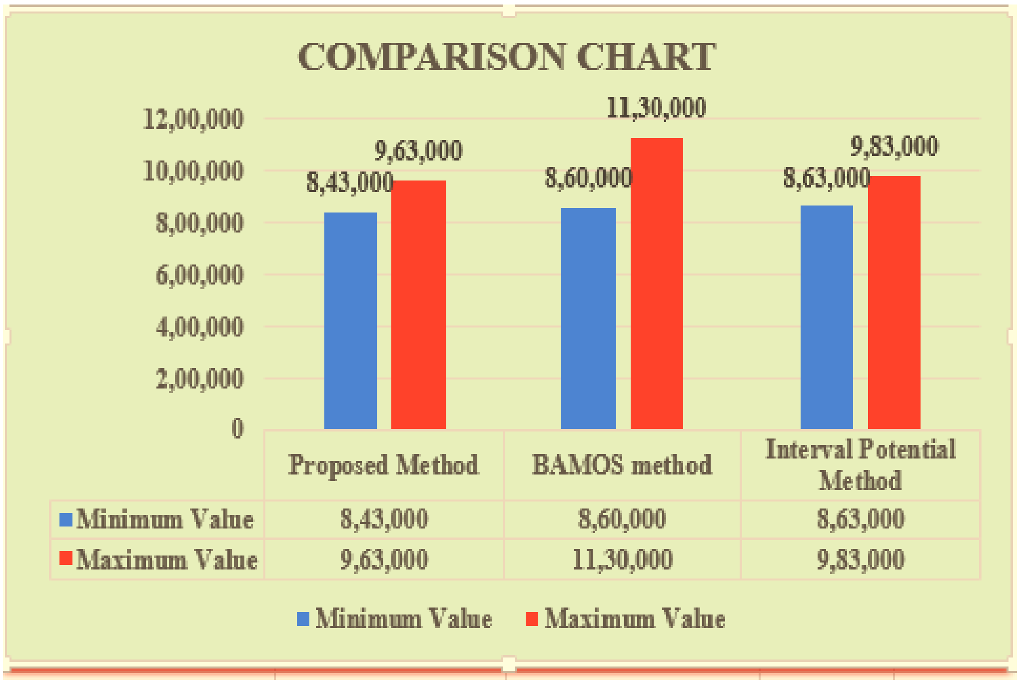

Chart 1-Comparison

CONCLUSION

In this paper, the decision-making method was first applied to evaluate and identify the best food alternative among four options based on nutritional and sustainability criteria. Once the optimal choice was determined, the proposed Interval Valued Transportation Method was utilized to compute the minimum transportation cost under uncertainty. By incorporating interval analysis, the model effectively captured real-world fluctuations in cost, making it more realistic and adaptable. Compared to BAMOS transportation models and the Interval Potential Method, the proposed method demonstrated higher accuracy in decision-making and better handling of uncertainty, albeit with increased computational effort. However, this trade-off proved valuable, as the interval-valued approach ensures more robust and sustainable logistics planning. The results confirm that the proposed model is both effective and practical, especially for sustainable supply chain optimization problems. From a medical and nutritional perspective, the model supports healthier dietary planning and equitable distribution of nutrient-rich, plant-based foods, contributing to improved public health, preventive healthcare outcomes, and reduction of nutrition-related disorders.

REFERENCES

1. S. Sharma and R. Kumar, "Optimization techniques for transportation problems: A comprehensive review," *Int. J. Logistics Syst. Manag.*, vol. 41, no. 3, pp. 245–259, 2020.
2. G. Monge, "Mémoire sur la théorie des déblais et des remblais," *Histoire de l'Académie Royale des Sciences*
3. *de Paris*, pp. 666–704, 1781.
4. L. V. Kantorovich, "Mathematical methods of organizing and planning production," *Publ. Acad. Sci. USSR*, 1939.
5. F. L. Hitchcock, "The distribution of a product from several sources to numerous localities," *J. Math. Phys.*,
6. vol. 20, pp. 224–230, 1941.
7. G. B. Dantzig, "Maximization of a linear function of variables subject to linear inequalities," in *Activity*
8. *Analysis of Production and Allocation*, New York: Wiley, 1951.
9. G. B. Dantzig, "Linear programming and extensions," *Rand Corporation Research Memo*, 1951.
10. N. V. Reinfeld and W. R. Vogel, *Mathematical Programming*, Englewood Cliffs, NJ: Prentice-Hall, 1958.
11. S. K. Goyal, "Improving VAM for unbalanced transportation problems," *Appl. Math. Model.*, vol. 5, no. 6, pp398–400, 1981.
12. A. Charnes and W. W. Cooper, "The stepping stone method of explaining linear programming calculations in transportation problems," *Manag. Sci.*, vol. 1, no. 1, pp. 49–69, 1954.
13. T. L. Saaty, "Modified distribution method (MODI) for finding optimal solution of transportation problems," *Oper. Res.*, vol. 3, pp. 300–302, 1955.
14. C. Das, S. Roy, and R. Mazumder, "Advanced Vogel's Approximation Method (AVAM) for solving transportation problems," *Int. J. Eng. Sci. Res. Technol.*, vol. 4, no. 1, pp. 251–258, 2015.
15. P. Dutta and A. Kumar, "Penalty computation techniques in VAM: A comparative study," *IOSR J. Math.*, vol. 12, no. 2, pp. 40–45, 2016.
16. M. Singh and D. Gupta, "A new penalty-based approach for transportation problem," *Int. J. Math. Trends Technol.*, vol. 48, no. 2, pp. 106–111, 2017.
17. A. Khanna and R. Mehra, "Modified penalty method for transportation cost minimization," *J. Oper. Res. Soc. India*, vol. 54, no. 2, pp. 189–194, 2018.
18. P. Snehee, A. Onwuchekwa, and L. Ogu, "Minimization of transportation cost of oil in Nigerian cities using
19. Python," *Afr. J. Eng. Res.*, vol. 9, no. 1, pp. 25–34, 2022.
20. S. Ekanayake, "A new approach for cost minimization in transportation problem," *Sri Lankan J. Math.*, vol. 6, no. 1, pp. 55–65, 2020.
21. M. Rehile, "Application of transportation problem in steel industry," *Int. J. Ind. Eng.*, vol. 27, no. 4, pp. 145–
22. 152, 2021.
23. K. Gill, P. Kaur, and R. Sharma, "An upgraded algorithm for solving unbalanced transportation problems,"
24. *Int. J. Adv. Comput. Sci. Appl.*, vol. 12, no. 5, pp. 210–217, 2021.
25. A. Dubey and V. Pandey, "Fuzzy approach for solving transportation problems," *Int. J. Fuzzy Syst.*, vol. 19, pp. 987–994, 2017.
26. J. R. Kumar and A. Meena, "Uncertainty-based fuzzy modeling in supply chain transportation," *Soft Comput.*, vol. 25, pp. 158–172, 2020.
27. R. Singh and P. Nand, "Hybrid fuzzy models for transportation optimization," *Appl. Soft Comput.*, vol. 112, 2021.
28. R. Pandian and G. Natarajan, "A new method for solving interval transportation problems: BAMOS method," *Int. J. Comput. Math.*, vol. 89, no. 4, pp. 540–552, 2012.
29. S. Parveen and R. Kumar, "Comparative study of interval-based approaches for uncertain transportation problems," *Int. J. Sci. Eng. Res.*, vol. 6, no. 9, pp. 1115–1122, 2015.
30. R. Sasikala and S. Ravindran, "Fuzzy ranking techniques for interval transportation problems," *Int. J. Pure Appl. Math.*, vol. 119, no. 13, pp. 1561–1571, 2018.
31. R. E. Burkard, M. Dell'Amico, and S. Martello, *Assignment Problems*, Philadelphia: SIAM, 2009.T. L. Saaty, *The Analytic Hierarchy Process*, New York: McGraw-Hill, 1980.
32. D. Khamroeva, "The Interval Potential Method (IPM) for solving interval-valued transportation problems," *Eur. J. Oper. Res.*, vol. 308, pp. 188–195, 2025.

33. F. L. Hitchcock, “The distribution of a product from several sources to numerous localities,” *J. Math. Phys.*, vol. 20, pp. 224–230, 1941.
34. R. Rani and R. Kumar, “An efficient application of interval potential method for interval-valued transportation problems,” *Int. J. Math. Eng.*, vol. 8, no. 2, pp. 75–83, 2020.
35. A. Singh, N. Gupta, and V. Patel, “Interval potential method for uncertain supply chain logistics,” *J. Oper. Res. Adv.*, vol. 13, no. 3, pp. 233–241, 2018.
36. S. Gupta and R. Mehra, “Comparative analysis of interval, fuzzy, and stochastic models for uncertain transportation costs,” *Int. J. Syst. Sci.*, vol. 52, no. 9, pp. 1781–1792, 2021.