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A STATISTICAL TECHNIQUE: NORMAL DISTRIBUTION AND INVERSE ROOT MEAN SQUARE FOR SOLVING TRANSPORTATION PROBLEM†

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Abstract. This research aims to determine an optimal (best) solution for transporting the logistics at a minimum cost from various sources to various destinations. We proposed a new algorithm for the initial basic feasible solution (IBFS). Developing a new IBFS is the first step towards finding the optimal solution. A new approach for the initial basic feasible solution that reduces iterations and produces the best answer in the initial process of the transportation issue. Different IBFS approaches have been generated in the literature review. Some statistical fundamentals, such as normal distribution and the root mean square technique, are employed to find new IBFS. A TP is transformed into a normal distribution, and penalties are determined using the root mean square method. Excel Solver is used to calculate normal distribution values. The second step involves using a stepping-stone approach to compute the optimum solution. The results of our study were calculated using numerical examples and contrasted with a few other methodologies, such as Vogel's approximation, the Continuous Allocation Method (CAM), the Supply Demand Repair Method (SDRM), and the Karagul-Sahin Approximation Method (KSAM). The conclusion of our proposed method gives more accurate results than the existing approach.

AMS Mathematics Subject Classification : 90C08, 90B06.
Key words and phrases : Transportation problem (TP), optimal solution, basic feasible solution, normal distribution, and inverse root mean square.

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1. Introduction

Transportation problems have been widely studied in operation research [1]. French mathematician Gaspard Monge (1781) formalized the TP [2]. Transportation can be seen as a special case of linear programming problems [3]. With TP, practical issues like personal assignments, task allocation in flow shop scheduling, and vehicle routing can be solved [4].

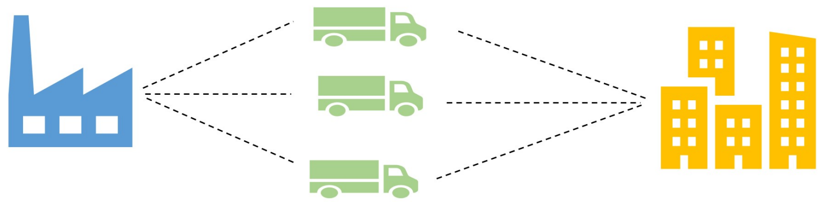

Figure 1. Transporting products from warehouses to distribution centers

A feasible solution is what's referred to as the optimal solution. A basic feasible solution to a transportation problem involves an m x n transportation problem and only m+n-1 non-negative independent allocations. The procedures of Vogel's approximation, Russell's approximation, the North-West corner, Matrix minimization, Row minimization, and Column minimization are well-known traditional techniques for obtaining the IBFS in the first phase. In the next phase, the Stepping Stone and Modified distribution technique approach commonly controls the initial solution's optimality [5].
The literature has suggested a lot of numerical models. To find an initial basic feasible solution Dr. Muwafaq Alkubais in 2015 proposed a new algorithm called modified Vogel's method to obtain a minimum cost and it will be closer to the optimum value [6]. Bilqis Amaliah et al. 2020 developed a new methodology known as the Bilqis Chastine Erma method to determine the initial feasible answer [7].
Balasubramani Prajwa, et al. in 2019 developed two new techniques for locating IBFS, the availability, and required entities for an issue are used as the key to determining allocations firstly, both for the supply-demand repair method (SDRM) and continuous allocation method (CAM) [8]. Spencer Madamedon et al. in 2022 proposed a novel method that increases the performance of the conventional Vogel's approximation method and breaks ties in the allocation decision-making process [9]. Utpal Kanti Das et al. 2014 implemented a new approach called the "Advanced Vogel's Approximation Method " to provide an efficient answer to the TP i.e., even closer to an optimal solution than Vogel's method [10].

Shubham Raval in 2023 the author developed a new approach, Raval's approximation, to discover an IBFS (Initial Basic Feasible Solution) for the ideal solution in transportation Problems. It reduces the Initial solutions with minimum TP Cost [11]. Ajoy Paul et al. in 2023 to minimize the cost of transportation the author calculated using a formula called the Index of dispersion that improves IBFS [12]. Opara Jude et al. 2017 implemented a statistical formula "Inverse Coefficient of Variation Method (ICVM)" which is a new efficient proposed method for finding the optimum solution [13]. Dhanshri A. Munot et al. 2023 developed a Modular arithmetic approach to the TP problem that reduces the transportation cost [14]. Rusli et al., in 2022 took real-life data in a bread company for transportation problems using an Improved exponential approach. The results obtained were more effective than the Northwest corner rule method [15].

Nabeela Baloch et al. in 2022 suggested Alternate allocation table method requires few processes and yields results more quickly when compared to the Allocation table method. Moreover, the goal is to minimize transportation cost [16]. K. P. O. Niluminda et al. 2023 provided a novel algorithm that addresses MOTP by combining geometric mean and the penalty technique [17].

Ekanayake et al.'s 2022 invention on, the multi-objective transportation issues in fuzzy environments using the geometric Mean Method and the Ant Colony optimization algorithm [18]. Ahmed Atallah Alsaraieh in 2023 the author developed a new method, a summation and ratio method, to determine the IBFS [19]. In 2021, the authors Amrit Das et al. plan to use the multi-objective stochastic solid transportation problem (MOSSTP) with uncertainties in supply, demand, and conveyance capacity to reduce multiple transportation costs in a solid transportation problem (STP) by using the Weibull distribution. Multi-objective optimization issues have been solved using the fuzzy goal programming methodology and the global criteria method [20].

Ekanayake E., M., D., B., et al. in 2022 innovated a novel algorithm that will reduce the cost of some restricted transportation problems. With a few modifications, the traditional Vogel approach has been enhanced [21]. A unique strategy for addressing the issue of fuzzy transportation is suggested in this research by Sandeep Singh et al. in 2014 [22]. Instead of reducing transportation costs, the major goal of this strategy is to minimize transportation time by using a maximum range method for all available resources to meet requirements. Transportation Problem with equality restrictions is where the MRM technique was developed by N. Anandhi et al. in 2022 [23]. The transportation problem in operations research is one of the optimization problems that aims to reduce the cost of TP cost, therefore the optimization can be done by Russel's and Vogel's method. Nelly Astuti Hasibuan in 2017 wanted to see the effectiveness of these two methods and also the comparison process [24]. Nopiyana, et al. in 2021 aim to provide an optimal solution to transportation issues using the Modified ASM approach [25].Amreen and Venkateswarlu developed a method based on exponential distribution and contraharmonic mean for finding the IBFs to achieve

the best solution [28]. Amreen and Venkateswarlu proposed a new algorithm for developing initial solution of transportation problem it is based on conditions [29]. Hemalatha and Venkateswarlu proposed a new ranking function for pythagorean fuzzy sets and used mean square approach for pythagorean fuzzy transportation problem [30].
Based on the above discussion, we may conclude authors proposed new techniques for allocating minimum supply and demand values to the decision variables. In our study, we proposed a new approach for finding an initial basic feasible solution with a statistical element for both conversion of TP and penalties which gives better results than the classical and existing approaches.
This study is divided into sections and subsections. Each section is important in this research. Section 1 describes the introduction and literature review. Section 2 represents the mathematical formulation of TP. Section 3 explains the materials and methods of the proposed study. Section 4 describes the numerical illustrations used in this study. Section 5 explains the results. Section 6 explains the conclusion of the proposed method.

2. Mathematical formulation for representing the Transportation Problem

This section explains the details of the mathematical formulation in Table 1.

	Destination Centers				
Warehouses	W_1	W_2	...	W_n	**Supply** (S_i)
F_1	C_{11} X_{11}	C_{12} X_{12}	...	C_{1n} X_{1n}	A_1
F_2	C_{21} X_{21}	C_{22} X_{22}	...	C_{2n} X_{2n}	A_2
$\vdots$	$\vdots$ $\vdots$	$\vdots$ $\vdots$	...	$\vdots$ $\vdots$	$\vdots$
F_m	C_{m1} X_{m1}	C_{m2} X_{m2}	...	C_{mn} X_{mn}	A_m
Demand (D_j)	B_1	B_2	...	B_n	

TABLE 1. Basic representation of TP [3]

The construction of Transportation problem is explained

$$Min\ Z = \sum_{i=1}^{m} \sum_{j=1}^{n} X_{ij} C_{ij}$$

subject to the constraints

$$\begin{aligned} \sum\nolimits_{j=1}^{n} x_{ij} &= A_i;\ i\ =\ 1\ to\ m \\ \sum\nolimits_{i=1}^{m} x_{ij} &= B_j;\ j\ =\ 1\ to\ n \\ x_{ij}\ &\geq\ 0\ \forall\ i\ and\ j \end{aligned} \tag{1}$$

Therefore,
$S_i(A_i)$ - The products that can be supplied from m warehouse to n distribution centers
$D_j(B_j)$ - Demand of the products from m warehouse to n distribution centers
m - Available supply of the products in the warehouse
n - Required demand of the products to the distribution centers
C_{ij} - Cost of transportation from available supply i to the required demand j
X_{ij} - Quantity of products transported from i warehouse to j distribution centers

3. Materials and Methods

This section, explains the details of the materials used in our method

3.1. Normal Distribution [26]**.** In probability and statistics, the Normal or Gaussian distribution is a continuous probability distribution for real-valued random variables. A continuous ND contains
i. Probability Density Function (PDF)
ii. Cumulative Distribution Function (CDF)

We employ CDF in our work to solve IBFS in TP. The per-unit cost of an item in the transportation problem will be an independent, real-valued random cost.

The general formula for cumulative distribution function (CDF) in a normal distribution (ND) is shown in equation 2.

$$\text{f(x)} = \int_{-\infty}^{x} e^{-(t-\mu)^2/2\sigma^2}/\sigma\sqrt{2\pi}\ \text{dt} \tag{2}$$

The parameter μ is the mean or expectation of the distribution, while the parameter σ is its standard deviation e=2.71, λ=1.618.

In the Excel sheet, the formula for CDF of ND is

$$= NORMDIST(X, mean,\ standard\ dev, True) \tag{3}$$

Where X is the per unit cost of a commodity in the transportation problem

$\mu = \sum_{i=1}^{n} x_i/n$, $\sigma = \sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2/n}$
The True function indicates the cumulative distribution function.
The False function indicates the probability density function.

3.2. Root Mean Square [27]**.** The arithmetic average of a set of numbers squares is known as root mean square (RMS), sometimes known as the square root of mean square. It is a different term for the quadratic mean.

$$\text{RMS} = (\sqrt{(x_1^2 + x_2^2 + ... + x_n^2)/n})) \tag{4}$$

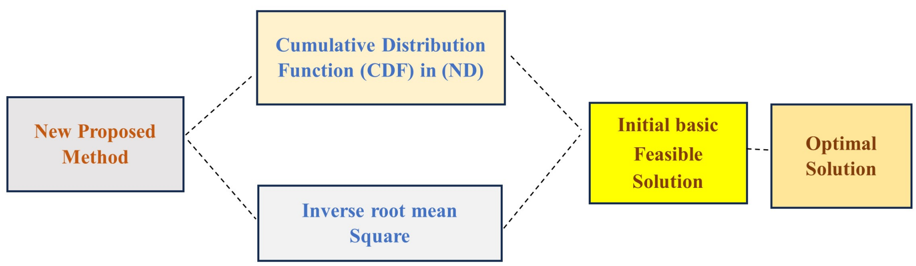

FIGURE 2. Combining two formulas for finding IBFS

3.3. Proposed Algorithm for IBFS. In this section, the proposed algorithm is explained for constructing an Initial feasible solution.
Step 1: Choose a transportation table.

- $\sum a_i = \sum b_j$ it is a balanced TP.
- $\sum a_i \neq \sum b_j$ it is an unbalanced TP.

A transportation problem is always balanced TP if the table is unbalanced, add a dummy row or column to make it balanced.
Step 2: Convert the transportation matrix into cumulative distribution cost values using equation 3
Step 3: Next for the cumulative distribution table we find penalties using equation 4 for each row and column.
Step 4: Determine which column and row penalties have the highest IRMS value.
Step 5: Choose the least cost cell value in that particular row or column. Allocate as many units of cost to the row cell or column.
Step 6: After allocating the supply and demand values remove the satisfied row or column.
Step 7: When two columns or rows are satisfied simultaneously, just one of them is crossed out and the other is assigned a zero demand (or supply).
Step 8: Repeat steps 3, 4, 5, 6, 7. Until the supply and demand values are satisfied.

Step 9: Finally, we obtain a solution to the initial basic feasible solution using equation 1.
Step 10: Table 3 is utilized to evaluate the optimality using the stepping stone method.

4. Numerical Illustration

In this section, numerical illustrations are explained for the transportation problem

4.1. Example [8]**:** Four markets (B) with demands of 40, 20, 60, and 80 units are served by three manufacturers (A) of bottled water from the supply of 100, 30, and 70 units. The cost of transportation problem is shown in Table 2.

	Destination				
Origin	B_1	B_2	B_3	B_4	Supply (S_i)
A_1	4	19	22	11	100
A_2	1	9	14	14	30
A_3	6	6	16	14	70
Demand (D_i)	40	20	60	80	

TABLE 2. Basic transportation matrix [8]

In the Excel sheet to solve the cumulative distribution function of Normal distribution is
= NORMDIST (x, μ, σ, True)

(1) X = per unit cost of a commodity
(2) Mean (μ)= Entire row's cost values
(3) Standard deviation (σ)= Entire row's cost values
(4) True= Cumulative distribution function in normal distribution

Example: $\mu = (4+19+22+11)/4 = 14$

$$\sigma = \sqrt{((4-14)^2_+(19-14)^2+(22-14)^2+(11-14)^2)/4} = 7.035$$

In the Excel sheet,
= NORMDIST (4, 14, 7.035, True) = 0.077

	Destination				
Origin	B_1	B_2	B_3	B_4	Supply (S_i)
A_1	0.077	0.761	0.872	0.334	100
A_2	0.054	0.462	0.801	0.801	30
A_3	0.161	0.161	0.886	0.778	70
Demand (D_i)	40	20	60	80	

TABLE 3. Cumulative distribution cost values

Now we find the penalty using the IRMS formula for both the row and the column.

i.e., IRMS $= \sqrt{[(0.077)^2 + (0.761)^2 + (0.872)^2 + (0.334)^2/4]}^{-1}$ =1.656

Similarly, we will find out the other penalties.

	Destination					
Origin	B_1	B_2	B_3	B_4	Supply (S_i)	IRMS*1
A_1	0.077	0.761	0.872	0.334	100	1.656
A_2	0.054 30	0.462	0.801	0.801	30	1.633
A_3	0.161	0.161	0.886	0.778	70	1.665
Demand (D_i)	40	20	60	80		
IRMS*1	[9.289]	1.914	1.399	1.486		

TABLE 4. Cumulative distribution cost values-IRMS*1

	Destination					
Origin	B_1	B_2	B_3	B_4	Supply (S_i)	IRMS*2
A_1	0.077 10	0.761	0.872	0.334	100	1.656
A_3	0.161	0.161	0.886	0.778	70	1.665
Demand (D_i)	10	20	60	80		
IRMS*2	[7.924]	1.818	1.137	1.670		

TABLE 5. Cumulative distribution cost values-IRMS*2

Calculating the IBFS in Table 10 using the suggested method, the transportation cost is 2,090. Using the stepping stone the optimal solution is 2,040.

4.2. Example[8]**:** Consider the transportation matrix.
By using the proposed method in Table 11 the IBFS is 1,900.

	Destination				
Origin	B_2	B_3	B_4	Supply (S_i)	IRMS*3
A_1	0.761	0.872	0.334	90	1.437
A_3	0.161 20	0.886	0.778	70	1.455
Demand (D_i)	20	60	80		
IRMS*3	[1.818]	1.137	1.670		

TABLE 6. Cumulative distribution cost values-IRMS*3

	Destination			
Origin	B_3	B_4	Supply (S_i)	IRMS*4
A_1	0.872	0.334 80	90	1.514
A_3	0.886	0.778	50	1.199
Demand (D_i)	60	80		
IRMS*4	1.137	[1.670]		

TABLE 7. Cumulative distribution cost values -IRMS*4

	Destination		
Origin	B_3	Supply (S_i)	IRMS*5
A_1	0.872 10	10	[1.514]
A_3	0.886 50	50	1.199
Demand (D_i)	60		
IRMS*5	1.137		

TABLE 8. Cumulative distribution cost values -IRMS*5

4.3. Example[8]**:** The following numbers of trucks are available at four Separate locations from The Bombay Transport Company. The matrix provides the

	Destination				
Origin	B_1	B_2	B_3	B_4	Supply (S_i)
A_1	0.077 10	0.761	0.872 10	0.334 80	100
A_2	0.054 30	0.462	0.801	0.801	30
A_3	0.161	0.161 20	0.886 50	0.778	70
Demand (D_i)	40	20	60	80	

Table 9. Final iteration

	Destination				
Origin	B_1	B_2	B_3	B_4	Supply (S_i)
A_1	4 10	19	22 10	11 80	100
A_2	1 30	9	14	14	30
A_3	6	6 20	16 50	14	70
Demand (D_i)	40	20	60	80	

Table 10. Allocated in original transportation problem[8]

variable costs of delivering trucks to consumers [8]

After calculating the initial solution using Table 12 the transportation cost is 90.

4.4. Random Values Example 1: A company has manufacturing facilities at S1, S2, S3, and S4 that supply warehouses at D1, D2, and D3. 100, 80, 90, and 120 units are the corresponding weekly factory capacities. Each week, 150, 150, and 90 units are needed in warehouses. The following are the unit shipping costs (in rupees). Determine the optimum solution for this company is to reduce shipping costs.

Using the proposed technique for finding the initial solution which is seen in Table 13 the transportation cost is 14,010.

	Destination							
Factory	P_1	P_2	P_3	P_4	P_5	P_6	P_7	Supply
M_1	12	7	3 40	8	10	6 20	6	60
M_2	6 20	9	7	12	8 60	12	4	80
M_3	10	12	8	4 70	9	9	3	70
M_4	8	5	11	6	7	9	3 100	100
M_5	7	6 30	8	11	9	5 60	6	90
Demand	20	30	40	70	60	80	100	

TABLE 11. Basic transportation matrix [8]

	Destination				
Origin	W	X	Z	Dummy	Supply
A	7	3 5	6	0	5
B	4 5	6 3	8	0 2	10
c	5	8	4 7	0	7
D	8	4	3 3	0	3
Demand	5	8	10	2	

TABLE 12. Unbalanced transportation matrix[8]

4.5. Random Values Example 2: An enterprise has four factories at locations S1, S2, S3 and S4, which supplies five warehouses located at D1, D2, D3, and D5. Monthly factory capacities are 100, 90, 80, and 65 units, respectively. Monthly warehousing needs are 80, 70,55, 75, and 50 units, correspondingly. The following table lists the unit shipping costs (in rupees). Determine the optimal

	Warehouse			
Factory	D_1	D_2	D_3	Capacity
S_1	30 / 100	42	66	100
S_2	111	28 / 80	80	80
S_3	79 / 20	44 / 70	57	90
S_4	77 / 30	50	20 / 90	120
Requirement	150	150	90	

TABLE 13. Random input values for the transportation problem

solution.

	Warehouse					
Factory	D_1	D_2	D_3	D_4	D_5	Supply
S_1	6	11 / 25	10	7 / 75	8	100
S_2	10	14 / 40	17	14	11 / 50	90
S_3	15 / 80	22	23	20	22	80
S_4	4	14 / 5	6 / 55	5	8	60
Demand	80	70	55	75	50	

TABLE 14. Random input values for TP

Calculating the initial solution using a proposed approach in Table 14 the total cost is 3,510.

5. Results and Discussion

In this section, we proposed an innovative method for developing a new algorithm for an initial basic feasible solution that minimizes the shipping cost of TP and gives the optimum solution. Fig 1, represents general TP. In the methodology initially, a cumulative distribution function in a normal distribution is applied to a general transportation problem by using equation 3. The general normal distribution for CDF can be seen in equation 2. The estimated transportation cost is shown in table 3. From Tables 4-9, the penalties are calculated using equation 4. The proposed method is explained in Fig 2. The existing method includes a TP for determining an IBFS in which they used the SDRM. In this method, the authors select the supply-demand parameter with the highest value to distribute resources to the relevant row or column's element with the lowest cost, whereas, to begin the allocation process using CAM, they select the cell in the transportation matrix with the lowest cost and assign the cell with the highest value and also followed a novel approximation method to obtain IBFS which is Karagul-Sahin Approximation Method (KSAM), the author used supply-demand coverage ratio (weights) as well as the cost and Vogel's approximation method.

Case Study:

A company manufacturing logistics has two warehouses located in Mumbai and Kolkata a weekly capacity of 200 tons and 100 tons respectively. The company supplies to its 4 branches situated at Hyderabad, Delhi, Chennai, and Vijayawada which have a demand of 100, 100, 75, and 25 tons (Approximately). The cost of transportation per ton (in Rs.). As shown in the following Table 15. Minimize the total cost of transportation.

	Distribution Centers				
Warehouse	Hyderabad	Delhi	Chennai	Vijayawada	Supply
Mumbai	400	510	800	270	200
Kolkata	600	450	750	500	100
Demand	100	100	75	25	

Table 15. Case study problem

The proposed IBFS is 1,51,750.

Looking at Table 16, and Figure 3, we can examine the transportation cost of our proposed method's numerical examples, random values, and a case study with the existing cost. The results were obtained by the Inverse Root Mean Square (IRMS) and the cumulative distribution function of normal distribution is optimal or extremely close to optimal. Our suggested strategy performs better than the other existing approaches.

	Staus	VAM	CAM	SDRM	KSAM	Proposed	Optimum
[4.1]	Balanced	2170	2160	2120	I-2090, II-2860	2090	2040
[4.2]	Balanced	1930	1900	1900	I-1930, II-2040	1900	1900
[4.3]	Unbalanced	98	90	90	I-90, II-90	90	90
[4.4]	Balanced	14,010	14,550	14,010	I-14,250, II-14,010	14,010	14,010
[4.5]	Balanced	3,645	4,525	3,820	I-3,945, II-3,907	3,510	3,415
Case Study	Balanced	1,51,750	1,51,750	1,51,750	I-1,52,500, II-1,51,750	1,51,750	1,51,750

TABLE 16. Comparison results of the transportation problem

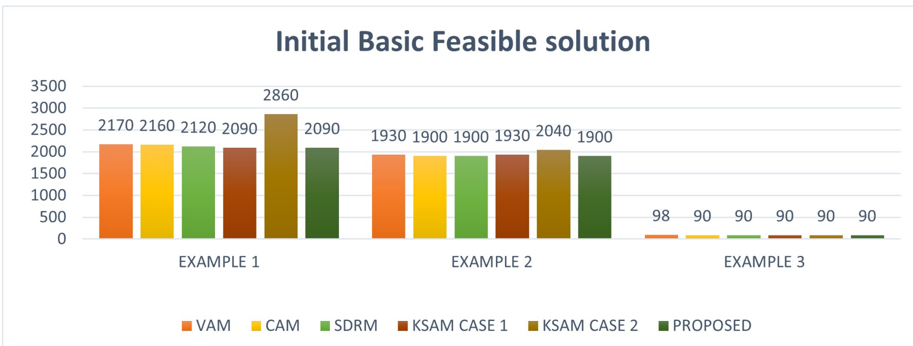

FIGURE 3. Comparison graph of proposed IBFS with existing methods

6. Conclusion

This research aims to identify an optimal solution to the transportation issue. The concept of the transportation problem is used to transport goods from several sources to several destinations with minimum cost. The role of IBFS is to allocate the supply and demand to per-unit transportation cost using the penalties. For this, an algorithm is required. This study developed a new algorithm for IBFS. The statistical fundamentals normal distribution is used for converting the original transportation cost into probability cost values, the root mean square is used to calculate the penalty for row and column. Combining the normal distribution and root mean square will produce better results. The suggested approach can still handle both the balanced and unbalanced transportation problems. In conclusion, it can be said that combining two different formulas is a unique approach and assures a minimum transportation cost, to obtain a better feasible Solution (optimal solution). The best part about this proposed strategy is that it frequently produces an optimal or close to an optimal solution. In this scenario, the initial basic feasible answer is evaluated for optimality using the Stepping Stone approach. This study is limited to the Normal Distribution's Cumulative Distribution Function; it is not appropriate for the ND's Probability Density Function.

In the future, this technique can be implemented in other fields i.e., in Real-life applications Assignment problems, Traveling salesman problems, and Transshipments problems.

Conflicts of interest : The authors did not disclose any conflicts of interest.

Data availability : Data is available in referenced articles.

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