

Research Article

Solving the Single-Valued Trapezoidal Neutrosophic Transportation Problems through the Novel Dhouib-Matrix-TP1 Heuristic

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The transportation problem has been widely studied in the field of supply chain management where circulation of products with a minimal transportation cost is an important issue. This paper presents the first adaptation of the Dhouib-Matrix-TP1 heuristic to solve the transportation problem in single-valued trapezoidal neutrosophic environment. Hence, the recently developed Dhouib-Matrix-TP1 heuristic is enriched with two functions to solve the neutrosophic transportation problem. On the one hand, a defuzzification function is exploited in order to convert the single-valued trapezoidal neutrosophic numbers to crisp numbers. On the other hand, an original metric function (*Average-Min*) is proposed with the intention of performing the nodes selection process. With an illustration from a literature example, we show to the decision maker the multiple advantages of the novel heuristic Dhouib-Matrix-TP1 which can be easily implemented in real-life industrial transportation under neutrosophic environment.

1. Introduction

The neutrosophic concept was introduced in 1995 by Smarandach [1] in order to make the chance of emulating the human thinking by using at the same time three membership functions: the Truth, the Falsity, and the Indeterminacy, noted, respectively, as (T) , (F) , and (I) . These three membership functions compose the neutrosophic set $\langle T, I, F \rangle$, where T, I and $F \in [0, 1]$.

The neutrosophic concept is becoming a major focus of several research papers. In fact, Ibrahim et al. [2] projected the idea of applying the neutrosophic analytical hierarchy process model to forecast the default of clients using five financial criteria (C_1 : the working capital, C_2 : the Liquidity, C_3 : the Profitability, C_4 : the Costs, and C_5 : the Customer obligation). The information was gathered in the form of neutrosophic datasets and evaluated in the credit department of one of private banks. In [3], the generalized assignment problem is considered in neutrosophic set theory, where elements of the cost matrix are presented as

trapezoidal fuzzy neutrosophic elements, and then, the problem is solved by the zero-suffix method. In [4], the assignment problem with costs as nonagonal number is optimized under three domains: fuzzy, intuitionistic, and neutrosophic. In [5], the neutrosophic assignment problem with the pentagonal neutrosophic number is solved using a new technique for ranking neutrosophic numbers into real numbers by the means of the magnitude function. In [6], the multicriteria assignment problem is solved using two methods where the different criteria have been considered as neutrosophic elements.

In [7], the order relation technique is applied to optimize the neutrosophic trapezoidal fuzzy assignment problem. In [8], the Branch and Bound method is used to optimize the neutrosophic assignment problem, where elements of the matrix are triangular fuzzy numbers. In [9, 10], the Branch and Bound technique and the Ones Assignment methods are, respectively, used to solve the neutrosophic Travelling Salesman Problem. Sikkannanl and Shanmugavel [11] introduce a new method to optimize the neutrosophic fuzzy

transportation problem using the Mean and Complete Contingency Cost Table.

The idea of trapezoidal neutrosophic is considered in [12], and the triangular fuzzy neutrosophic sets are proposed in [13]. Also, the Travelling Salesman Problem is solved under single-valued triangular neutrosophic parameters in [14]. A real-life TP under neutrosophic domain is solved in [15, 16], while the neutrosophic shortest path problem is optimized in [17]. Several operations on neutrosophic matrices are introduced in [18], and an application of the multicriteria group decision in a real-life problem is illustrated. The application of the neutrosophic N-structures to p-ideals of BCI-algebras is presented in [19]. The optimal hydrogen power plant site using a single-valued neutrosophic multiattribute decision-making technique is selected in [20].

In this paper, we focus to practically help the decision maker to handle a suitable solution for TP in neutrosophic domains and specially the case of single-valued trapezoidal numbers. Obviously, an easy and convivially neutrosophic decision support system is needed in order to depict graphically the crisp and neutrosophic solutions (graphical representation of the crisp and the single-valued trapezoidal neutrosophic solutions). Furthermore, this paper presents the first application of our novel heuristic Dhoub-Matrix-TP1 (DM-TP1) to solve the TP under the single-valued trapezoidal neutrosophic environment. The DM-TP1 was developed using Python programming language and enhanced with two techniques: on the one hand, the defuzzification score function in order to convert the neutrosophic trapezoidal fuzzy number to crisp number, and on the other hand, by the proposed original metric function (*Average-Min*) in order to drive the node (sources and destinations) selection process.

The remaining of this paper is organized as follows. Section 2 introduces the transportation problem. Section 3 presents some basic definitions on neutrosophic environment. Section 4 explains in detail the proposed heuristic DM-TP1. Section 5 depicts the stepwise application of the proposed method. Finally, conclusions with further research works are presented in Section 6.

2. The Transportation Problem

The transportation problem (TP) is a very well-studied topic in the field of supply chain management, and it deals with the minimization of the transportation cost of products from a certain number of sources to a certain number of destinations. The objective of the TP is to search for the optimal value of x_{ij} that will minimize the total transportation cost (see equation (1)) while satisfying the supply and demand restrictions (see equation (2)). The TP is mathematically formulated as follows.

Minimize

$$Z = \sum_{i=1}^m \sum_{j=1}^n c_{ij} x_{ij}, \quad (1)$$

which subjects to

$$\begin{aligned} \sum_{j=1}^n x_{ij} &= a_i; i = 1, 2, \dots, m, \\ \sum_{i=1}^m x_{ij} &= b_j; j = 1, 2, \dots, n, \\ x_{ij} &\geq 0 \text{ for all } i \text{ and } j. \end{aligned} \quad (2)$$

The notation of the TP is

m is the total number of supplies (sources)

n is the total number of demands (destinations)

a_i is the amount of supply at source i

b_j is the amount of demand at destination j

c_{ij} is the transportation cost from supply i to demand j

x_{ij} is the amount to be shipped from source i to destination j

The TP was firstly designed by Hitchcock in [21]. Charnes and Cooper in [22] proposed the Stepping Stone Method to find the optimal solution for TP. Dantzig, in [23], presented the simplex technique for the classical TP. Shell, in [24], introduced a solid transportation problem using three bounds: supply, demand, and conveyance that represent the different transport modes such as ships, goods train, trucks, and cargo flights. Haley, in [25], presented an enhanced version of the modified distribution method to optimize the solid transportation problem.

In real-life situations and in many cases, the decision maker has no precise information about the TP parameters: the transportation costs and the value of demands and supplies. In this situation, the corresponding elements defining the problem can be formulated by the means of fuzzy set, intuitionistic set, or neutrosophic set. Pandian and Natarajan, in [26], solved the TP under trapezoidal fuzzy numbers for all parameters. Kumar, in [27], designed the PSK method to solve the fuzzy TP type-1 and type-3. Mhaske and Bondar, in [28], solved the TP under triangular, pentagonal, and heptagonal fuzzy numbers and proposed the application of Lagrange's polynomial function for the nonagonal and hendecagonal fuzzy numbers. Dinagar and Thiripurasundari, in [29], solved the fuzzy TP under intuitionistic trapezoidal fuzzy numbers, and Sikkannan and Shanmugavel, in [30], used the magnitude ranking function with the Entire Contingency Cost Table method to solve the triangular fuzzy TP.

3. Basic Definitions

The neutrosophic concept allows to the decision maker, in real-world problems, to rely not only on true values but also on false ones as well as on indeterminacy membership.

Definition 1 (see [1]). Let us define by X the space of objects and define x as its generic element $x \in X$. The neutrosophic set N has the form $N = \{ \langle x: T_N(x), I_N(x), F_N(x) \rangle, x \in X \}$, where the functions $T, I, F: X \rightarrow]^{-0}, 1^{+}[$ with the condition $^{-0} \leq T_N(x) + I_N(x) + F_N(x) \leq 3^{+}$.

Definition 2 (see [31]). The truth (T), indeterminacy (I), and falsity (F) membership functions for the neutrosophic trapezoidal fuzzy number are defined by

$$\mu(X) = \begin{cases} \frac{(x-a)T_N}{b-a}, & a \leq x \leq b, \\ T_N & b \leq x \leq c, \\ \frac{(d-x)T_N}{d-c}, & c \leq x \leq d, \\ 0, & \text{otherwise,} \end{cases}$$

$$\theta(X) = \begin{cases} \frac{b-x+(x-a)I_N}{b-a}, & a \leq x \leq b, \\ I_N & b \leq x \leq c, \\ \frac{x-c+(d-x)I_N}{d-c}, & c \leq x \leq d, \\ 0, & \text{otherwise,} \end{cases} \quad (3)$$

$$\lambda(X) = \begin{cases} \frac{b-x+(x-a)F_N}{b-a}, & a \leq x \leq b, \\ F_N, & b \leq x \leq c, \\ \frac{x-c+(d-x)F_N}{d-c}, & c \leq x \leq d, \\ 0 & \text{otherwise.} \end{cases}$$

Here is an example (see Figure 1) of a graphical representation of a single-valued trapezoidal neutrosophic set $N = \langle (1, 3, 5, 7); 0.9, 0.2, 0.4 \rangle$.

Definition 3 (see [15]). Let us assume two neutrosophic trapezoidal fuzzy numbers $N = \langle (N_a, N_b, N_c, N_d); T_N, I_N, F_N \rangle$ and $M = \langle (M_a, M_b, M_c, M_d); T_M, I_M, F_M \rangle$. Then, their operations are defined as follows:

$$\begin{aligned}
M + N &= \langle (M_a + N_a, M_b + N_b, M_c + N_c, M_d + N_d); T_M \wedge T_N, I_M \vee I_N, F_M \vee F_N \rangle, \\
M - N &= \langle (M_a - N_d, M_b - N_c, M_c - N_b, M_d - N_a); T_M \wedge T_N, I_M \vee I_N, F_M \vee F_N \rangle, \\
M \times N &= \begin{cases} \langle (M_a \times N_a, M_b \times N_b, M_c \times N_c, M_d \times N_d); T_M \wedge T_N, I_M \vee I_N, F_M \vee F_N \rangle & \text{if } M_d > 0, N_d > 0, \\ \langle (M_a \times N_d, M_b \times N_c, M_c \times N_b, M_d \times N_a); T_M \wedge T_N, I_M \vee I_N, F_M \vee F_N \rangle & \text{if } M_d < 0, N_d > 0, \\ \langle (M_d \times N_d, M_c \times N_c, M_b \times N_b, M_a \times N_a); T_M \wedge T_N, I_M \vee I_N, F_M \vee F_N \rangle & \text{if } M_d < 0, N_d < 0, \end{cases} \\
\frac{M}{N} &= \begin{cases} \left\langle \left(\frac{M_a}{N_d}, \frac{M_b}{N_c}, \frac{M_c}{N_b}, \frac{M_d}{N_a} \right); T_M \wedge T_N, I_M \vee I_N, F_M \vee F_N \right\rangle & \text{if } M_d > 0, N_d > 0, \\ \left\langle \left(\frac{M_d}{N_d}, \frac{M_c}{N_c}, \frac{M_b}{N_b}, \frac{M_a}{N_a} \right); T_M \wedge T_N, I_M \vee I_N, F_M \vee F_N \right\rangle & \text{if } M_d < 0, N_d > 0, \\ \left\langle \left(\frac{M_d}{N_a}, \frac{M_c}{N_b}, \frac{M_b}{N_c}, \frac{M_a}{N_d} \right); T_M \wedge T_N, I_M \vee I_N, F_M \vee F_N \right\rangle & \text{if } M_d < 0, N_d < 0, \end{cases} \\
k * N &= \begin{cases} \langle (k * N_a, k * N_b, k * N_c, k * N_d); T_N, I_N, F_N \rangle & \text{if } k > 0, \\ \langle (k * N_d, k * N_c, k * N_b, k * N_a); T_N, I_N, F_N \rangle & \text{if } k < 0, \end{cases} \\
N^{-1} &= \left\langle \left(\frac{1}{N_d}, \frac{1}{N_c}, \frac{1}{N_b}, \frac{1}{N_a} \right); T_M, I_M, F_M \right\rangle, \text{ where } N \neq 0.
\end{aligned} \tag{4}$$

Definition 4 (see [16]). For a single-valued neutrosophic number $N = \langle (N_a, N_b, N_c, N_d); T_N, I_N, F_N \rangle$, its score function is defined by $M(\tilde{c}_{ij}^N)$ as follows:

$$\begin{aligned}
M(\tilde{c}_{ij}^N) &= \left(\min_{1 \leq i \leq n} (\mu_{c_{ij}}^N) + \min_{1 \leq i \leq n} (\vartheta_{c_{ij}}^N) + \max_{1 \leq i \leq n} (1 - \lambda_{c_{ij}}^N) \right) \\
&\times \sum_{i=1}^m \sum_{j=1}^n \left(\frac{S(\tilde{c}_{ij}^N, x_{ij})}{\mu_{c_{ij}}^N + (1 - \vartheta_{c_{ij}}^N) + (1 - \lambda_{c_{ij}}^N)} \right), \tag{5}
\end{aligned}$$

where

$$\begin{aligned}
S(\tilde{c}_{ij}^N) &= \left(\frac{1}{16} \right) \times (N_a + N_b + N_c + N_d) \\
&\times (T_N + (1 - I_N) + (1 - F_N)). \tag{6}
\end{aligned}$$

4. The Proposed Method: Dhoub-Matrix-TP1 (DM-TP1)

Very recently, we invent in [32] a new constructive method entitled Dhoub-Matrix-TSP1 (DM-TSP1) to solve the classical Travelling Salesman Problem (TSP). The proposed method is based on several rules, and we handle it to solve the trapezoidal fuzzy TSP using the magnitude ranking function [33]. Then, in [34], we enhance the DM-TSP1 method with the α -Cut Technique to optimize the octagonal fuzzy TSP. Moreover, in [35], we generate a stochastic version, namely, the Dhoub-Matrix-TSP2 to solve the TSP.

In [36], we introduce a novel heuristic entitled Dhoub-Matrix-TP1 (DM-TP1) to solve the classical transportation problem (TP).

In this paper, we focus on the application of enhanced version of the DM-TP1 to solve the neutrosophic trapezoidal fuzzy TP. In fact, the DM-TP1 was presented in [18] using the standard deviation metric, whereas in this paper, we introduce a new original metric the (*Average-Min*) metric in order to drive the selection of sources and destinations. A stepwise application of this metric will be presented in the next section.

Furthermore, we enrich the DM-TP1 with the defuzzification score function [16] in order to convert the neutrosophic trapezoidal fuzzy parameters to crisp number. Thus, the score function for the neutrosophic trapezoidal fuzzy number $N = \langle (N_a, N_b, N_c, N_d); T_N, I_N, F_N \rangle$ is defined by equations (5) and (6).

The proposed method DM-TP1 is accomplished into nine steps (see Figure 2). Steps 1, 2, and 9 are executed only once, and Steps 3, 4, 5, 6, 7, and 8 are repeated until all columns are discarded.

Step 1 : transform the single-valued trapezoidal neutrosophic parameters to crisp parameters using the defuzzification functions described in equations (5) and (6).

Step 2 : balance the sum of supplies and demands for the transport matrix by adding fictive row and column with corresponding quantity. Next, in the transportation matrix, we add a row below,

entitled the Average Min Demand Column (AMDC), and insert a column at right, named the Average Min Supply Row (AMSR).

- Step 3 : compute the original function (*Average-Min*) for each row which affects the corresponding value for each element in the AMSR.
- Step 4 : apply the same operation on each column. Compute the original proposed function (*Average-Min*) for each column. Then, it affects the corresponding value for each element of the AMDC.
- Step 5 : identify the highest element among the AMSR and AMDC; if it is in AMSR, then select the minimal element (x_{ij}) of its corresponding row else check the minimal element (x_{ij}) of its corresponding column.
- Step 6 : if $a_i \leq b_j$ then allocate the a_i amount of units to x_{ij} , which affects $b'_j = b_j - a_i$, and discard row i .
- Step 7 : if $a_i > b_j$ then allocate the b_j amount of units to x_{ij} , which affects $a'_i = a_i - b_j$, and discard column j .
- Step 8 : repeat Steps 3, 4, 5, 6, and 7 until all columns are discarded.
- Step 9 : calculate the total minimal transportation cost.

5. Numerical Example

In this section, an example from [16] is used to prove the performance of the DM-TP1 heuristic in order to easily solve the TP under single-valued trapezoidal neutrosophic numbers. In fact, this problem was firstly introduced by [15] in order to present a peanut butter manufacturing company with three sources and four different destinations. In this problem, the cost parameters (\tilde{c}_{ij}^N) are presented as single-valued trapezoidal neutrosophic numbers, while the supply and demand quantities are presented as crisp numbers as given in Figure 3.

The mathematical formulation of this problem is given below:

$$\begin{aligned} \text{Minimize : } \tilde{Z}^N &= \sum_{i=1}^m \sum_{j=1}^n \tilde{c}_{ij}^N x_{ij}, \\ \text{Subject to :} \\ \sum_{j=1}^n x_{ij} &= a_i; \quad i = 1, 2, \dots, m, \\ \sum_{i=1}^m x_{ij} &= b_j; \quad j = 1, 2, \dots, n, \\ x_{ij} &\geq 0 \text{ for all } i \text{ and } j. \end{aligned} \tag{7}$$

The DM-TP1 starts by transforming the neutrosophic trapezoidal fuzzy number to crisp number using equation (5) and equation (6).

Here is an example for the first cost element: $N = \langle (3, 5, 6, 8); 0.6, 0.5, 0.4 \rangle$.

Then, $S(N) = (1/16) \times (3 + 5 + 6 + 8) \times (2 + 0.6 - 0.5 - 0.4) = 2.3$.

The second step is to calculate the AMSR and the AMDC for all rows and columns using the proposed formula (*Average-Min*). Let us give an example how to compute easily the first element of AMSR:

$$\text{AMSR}[1] = \text{Average}_{r1} - \text{Min}_{r1}, \tag{8}$$

where

$$\text{Average}_{r1} = \frac{(3 + 4 + 8 + 9)}{4} = 6, \tag{9}$$

$$\text{Min}_{r1} = (3, 4, 8, 9) = 3.$$

Thus, $\text{AMSR}[1] = 6 - 3 = 3$.

The same process is followed for the first element for AMDC:

$$\text{AMDC}[1] = \text{Average}_{c1} - \text{Min}_{c1}, \tag{10}$$

where

$$\text{Average}_{c1} = \frac{(3 + 1 + 4)}{3} = 2.66, \tag{11}$$

$$\text{Min}_{c1} = (3, 1, 4) = 1.$$

Thus, $\text{AMDC}[1] = 2.66 - 1 = 1.66$.

The next step is to select the highest element in AMSR and AMDC: 3.75 is the highest value and it is in the second row of AMSR (see Figure 4).

Thus, select the minimal element in the second row of AMSR which is equal to 1 at position d_{21} , affect 17 units (which represents the smallest element between demand 17 and supply 24), and discard the saturated element which is column 1. Hence, compute again the AMSR and AMDC indicators, select the highest one (3.33), and find its corresponding minimal element (3) at position d_{32} (see Figure 5).

Therefore, 28 units (the smallest element between demand 28 and supply 30) are affected and the saturated element which is column 3 is discarded. Next, calculate the AMSR and AMDC indicators, select the highest one (2.50), and find its corresponding minimal element (4) at position d_{12} (see Figure 6).

Consequently, 23 units (the smallest element between demand 23 and supply 26) are affected and the saturated element which is column 2 is discarded. Next, calculate the AMSR and AMDC indicators, select the highest one (1.67), and find its corresponding minimal element (5) at position d_{34} (see Figure 7).

Accordingly, 2 units (the smallest element between demand 12 and supply 2) are affected and the saturated element which is row 3 is discarded. Next, calculate the AMSR and AMDC indicators, select the highest one (1.50), and find its corresponding minimal element (6) at position d_{24} (see Figure 8).

Hence, 7 units (the smallest element between demand 10 and supply 7) are affected and the saturated element which is

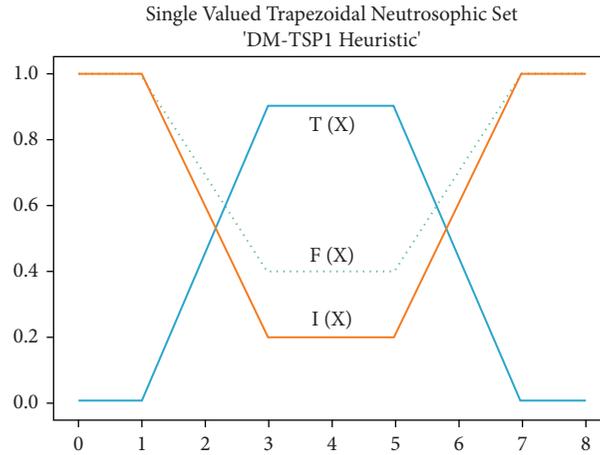


FIGURE 1: Graphical representation of a single-valued trapezoidal neutrosophic set.

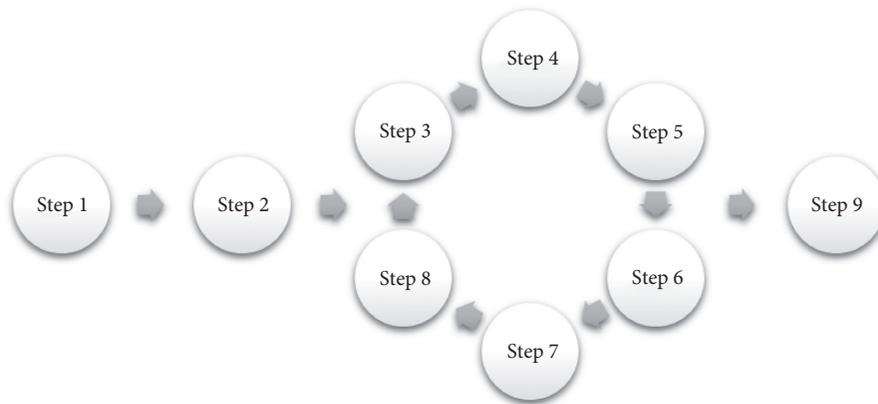


FIGURE 2: The flowchart of the proposed DM-TP1.

Source	Destination				Inventory
	$D1$	$D2$	$D3$	$D4$	
$O1$	(3,5,6,8); 0.6,0.5,0.4	(5,8,10,14); 0.3,0.6,0.6	(12,15,19,22); 0.6,0.4,0.5	(14,17,21,28); 0.8,0.2,0.6	26
$O2$	(0,1,3,6); 0.7,0.5,0.3	(5,7,9,11); 0.9,0.7,0.5	(15,17,19,22); 0.4,0.8,0.4	(9,11,14,16); 0.5,0.4,0.7	24
$O3$	(4,8,11,15); 0.6,0.3,0.2	(1,3,4,6); 0.6,0.3,0.5	(5,7,8,10); 0.5,0.4,0.7	(5,9,14,19); 0.3,0.7,0.6	30
Demand	17	23	28	12	

FIGURE 3: The single-valued trapezoidal neutrosophic TP.

row 2 is discarded. Finally, it remains only one element at position d_{14} , affects 3 units, and discards row 1 (see Figure 9).

Therefore, the obtained optimal solution using DM-TP1 heuristic is $x_{14} = 3$, $x_{24} = 7$, $x_{34} = 2$, $x_{12} = 23$, $x_{33} = 28$, and $x_{21} = 17$ with $Z = (9 * 3) + (6 * 7) + (5 * 2) + (4 * 23) + (3 * 28) + (1 * 17) = 272$.

Then, the DM-TP1 heuristic found the minimal total crisp cost equal to 272 and graphically presented in Figure 10. This result was also found by [16].

Consequently, the minimal total single-valued trapezoidal neutrosophic cost is

Source	Destination				Inventory	AMSR
	D1	D2	D3	D4		
D1	3	4	8	9	26	3.00
D2	1	4	8	6	24	3.75
D3	4	2	3	5	30	1.50
Demand	17	23	28	12		
AMDC	1.66	1.33	3.33	1.67		

FIGURE 4: After the defuzzification step.

Source	Destination				Inventory	AMSR
	D1	D2	D3	D4		
D1		4	8	9	26	3.00
D2		4	8	6	7	3.00
D3		2	3	5	30	1.33
Demand		23	28	12		
AMDC		1.33	3.33	1.67		

FIGURE 5: Discard column 1.

$$\begin{aligned}
 \text{Minimize: } \tilde{Z}^N &= \sum_{i=1}^3 \sum_{j=1}^4 \tilde{c}_{ij}^N x_{ij}, \\
 \tilde{Z}^N &= 3 \times \langle (14, 17, 21, 28); 0.3, 0.8, 0.7 \rangle, \\
 &+ 7 \times \langle (9, 11, 14, 16); 0.3, 0.8, 0.7 \rangle, \\
 &+ 2 \times \langle (5, 9, 14, 19); 0.3, 0.8, 0.7 \rangle, \quad (12) \\
 &+ 23 \times \langle (5, 8, 10, 14); 0.3, 0.8, 0.7 \rangle, \\
 &+ 28 \times \langle (5, 7, 8, 10); 0.3, 0.8, 0.7 \rangle, \\
 &+ 17 \times \langle (0, 1, 3, 6); 0.3, 0.8, 0.7 \rangle, \\
 &= \langle (370, 543, 694, 938); 0.3, 0.8, 0.7 \rangle.
 \end{aligned}$$

The graphical representation of the minimal total solution is depicted in Figure 11, where the total single-valued trapezoidal neutrosophic optimal solution will be greater than 370 and less than 938 with a level of acceptance 30% for the total neutrosophic cost lying between 543 and 694.

Therefore, a decision maker can conclude the minimal trapezoidal neutrosophic cost from the range 370 to 938, with its truth, indeterminacy, and falsity degrees. The truth membership function for the generated solution is denoted by

$$\mu(X) = \begin{cases} \frac{(x - 370) \times 0.3}{543 - 370}, & 370 \leq x \leq 543, \\ 0.3, & 543 \leq x \leq 694, \\ \frac{(938 - x) \times 0.3}{938 - 694}, & 694 \leq x \leq 938, \\ 0, & \text{otherwise.} \end{cases} \quad (13)$$

Correspondingly, the indeterminacy membership function for the minimal single-valued trapezoidal neutrosophic number cost is presented by

$$\vartheta(X) = \begin{cases} \frac{543 - x + (x - 370) \times 0.8}{543 - 370}, & 370 \leq x \leq 543, \\ 0.8, & 543 \leq x \leq 694, \\ \frac{x - 694 + (938 - x) \times 0.8}{938 - 694}, & 694 \leq x \leq 938, \\ 0, & \text{otherwise.} \end{cases} \quad (14)$$

Source	Destination				Inventory	AMSR
	<i>D1</i>	<i>D2</i>	<i>D3</i>	<i>D4</i>		
<i>D1</i>		4		9	26	2.50
<i>D2</i>		4		6	7	1.00
<i>D3</i>		2		5	2	1.50
Demand		23		12		
AMDC		1.33		1.67		

FIGURE 6: Discard column 3.

Source	Destination				Inventory	AMSR
	<i>D1</i>	<i>D2</i>	<i>D3</i>	<i>D4</i>		
<i>D1</i>				9	3	0.00
<i>D2</i>				6	7	0.00
<i>D3</i>				5	2	0.00
Demand				12		
AMDC				1.67		

FIGURE 7: Discard column 2.

Source	Destination				Inventory	AMSR
	<i>D1</i>	<i>D2</i>	<i>D3</i>	<i>D4</i>		
<i>D1</i>				9	3	0.00
<i>D2</i>				6	7	0.00
<i>D3</i>						
Demand				10		
AMDC				1.50		

FIGURE 8: Discard row 3.

Source	Destination				Inventory	AMSR
	<i>D1</i>	<i>D2</i>	<i>D3</i>	<i>D4</i>		
<i>D1</i>				9	3	0.00
<i>D2</i>						
<i>D3</i>						
Demand				3		
AMDC				0.00		

FIGURE 9: Discard row 2.

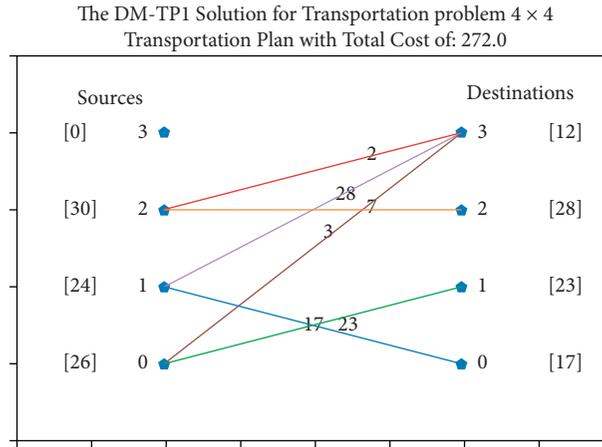


FIGURE 10: The generated transportation problem network diagram plan using DM-TP1 heuristic.

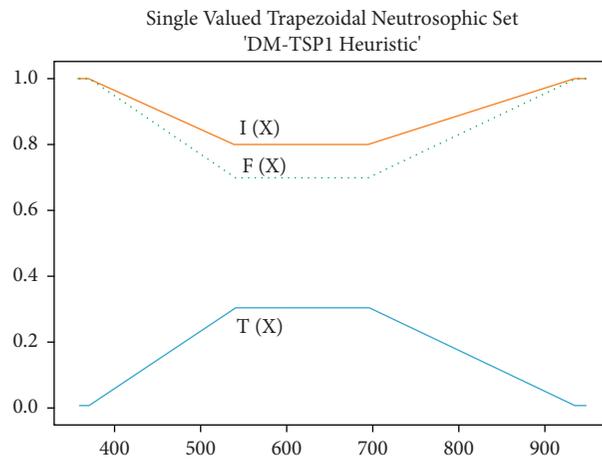


FIGURE 11: The minimal total single-valued trapezoidal neutrosophic cost using the DM-TP1 heuristic.

Consequently, the degree of falsity for the minimal single-valued trapezoidal neutrosophic number cost is depicted by

$$\lambda(X) = \begin{cases} \frac{543 - x + (x - 370) \times 0.7}{543 - 370}, & 370 \leq x \leq 543, \\ 0.7, & 543 \leq x \leq 694, \\ \frac{x - 694 + (938 - x) \times 0.7}{938 - 694}, & 694 \leq x \leq 938, \\ 0, & \text{otherwise.} \end{cases} \quad (15)$$

Based on the above result generated by the DM-TP1 heuristic, the decision maker can schedule the transportation network diagram plan.

6. Conclusion

The transportation problem is a special type in supply chain management where the aim is to minimize the total transportation cost of shipping products from sources to destinations. This paper addresses a transportation problem model under single-valued trapezoidal neutrosophic environment. To solve this problem, the novel Dhouib-Matrix-TP1 heuristic is enhanced at first with a score function in order to ensure the defuzzification of the neutrosophic trapezoidal fuzzy numbers into crisp numbers and at second with a new metric function (*Average-Min*) in order to drive the selection process.

Stepwise numerical applications are used to explain and to prove the performance of the proposed DM-TP1 heuristic. It also shows the effect of using the *Average* and the *Min* descriptive statistical metrics on the accuracy of the decision made. Further research will focus on the application

of the Dhouib-Matrix-TPI to solve the multiobjective transportation problem in uncertain environment.

Data Availability

All data used to support the findings of the study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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