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An Analysis of Trapezoidal Neutrosphic Fuzzy Traveling Salesman Problem for Medical Equipment Distribution to Hospitals

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ABSTRACT: The Traveling Salesman problem (TSP) is one optimization problem that has received a lot of interest in research. Trapezoidal Neutrosophic numbers (NNs) are used in the present work to examine the Neutrosophic Fuzzy Travelling Salesman Problem (NFTSP). The main objective of this TSP is to optimize the routes for medical items, like equipment or vaccines, to be transported to hospitals and clinics in order to guarantee quick and effective distribution. Here , we use the diagonal completion approach to solve the given TSP.

KEYWORDS: Diagonal Completion Approach, NFTSP, Trapezoidal Neutrosophic numbers, Graded Mean Integration Method.

I. INTRODUCTION

One of the most well-known issues in computer science, operations research, and combinatorial optimization is the **Travelling Salesman Problem** (TSP). It means figuring out the quickest path that enables a "salesman" to travel to a specific group of cities precisely once before returning to the starting point.By adding uncertainty by using fuzzy numbers to represent costs or distances, the **Fuzzy Travelling Salesman Problem** (FTSP) expands on the traditional TSP. Though it involves specific techniques for processing fuzzy data and determining approximation or optimal solutions under ambiguity, it is helpful for simulating real-world problems where accurate data is unattainable.

In the **Neutrosophic Fuzzy Travelling Salesman Problem** (NFTSP), which is an advanced version of the TSP, the distances or costs between cities are not only uncertain (fuzzy) but also contain elements of indeterminacy—situations where data may be incomplete, contradictory, or partially known. In NFTSP, the distances or costs between cities are represented using neutrosophic fuzzy numbers to reflect uncertainty, indeterminacy, and partial truth in the data. This can model real-world situations where not only are the distances imprecise (fuzzy), but also some parts of the data may be contradictory (indeterminate) or unknown (indeterminate).

FlorentinSmarandache[1]introduced the concept of **Neutrosophic fuzzy** in the year **1995**, which extends traditional fuzzy to include degrees of truth, indeterminacy, and falsity. In 2015, K. M. Agarwal [2] focused on the fuzzy multi objective travelling salesman problem. Broumi et al. [3] used triangular fuzzy neutrosophic information for examining the Shortest Path problem. The ones assignment approach was being used by Subasri, and Selvakumari [4] to solve the neutrosophic traveling salesman problem with triangular fuzzy numbers. NAP was organized by Khalifa et al. [5] using an interval-valued trapezoidal neutrosophic number. DhouibSouhail [6] uses the dhouib-matrix-TSP1 heuristic to explain and demonstrate the Neutrosophic triangular fuzzy traveling salesman problem. Using the Nearest Neighbor Technique, Framila et al. [7] developed the NTSP in Hexagonal Fuzzy Numbers. Nithya and Harini [8] (2022) utilized the Hungarian method to study the fuzzy transportation issue. Ye Jun (2014) developed a trapezoidal neutrosophic set and used it to make decisions based on multiple attributes.For the Single-valued Triangular Neutrosophic Fuzzy Traveling Salesman Problem, Srinivas et al.[10] introduced an optimization approach.

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The format of this article is as follows:

- We discuss some basic ideas that will be considerably more useful when utilizing Neutrosophic fuzzy sets in section 2, which comes after the introduction.
- Methodology of the problem is covered in Section 3.
- Section 4 discusses how to apply for NTSP.
- Section 5 presents a discussion and the results.
- Lastly, section 6 contains the conclusion.

II. PRELIMINARIES

2.1 Neutrosophic fuzzy set

Let U be an universe of discourse. The neutrosophic set A in U is expressed by $A = \{\langle x: T_{A(X)}, I_{A(X)}, F_{A(X)}\rangle, x \in U\}$, where the characteristic functions $T, I, F: U \to]0^-, 1^+[$ respectively define the degree of membership, the degree of indeterminacy and the degree of non-membership of the element $x \in U$ to the set A with the condition, $0^- \leq T_{A(X)} + I_{A(X)} + F_{A(X)} \leq 3^+$

2.2 Trapezoidal Fuzzy Numbers

A Trapezoidal Fuzzy Numbers $\tilde{T}(a, b, c, d)$ is defined by four real numbers a,b,c and d, where $a \leq b \leq c \leq d$. The membership function $\mu_{\tilde{T}}(x)$ of a trapezoidal fuzzy number $\tilde{T}(a, b, c, d)$ is described as follows:

$$\mu_{\tilde{T}}(x) = \begin{cases} 0 & \text{if } x < a \\ \dfrac{x-a}{b-a} & \text{if } a \leq x < b, \\ 1 & \text{if } b \leq x \leq c \\ \dfrac{d-x}{d-c} & \text{if } a < x \leq d \\ 0 & \text{if } x > d \end{cases}$$

2.3 Neutrosophic Trapezoidal Fuzzy Number

Let X be a universe of discourse, a trapezoidal neutrosophic set A in X is defined as the following form $\widetilde{NT} = \{\langle x, : T_{AN}(x), I_{AN}(x), F_{AN}(x)/x \in X\rangle\}$, where $T_{AN}(x) \subset [0,1]$, $I_{AN}(x) \subset [0,1]$ and $F_{AN}(x) \subset [0,1]$ are three trapezoidal fuzzy numbers,

$T_{AN}(x) = (T_N^1(x), T_N^2(x), T_N^3(x), T_N^4(x)) : X \to [0,1]$

2.2 Graded Mean Integration Method

Graded mean integration technique will maps the set of all neutrosophic fuzzy numbers to set of real numbers and it is defined as follows

$$G(\tilde{A}) = \frac{a_1 + 4a_2 + a_3}{6}$$

III. METHODOLOGY

3.1 Travelling Salesman Problem using Diagonal Completion Method

- Mention the problem
- Determine each row's minimum element and deduct it from the row.
- Determine each column's minimum element and deduct it from the column.
- Determine the penalty for every zero.
- Put the penalties P(i,j) in value-based descending order.
- The links should to be chosen for the workable partial travel/circuit.
- Determine the partial travel chains that are viable.
- Determine how far away the end path is overall.

3.2 Formation of Neutrosophic Travelling Salesman Problem

The generalized neutrosophic fuzzy TSP can be denoted in the form of $n \times n$ neutrosophic fuzzy matrix (T_{ij}, I_{ij}, F_{ij}) is shown as follows

	1	2	3	…j…	N
1	∞	(T_{12}, I_{12}, F_{12})	(T_{13}, I_{13}, F_{13})	(T_{1j}, I_{1j}, F_{1j})	(T_{1n}, I_{1n}, F_{1n})
2	(T_{21}, I_{21}, F_{21})	∞	(T_{23}, I_{23}, F_{23})	(T_{2j}, I_{2j}, F_{2j})	(T_{2n}, I_{2n}, F_{2n})
-	-	-	-	-	-
-	-	-	-	-	-
I	(T_{i1}, I_{i1}, F_{i1})	(T_{i2}, I_{i2}, F_{i2})	(T_{i3}, I_{i3}, F_{i3})	(T_{ij}, I_{ij}, F_{ij})	(T_{in}, I_{in}, F_{in})
-	-	-	-	-	-
N	(T_{n1}, I_{n1}, F_{n1})	(T_{n2}, I_{n2}, F_{n2})	(T_{n3}, I_{n3}, F_{n3})	(T_{nj}, I_{nj}, F_{nj})	∞

Mathematically, the Neutrosophic fuzzy TSP can be stated as,

$$(T_{ij}, I_{ij}, F_{ij}) = \begin{cases} 1, & \text{from city i to city j} \\ 0, & \text{otherwise} \end{cases}$$

Thus, the above can be expressed as,

$$D_N = \left(\bigcap_{i=1}^{m} O_i\right)\left(\bigcap_{j=1}^{n} C_j\right)(x, T_D(x), I_D(x), F_D(x))$$

Where $O_i \to$ neutrosophic objectives;

$C_i \to$ neutrosophic constrains;

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$T_D \rightarrow$ truth membership grade ; $I_D \rightarrow$ indeterminacy membership grade;
$F_D \rightarrow$ falsity membership grade.

$$\text{MinZ} = \sum_i \sum_j (T_{ij},\ I_{ij},\ F_{ij})\ x(T_{ij},\ I_{ij},\ F_{ij})$$

Subject to the constraints

$$\sum_{i=1}^{m} x(T_{ij},\ I_{ij},\ F_{ij}) = 1\ ;$$

$$j = 1,2,3,\dots,n \sum_{j=1}^{n} x_{ij} = 1\ ;$$

$$i = 1,2,3,\dots,n \sum_{i=1}^{m} x_{ij} = 0 \text{ or } 1$$

Proposed Algorithm

SanthiyaAmaliFramila (2022) has given a new approach for TSP in hexagonal fuzzy number using nearest neighbour technique and Nithya (2022) has proposed the technique to solve fuzzy transportation problem using Hungarian method. Following their algorithms and ideas, we modified a new approach.

- Define a problem
- Find the membership function for the given neutrosophic trapezoidal numbers
- Check whether the given cost matrix is balanced or not. If it's not balanced then add dummy row or column to balance the defined problem. If it is balance then go to next step.
- Now defuzzify the Neutrosophic cost matrix by using Graded Mean Integration method.

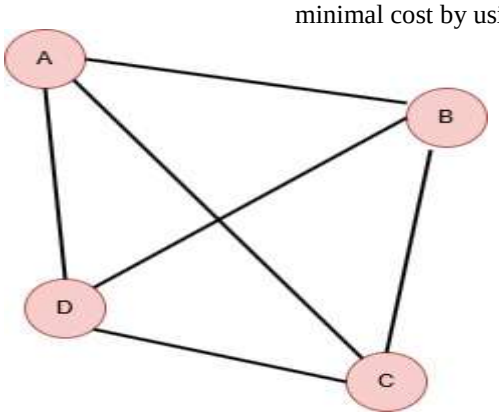
Apply diagonal completion method to determine the best optimal solution.

IV. APPLICATION:

In this section, the new approach of travelling salesman problem has been successfully discussed and solved.

Numerical Example

Let us consider the following Neutrosophic trapezoidal fuzzy travelling salesman problem with 4 hospitals A,B,C and D. The cost matrix $[C_{ij}]$ is given in trapezoidal neutrosophic fuzzy numbers. The problem is to find the route which starts from town A, passes through the each town and return to the home town exactly once at minimal cost by using membership function.



	A	B	C	D
A	∞	(4,6,8,10); (62,66,72,74); (105,110,113,114)	(26,29,35,37); (87,89,91,93); (124,127,133,136)	(44,50,54,55); (82,85,90,96); (112,114,115,116)
B	(4,6,8,10); (62,66,72,74); (105,110,113,114)	∞	(61,64,67,73); (102,109,110,117); (123,126,130,132)	(102,109,110,117); (124,125,131,134); (144,149,155,159)
C	(26,29,35,37); (87,89,91,93); (124,127,133,136)	(61,64,67,73); (102,109,110,117); (123,126,130,132)	∞	(143,147,151,156); (161,167,172,177); (183,187,190,192)
D	(44,50,54,55); (82,85,90,96); (112,114,115,116)	(102,109,110,117); (124,125,131,134); (144,149,155,159)	(143,147,151,156); (161,167,172,177); (183,187,190,192)	∞

Table.1: Membership Function of Neutrosophic Fuzzy Number

International Journal of Advances in Engineering and Management (IJAEM)
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Neutrosophic Fuzzy Number	Membership Function
0-20	0.6
20-40	0.10
40-60	0.14
60-80	0.18
80-100	0.20
100-120	0.22
120-140	0.24
140-160	0.28
160-180	0.30
180-200	0.36

$$\begin{bmatrix} \infty & (0.6,0.18,0.22) & (0.10,0.20,0.24) & (0.14,0.20,0.22) \\ (0.6,0.18,0.22) & \infty & (0.18,0.22,0.24) & (0.22,0.24,0.28) \\ (0.10,0.20,0.24) & (0.18,0.22,0.24) & \infty & (0.28,0.30,0.36) \\ (0.14,0.20,0.22) & (0.22,0.24,0.28) & (0.28,0.30,0.36) & \infty \end{bmatrix}$$

Now, converting the neutrosophic fuzzy into a crisp travelling salesman problem with the graded mean integration technique and get the following table

Table 2: Crisp Values

	A	B	C	D
A	∞	0.257	0.19	0.193
B	0.257	∞	0.217	0.243
C	0.19	0.217	∞	0.307
D	0.193	0.243	0.307	∞

Travelling Salesman Problem using Diagonal Completion Method

Finding the each row minimum element and subtract it from that row

	1	2	3	4	Row-minimum
1	-	0.067	0	0.003	(-0.19)
2	0.04	-	0	0.026	(-0.217)
3	0	0.027	-	0.117	(-0.19)
4	0	0.05	0.114	-	(-0.193)

International Journal of Advances in Engineering and Management (IJAEM)
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Similarly, finding the minimum element of each column and subtract it from that column

	1	2	3	4
1	-	0.04	0	0
2	0.04	-	0	0.023
3	0	0	-	0.114
4	0	0.023	0.114	-
	(-0)	(-0.027)	(-0)	(-0.003)

Now, Calculating the penalty of all 0's (penalty = minimum element of that row + minimum element of that column.)

	1	2	3	4
1	-	0.04	0(0)	0(0.023)
2	0.04	-	0(0.023)	0.023
3	0(0)	0(0.023)	-	0.114
4	0(0.023)	0.023	0.114	-

Now, List the penalties P(i,j) in descending order by value.
P(1,4)=0.023
P(2,3)=0.023
P(3,2)=0.023
P(4,1)=0.023
P(1,3)=0
P(3,1)=0

The links (1,4),(2,3),(4,1) are selected for inclusion in the feasible partial travel/transfer of medical equipment.
Feasible partial travel of medical equipment contains the following chains2→3→1→4
So our final path is B→C→A→D→B
and total distance is 0.217+0.19+0.193+0.243=0.843

V. RESULT AND DISCUSSION

Diagonal Completion Method	**Chain**	**2→3→1→4**
	Our final path	**B→C→A→D→B**
	Total distance	**0.843**

The neutrosophic fuzzy traveling salesman problem technique will help us to take a better decision for making a tour in a successive way within a short period. This analysis has presented the successful implementation of Trapezoidal Neutrosophic Fuzzy Transportation Salesman Problem using diagonal completion method. This new approach will be an effective tool for optimizing the transportation routes for medical goods, such as equipment or vaccinations, to hospitals and clinics. This technique will provide very simple and powerful ways to find the most desirable path with short distance and minimum cost.

VI. CONCLUSION

The neutrosophic fuzzy traveling salesman problem technique will help us to take a better decision for transporting medical goods in a successive way within a short period. This analysis has presented the successful implementation of Trapezoidal Neutrosophic Fuzzy Transportation

Salesman Problem using diagonal completion method will be an effective tool for planning this kind of medical item transportation. This technique will provide very simple and powerful ways to find the most desirable path with short distance and minimum cost.

Future Research Direction

In future this technique can be solved and compared by using branch and bound (penalty) method, and TSP using nearest neighbor method. And also, this technique can be implementing in interval-valued Neutrosophicfuzzy.

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