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# A Study on Multi-Objective Emergency Transportation Problem Using Neutrosophic Fuzzy Set

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In this paper, the several Multi-Objective Transportation Problem (MOTP) techniques are applied to solve real life problems. The objective of this application is to select the best transportation path with minimum time and cost as well as maximum man power and fund to the landslide affected area peoples. MOTP methodology has treated as a large number of successful applications in a variety of fields, like industrial location, investments, manpower planning, tourism, and so on. The victory of this technique is primarily due to its mathematical properties and its particular friendliness.

## 1. Introduction

Transportation Problems (TP) was analysed and introduced by Hitchcock (1941). These transportation problems are associated with single objective. But mostly in real-life situations, transportation problem usually involves multiple, conflicting, and imprecise parameters. For this type of problem there exists a technique, Multi-Objective Transportation Problem (MOTP). It is more difficult to solve because of the conflict and imprecise nature. To overcome this difficulty, Fuzzy Set Theory (FST) was developed by Zadeh (1965).

## 2. Multi-Objective Transportation Problem under Neutrosophic Environment

Defining the problem in the form of Neutrosophic fuzzy set as

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

Where $O_i \rightarrow$ neutrosophic objectives;

$C_i \rightarrow$ neutrosophic constrains;

$M_D \rightarrow$ truth membership grade ;

$F_D \rightarrow$ indeterminacy membership grade;

$T_D \rightarrow$ falsity membership grade.

$$M_D(x) = \max\left\{\begin{matrix} M_{o1}(x), M_{o2}(x), \dots M_{om}(x); \\ M_{c1}(x), M_{c2}(x), \dots M_{cn}(x) \end{matrix}\right\} \forall x \in X$$

$$F_D(x) = \max\left\{\begin{matrix} F_{o1}(x), F_{o2}(x), \dots F_{om}(x); \\ F_{c1}(x), F_{c2}(x), \dots F_{cn}(x) \end{matrix}\right\} \forall x \in X$$

$$T_D(x) = \min\left\{\begin{matrix} T_{o1}(x), T_{o2}(x), \dots T_{om}(x); \\ T_{c1}(x), T_{c2}(x), \dots T_{cn}(x) \end{matrix}\right\} \forall x \in X$$

For formulating the membership values, need to find an upper ($U_K$) and lower ($L_K$) bounds for each objective function and is defined as follows

$U_K = \max\{H_K(x)\}_{K=1}^{K}$ and

$L_K = \min\{H_K(x)\}_{K=1}^{K}$

Then, with the help of bounded values, the membership values are determined as follows

$$M_K(Z_K(x)) = \begin{cases} 1 & Z_K(x) \le L_K^M \\ 1 - \dfrac{Z_K(X) - L_K^M}{U_K^M - L_K^M} & L_K^M \le Z_K(x) \le U_K^M \\ 0 & Z_K(x) \ge U_K^M \end{cases}$$

$$F_K(Z_K(x)) = \begin{cases} 1 & Z_K(x) \le L_K^F \\ 1 - \dfrac{Z_K(X) - L_K^F}{U_K^F - L_K^F} & L_K^F \le Z_K(x) \le U_K^F \\ 0 & Z_K(x) \ge U_K^F \end{cases}$$

$$T_K(Z_K(x)) = \begin{cases} 1 & Z_K(x) \ge L_K^T \\ 1 - \dfrac{L_K^T - Z_K(X)}{U_K^T - L_K^T} & L_K^T \le Z_K(x) \le U_K^T \\ 0 & Z_K(x) \le U_K^T \end{cases}$$

## 3. EXAMPLE PROBLEM:

After a landslide, the community welfare team has shipped their units of

i) Man power

ii) Fund for food and water items

iii) Health supplies like medicine and sanitation etc.,

From their welfare centres S1, S2, S3 to most affected landslide areas D1, D2, D3, D4 respectively with the following characteristics; the transportation cost, time, and loss of deterioration are considered as Neutrosophic penalties.

Supplies: 7,18,16

Demand: 10, 2, 13,15

Penalties:

Category 1:

$$C_1 = \begin{bmatrix} (0.5,0.4,0.6) & (0.4,0.4,0.5) & (0.5,0.3,0.7) & (0.5,0.5,0.4) \\ (0.5,0.3,0.6) & (0.3,0.1,0.2) & (0.6,0.7,0.3) & (0.5,0.4,0.6) \\ (0.6,0.5,0.3) & (0.6,0.7,0.4) & (0.4,0.4,0.5) & (0.6,0.4,0.3) \end{bmatrix}$$

Category 2:

$$C_2 = \begin{bmatrix} (0.4,0.4,0.5) & (0.4,0.3,0.7) & (0.5,0.6,0.3) & (0.6,0.5,0.2) \\ (0.4,0.3,0.6) & (0.6,0.5,0.7) & (0.5,0.2,0.6) & (0.6,0.4,0.3) \\ (0.6,0.5,0.2) & (0.7,0.6,0.4) & (0.3,0.7,0.3) & (0.5,0.3,0.7) \end{bmatrix}$$

Objective function for the above problem is as follows

$$\mathrm{MaxM}_1(U(u)) = 0.5u_{11} + 0.4u_{12} + 0.5u_{13} + 0.5u_{14} + 0.5u_{21} + 0.3u_{22} + 0.6u_{23} + 0.5u_{24} + 0.6u_{31} + 0.6u_{32} + 0.4u_{33} + 0.6u_{34}$$

$$\mathrm{MaxM}_2(V(v)) = 0.4v_{11} + 0.4v_{12} + 0.5v_{13} + 0.6v_{14} + 0.4v_{21} + 0.6v_{22} + 0.5v_{23} + 0.6v_{24} + 0.6v_{31} + 0.7v_{32} + 0.3v_{33} + 0.5v_{34}$$

$$\mathrm{MaxF}_1(U(u)) = 0.4u_{11} + 0.4u_{12} + 0.3u_{13} + 0.5u_{14} + 0.3u_{21} + 0.1u_{22} + 0.7u_{23} + 0.4u_{24} + 0.5u_{31} + 0.7u_{32} + 0.4u_{33} + 0.4u_{34}$$

$$\mathrm{MaxF}_2(V(v)) = 0.4v_{11} + 0.3v_{12} + 0.6v_{13} + 0.5v_{14} + 0.3v_{21} + 0.5v_{22} + 0.2v_{23} + 0.4v_{24} + 0.5v_{31} + 0.6v_{32} + 0.7v_{33} + 0.3v_{34}$$

$$\mathrm{MinT}_1(U(u)) = 0.6u_{11} + 0.5u_{12} + 0.7u_{13} + 0.4u_{14} + 0.6u_{21} + 0.2u_{22} + 0.3u_{23} + 0.6u_{24} + 0.3u_{31} + 0.4u_{32} + 0.5u_{33} + 0.3u_{34}$$

$$\mathrm{MinT}_2(V(v)) = 0.5v_{11} + 0.7v_{12} + 0.3v_{13} + 0.2v_{14} + 0.6v_{21} + 0.7v_{22} + 0.6v_{23} + 0.3v_{24} + 0.2v_{31} + 0.4v_{32} + 0.3v_{33} + 0.7v_{34}$$

Then, separating the membership function in matrix format as shown below

$$M_1 = \begin{bmatrix} 0.5 & 0.4 & 0.5 & 0.5 \\ 0.5 & 0.3 & 0.6 & 0.5 \\ 0.6 & 0.6 & 0.4 & 0.6 \end{bmatrix} \;\&\; M_2 = \begin{bmatrix} 0.4 & 0.4 & 0.5 & 0.6 \\ 0.4 & 0.6 & 0.5 & 0.6 \\ 0.6 & 0.7 & 0.3 & 0.5 \end{bmatrix}$$

$$F_1 = \begin{bmatrix} 0.4 & 0.4 & 0.3 & 0.5 \\ 0.3 & 0.1 & 0.7 & 0.4 \\ 0.5 & 0.7 & 0.4 & 0.4 \end{bmatrix} \;\&\; F_2 = \begin{bmatrix} 0.4 & 0.3 & 0.6 & 0.5 \\ 0.3 & 0.5 & 0.2 & 0.4 \\ 0.5 & 0.6 & 0.7 & 0.3 \end{bmatrix}$$

$$T_1 = \begin{bmatrix} 0.6 & 0.5 & 0.7 & 0.4 \\ 0.6 & 0.2 & 0.3 & 0.6 \\ 0.3 & 0.4 & 0.5 & 0.3 \end{bmatrix} \;\&\; T_2 = \begin{bmatrix} 0.5 & 0.7 & 0.3 & 0.2 \\ 0.6 & 0.7 & 0.6 & 0.3 \\ 0.2 & 0.4 & 0.3 & 0.7 \end{bmatrix}$$

Now, evaluating the membership values and we get

$$M_1 = \begin{bmatrix} 0.5 & 0.4 & 0.5 & 0.5 \\ 0.5 & 0.3 & 0.6 & 0.5 \\ 0.6 & 0.6 & 0.4 & 0.6 \end{bmatrix};\; U_1^M = 0.6 \;\&\; L_1^M = 0.3$$

$$M_2 = \begin{bmatrix} 0.4 & 0.4 & 0.5 & 0.6 \\ 0.4 & 0.6 & 0.5 & 0.6 \\ 0.6 & 0.7 & 0.3 & 0.5 \end{bmatrix};\; U_2^M = 0.7 \;\&\; L_2^M = 0.3$$

We get the truth membership values as given below

$$M_1(U(u)) = \begin{bmatrix} 0.33 & 0.67 & 0.33 & 0.33 \\ 0.33 & 1 & 0 & 0.33 \\ 0 & 0 & 0.67 & 0 \end{bmatrix} \&$$

$$M_2(V(v)) = \begin{bmatrix} 0.75 & 0.75 & 0.50 & 0.25 \\ 0.75 & 0.25 & 0.50 & 0.25 \\ 0.25 & 0 & 1 & 0.50 \end{bmatrix}$$

From above two matrices, we get a truth membership matrix as

| | D1 | D2 | D3 | D4 | Supply |
|---|---|---|---|---|---|
| S1 | 0.75 | 0.67 | 0.50 | 0.33 | 7 |
| S2 | 0.75 | 1 | 0.50 | 0.33 | 18 |
| S3 | 0.25 | 0 | 1 | 0.50 | 16 |
| Demand | 10 | 2 | 13 | 15 | |

Table 2.1: Truth Membership Matrix

Now taking the indeterminacy values

$$F_1 = \begin{bmatrix} 0.4 & 0.4 & 0.3 & 0.5 \\ 0.3 & 0.1 & 0.7 & 0.4 \\ 0.5 & 0.7 & 0.4 & 0.4 \end{bmatrix};\; U_1^F = 0.7 \;\&\; L_1^F = 0.1$$

$$F_2 = \begin{bmatrix} 0.4 & 0.3 & 0.6 & 0.5 \\ 0.3 & 0.5 & 0.2 & 0.4 \\ 0.5 & 0.6 & 0.7 & 0.3 \end{bmatrix};\; U_1^F = 0.7 \;\&\; L_1^F = 0.2$$

We get the indeterminacy membership values as given below

$$F_1(U(u)) = \begin{bmatrix} 0.5 & 0.5 & 0.67 & 0.3 \\ 0.67 & 1 & 0 & 0.5 \\ 0.3 & 0 & 0.5 & 0.5 \end{bmatrix} \&$$

$$F_2(V(v)) = \begin{bmatrix} 0.6 & 0.8 & 0.2 & 0.4 \\ 0.8 & 0.4 & 1 & 0.6 \\ 0.4 & 0.2 & 0 & 0.8 \end{bmatrix}$$

From above two matrices, we get a indeterminacy membership matrix as

| | D1 | D2 | D3 | D4 | Supply |
|---|---|---|---|---|---|
| S1 | 0.6 | 0.8 | 0.67 | 0.4 | 7 |
| S2 | 0.8 | 1 | 1 | 0.6 | 18 |
| S3 | 0.4 | 0.2 | 0.5 | 0.8 | 16 |
| Demand | 10 | 2 | 13 | 15 | |

Table 2.2: indeterminacy membership matrix

Now taking the falsity values

$$T_1 = \begin{bmatrix} 0.6 & 0.5 & 0.7 & 0.4 \\ 0.6 & 0.2 & 0.3 & 0.6 \\ 0.3 & 0.4 & 0.5 & 0.3 \end{bmatrix}; U_1^T = 0.7 \;\&\; L_1^T = 0.2$$

$$T_2 = \begin{bmatrix} 0.5 & 0.7 & 0.3 & 0.2 \\ 0.6 & 0.7 & 0.6 & 0.3 \\ 0.2 & 0.4 & 0.3 & 0.7 \end{bmatrix}; U_1^T = 0.7 \;\&\; L_1^T = 0.2$$

We get the falsity membership values as given below

$$T_1(U(u)) = \begin{bmatrix} 0.8 & 0.6 & 1 & 0.4 \\ 0.8 & 0 & 0.20 & 0.8 \\ 0.2 & 0.4 & 0.6 & 0.2 \end{bmatrix} \&$$

$$T_2(V(v)) = \begin{bmatrix} 0.6 & 1 & 0.2 & 0 \\ 0.8 & 1 & 0.8 & 0.2 \\ 0 & 0.4 & 0.2 & 1 \end{bmatrix}$$

From above two matrices, we get a falsity membership matrix as

| | D1 | D2 | D3 | D4 | Supply |
|---|---|---|---|---|---|
| S1 | 0.6 | 0.6 | 0.2 | 0 | 7 |
| S2 | 0.8 | 0 | 0.20 | 0.2 | 18 |
| S3 | 0 | 0.4 | 0.2 | 0.2 | 16 |
| Demand | 10 | 2 | 13 | 15 | |

Table 2.3: Falsity Membership Matrix

Solving the tables 2.1,2.2,2.3 separately by VAM method, we get the values,

| | VAM |
|---|---|
| M | 27.96 |
| F | 33.6 |
| T | 4.2 |

## 4. CONCLUSION:

The above results show that the maximum man power and fund (M and F) for transportation to supply food, water and health supplies like medicine and so on. And minimize the travelling time (T) to help the landslide affected area peoples in correct time. A natural disaster is an unexpected occurrence of events that harm society. Some of them are earthquake, tsunami, landslide, flood, volcanic eruption, cyclone, and so on. the main motive is to provide an optimal solution for a transportation problem with multiple objective functions in any emergency situation.

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