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Yeola M.C and Jahav V.A

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RESEARCH ARTICLE

SOLVING MULTI-OBJECTIVE TRANSPORTATION PROBLEM USING FUZZY PROGRAMMING TECHNIQUE-PARALLEL METHOD

Yeola M.C[1] and Jahav V.A[2]

[1]Department of Statistics, Ahmednagar College, Ahmednagar
[2]Department of Statistics, Computer Science & IT, N.E.S. Science College, Nanded

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ABSTRACT

In this paper, we have proposed a method to solve the Multi-Objective Transportation Problem (MOTP). Here, fuzzy programming technique is used with fuzzy linear membership function for different costs to solve MOTP. The proposed method is parallel to New Row Maxima Method. It gives better results for solving MOTP with less complexity. Finally, numerical examples are illustrated to check the feasibility of the proposed study.

INTRODUCTION

The transportation problem (TP) is a specific problem of resource allocation, can be formulated as a linear programming problem, where the constraints have a special structure. The classical form of the transportation problem minimizes transporting cost of some commodity that is available at m sources and required at n destinations. The sources are the production facilities, warehouses or supply points and destinations are the consumption points, warehouses or demand points. The transportation problem was firstly developed by Hitchcock in 1947 [4]. Efficient method of solution derived from the simplex algorithm were primarily developed by Dantzig [5] and then by Charneset. al [1]. The transportation problem can be modelled as a standard linear programming problem, which can be solved by the Simplex method.

The objective of the transportation problem is to determine the optimum schedule from different sources to different destinations so as minimize the cost of transportation. The methods like North West Corner Rule, Row minima, Column minima and Vogel's approximation method are available to get Initial Basic Feasible Solution and Modified Distribution Method (MODI) for obtaining optimal solution.

A transportation problem for a single objective can be stated as:

$$Mi\ \ f(x) = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}x_{ij}$$

Subject to the constraints

$$\sum_{j=1}^{n} x_{ij} = a_i\ ,\quad for i = 1, 2, \dots m$$

$$\sum_{i=1}^{m} x_{ij} = b_j\ \ for j = 1, 2, \dots, n$$

$$x_{ij} \geq\ 0\ ,\quad i = 1,2, \dots, m and j = 1, 2, \dots n$$

In the real life situation, all transportation problems are not single objective. The transportation problem involves multiple

*Corresponding author: **Yeola M.C**
Department of Statistics, Ahmednagar College, Ahmednagar

conflicting and incommensurable objective functions are called as multi-objective transportation problem. The mathematical model of MOTP can be expressed as follows:

$$Mi\; f^k(x) = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}^k x_{ij} \; k = 1,2,\dots\dots\dots p$$

Subject to the constraints

$$\sum_{j=1}^{n} x_{ij} = a_i \;,\quad for i = 1,2,\dots m$$

$$\sum_{i=1}^{m} x_{ij} = b_j \quad for j = 1,2,\dots,n$$

$$x_{ij} \geq 0 \;,\quad i = 1,2,\dots.,m and j = 1,2,\dots n$$

The superscript on $f^k(x)$ and C_{ij}^k denote the k-th penalty criterion, $a_i > 0$ for all i, $b_j > 0$ for all j, $C_{ij}^k \geq 0$ for all (i , j) and $\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$ (balanced condition)

The balanced condition is both necessary and sufficient for solving the transportation problem in both the cases single and multiple objectives.

Fuzzy Preliminaries

Definition

In this paper, penalties (transportation cost, delivery time etc.) as membership value through defined membership function. As membership value is higher it is closer to the optimal solution. The decision maker would like to minimise the set of p objectives. Here linear membership function is used and defined as:

$$\mu_k(x_{ij}^k) = \left\{ \begin{array}{ll} 1 & x_{ij}^k \leq L_k \\ \dfrac{U_k - x_{ij}^k}{U_k - L_k} & L_k \leq x_{ij}^k \leq U_k \\ 0 & x_{ij}^k \geq U_k \end{array} \right\} \quad --- (1)$$

Where $L_k \neq U_k$,k= 1,2,..........p. If $L_k = U_k$ then membership value is 1 for any value of k.

Proposed parallel methodology

For solving MOTP, the proposed method is summarised in the following Steps:

Step 1: Calculate the linear membership value using equation (1) for each cell and for each objective table.

Step 2: Construct a new table in which each cell having minimum membership value of all objective tables.

Step 3: Take the first row and search maximum membership value, allocate in this cell maximum possible to get rim condition. If tie occurs then compare the two columns and allocate maximum possible for the column where minimum elements are occurred in the subsequent rows.

Step 4: If rim condition is in row then go to next row and repeat step 3. If rim condition is in column, then search next maximum membership value in the same row and allocate in this cell maximum possible to get rim condition.

Step 5: Repeat steps 3 and 4 until supply and demand are exhausted.

Illustrative Example

Problem 1: Let us consider the following example [3] to illustrate the proposed method.

A supplier, supply a product to different destinations from different sources. The supplier has to take decision in this transportation problem so that cost and transportation time should be minimum. The data for the cost and time is as follows:

Data for time (**Table 1**)

Destination → Sources ↓	D1	D2	D3	Supply
S1	16	19	12	14
S2	22	13	19	16
S3	14	28	8	12
Demand	10	15	17	42

Data for cost (**Table 2**)

Destination → Sources ↓	D1	D2	D3	Supply
S1	9	14	12	14
S2	16	10	14	16
S3	8	20	6	12
Demand	10	15	17	42

As the first step we calculate membership value for time, here U_k = 28 and L_k = 8 then membership values are as follows:

Table 3

Destination → Sources ↓	D1	D2	D3	Supply
S1	0.6	0.45	0.8	14
S2	0.3	0.75	0.45	16
S3	0.7	0	1	12
Demand	10	15	17	42

Membership value for cost, here U_k = 20 and L_k = 6 then membership values are as follows:

Table 4

Destination → Sources ↓	D1	D2	D3	Supply
S1	0.79	0.43	0.57	14
S2	0.29	0.71	0.43	16
S3	0.86	0.00	1.00	12
Demand	10	15	17	42

Now we calculate minimum membership value

Table 5

Destination → Sources ↓	D1	D2	D3	Supply
S1	0.60	0.43	0.57	14
S2	0.29	0.71	0.43	16
S3	0.70	0.00	1.00	12
Demand	10	15	17	42

After applying the proposed parallel method we get the solution as follows:

X = { X_{11} = 10 ,X_{13} = 4, X_{22} = 15, X_{23} = 1, X_{33} = 12}

The corresponding objective functions values are $f^1(x) = 518$ and $f^2(x) = 374$ Problem 2:Let us consider another example of MOTP [2,6,7,8] having the following characteristics.

Table 6

Destination → Sources ↓	D1	D2	D3	D4	Supply
S1	1	2	7	7	8
S2	1	9	3	4	19
S3	8	9	4	6	17
Demand	11	3	14	16	44

Table 7

Destination → Sources ↓	D1	D2	D3	D4	Supply
S1	4	4	3	4	8
S2	5	8	9	10	19
S3	6	2	5	1	17
Demand	11	3	14	16	44

As the first step we calculate membership value for first objective table, here U_k = 9 and L_k = 1, then membership values are as follows:

Table 8

Destination → Sources ↓	D1	D2	D3	D4	Supply
S1	1	0.875	0.25	0.25	8
S2	1	0	0.75	0.625	19
S3	0.125	0	0.625	0.375	17
Demand	11	3	14	16	44

Membership value for second objective table, here U_k = 10 and L_k = 1 then membership values are as follows:

Table 9

Destination → Sources ↓	D1	D2	D3	D4	Supply
S1	0.667	0.667	0.778	0.667	8
S2	0.556	0.222	0.111	0	19
S3	0.444	0.889	0.556	1	17
Demand	11	3	14	16	44

Here we calculate minimum membership value

Table 10

Destination → Sources ↓	D1	D2	D3	D4	Supply
S1	0.667	0.667	0.25	0.25	8
S2	0.556	0	0.111	0	19
S3	0.125	0	0.556	0.375	17
Demand	11	3	14	16	44

On applying the proposed parallel methodology we get the solution as follows:

X = { X_{11}= 5,X_{12} = 3, X_{21} = 6, X_{23} = 13, X_{33} = 1, X_{34} = 16}
The corresponding objective functions values are

$f^1(x) = 156$ and $f^2(x) = 200$

The results of the above two examples are summarised and shown below in Table 11 and Table 12 respectively.

Table 11

Objective functions	Proposed method	New Row maxima method
$f^1(x)$	518	518
$f^2(x)$	374	374

Table 12

Objective functions	Proposed method	New Row maxima method	Fuzzy Goal programming Approach K Venkatasubbaiah
$f^1(x)$	156	172	160
$f^2(x)$	200	213	195

CONCLUSIONS

In this paper, we propose a parallel algorithm for solving MOTP. Proposed method is a modified method to new row maxima method. Instead of considering average we have considered minimum of membership value. To take minimum of cost and time in first example (or in any other examples all the cost matrices may not have the same units of measurements) is not logically true because of their units. But by converting them in membership value they become unit less pure numbers and its possible to take minimum of two or more cost matrix. Two numerical examples are illustrated and obtained results compared with some of the methods in literature. In first problem we get the same solution for both objectives cost as well as time as in new row matrix maxima method. But in second problem, we get improved solutions as compared to the new row matrix maxima method.

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