CHAPTER-3

OPTIMAL SOLUTION OF MULTI-OBJECTIVE TRANSPORTATION PROBLEM WITH FUZZY DEMAND AND FUZZY PRODUCT BASED ON LEVEL $(\lambda, 1)$ AS FUZZY NUMBERS

3.1 INTRODUCTION

The transportation problem is a special types of linear programming problem and the constraints represents the mathematical formulation. The source (origin) parameter $(a_i)$ may be production facilities, and the destination parameter $(b_j)$ may be warehouses or sales outlet etc. The unit transportation cost $C_{ij}$ or penalty is the coefficients of the objective functions represented transportation cost, delivery time, number of goods transported, unfulfilled demand and many others. For solving the multi-objective transportation problem, Bit, A.K.(1992) developed a solution procedure using fuzzy programming technique for multi-objective criteria decision-making transportation problems. S. Chanas and D. Kuchta(1996) presented a concept of the optimal solution of the transportation problems with fuzzy coefficients. For solving of the transportation problems with the assumption that the coefficients of the objective function and the supply and demand values in a precise of crisp manner. J.M. Cadenas and J. L. Verdeg (1997) they fuzzified the constraints in linear programming through fuzzy
numbers and used fuzzy level to obtain linear programming in fuzzy manner.


The method in this chapter is to fuzzify the coefficients of the constraints and constant terms of fuzzy number with the product and demand to the level \((\lambda, 1)\) interval-valued fuzzy numbers. We propose a method to solve the multi-objective transportation problem in which the co-efficient of the objective function as well as source and destination parameters are in the form of interval.

In order to illustrate solution method and numerical examples are provided.
3.2 MULTI-OBJECTIVE INTERVAL TRANSPORTATION PROBLEM

The multi-objective interval transportation problem is the problem of minimizing \( k \) interval-valued objective functions with interval origin and interval destination parameters.

Let \( a_i \) and \( b_j \) be the amount of supply of the \( i^{th} \) origin and the amount of demand of the \( j^{th} \) destination respectively. The multi-objective transportation cost from \( i^{th} \) origin to \( j^{th} \) destination is \( C_{ij}^k \) is divided into an interval \( \left[ C_{L_{ij}}^k, C_{R_{ij}}^k \right] \) representing the uncertain cost for the transportation problem, let \( x_{ij} \) represent the amount transported from origin \( i \) to destination \( j \), the origin parameter lies between the left limit \( a_{L_i} \) and right limit \( a_{R_i} \), as well as the destination parameter lies between left limit \( b_{L_j} \) and right limit \( b_{R_j} \). We have the crisp multi-objective transportation model.

Minimize \( Z^k = \sum_{i=1}^{m} \sum_{j=1}^{n} \left[ C_{L_{ij}}^k, C_{R_{ij}}^k \right] x_{ij}, k = 1, 2, 3, \ldots, K \) \( \ldots(3.1) \)

\[
\sum_{j=1}^{n} x_{ij}^k = [a_{L_i}, a_{R_i}], \quad i = 1, 2, 3, \ldots, m
\]

s.t. \( \sum_{i=1}^{m} x_{ij}^k = [b_{L_j}, b_{R_j}], \quad j = 1, 2, 3, \ldots, n \) \( \ldots(3.2) \)

\( x_{ij} \geq 0, \quad i = 1, 2, 3, \ldots m, \quad j = 1, 2, 3, \ldots, n \)
Consistently,

\[
\sum_{i=1}^{m} a_{L_i} = \sum_{j=1}^{n} b_{L_j} \quad \text{and} \quad \sum_{i=1}^{m} a_{R_i} = \sum_{j=1}^{n} b_{R_j} \quad \ldots(3.3)
\]

If we have \( C_{ij}^{k}, a_i, b_j, \ i = 1, 2, 3 \ldots m, j = 1, 2, 3 \ldots n, \) then we can use simplex method, north-west corner rule, the least-cost method and etc. for solving these types of problem.

Suppose the transportation plan does not execute once, since the amount of supply at the \( i^{\text{th}} \) origin may not be exactly \( a_i \) each time, At any time it could be fluctuate shortly. Hence the decision maker would decide the amount of supply to lie in the interval.

\[
[a_{L_i} - \theta_{1i}, a_{L_i} + \theta_{2i}] < 0 < \theta_{1i} < a_{L_i}, \ 0 < \theta_{2i}
\]

Since, we know that by the fuzzy theory

\[
[a_{L_i} - \theta_{1i}, a_{L_i} + \theta_{2i}] \text{ is not a value. So corresponding to this interval, let the fuzzy product is based on level 1 which can fuzzy } \tilde{a}_i \text{ to a level 1 fuzzy numbers.}
\]

\[
\tilde{a}_i = [a_{Li} - \theta_{1i}, a_i, a_{Ri} + \theta_{2i}; 1] < 0 < \theta_{1i} < a_i; \ 0 < \theta_{2i}
\]

\[\forall \ i = 1, 2, 3, \ldots m\]

\[
\ldots(3.4)
\]

Similarly we can also fuzzify \( \tilde{b}_j \) for a level of 1 which is a fuzzy number.
\[ \tilde{b}_j = [b_{L_j} - \delta_{1_j}, b_j, b_{R_j} + \delta_{2_j}; 1], \quad 0 < \delta_{1_j} < b_j, \quad 0 < \delta_{2_j} \]

\[ \forall j = 1, 2, 3, \ldots, n \quad \text{...(3.5)} \]

Let us consider \( C_{ij}^{k}, \quad i = 1, 2, 3, \ldots, m \) and \( j = 1, 2, 3, \ldots, n \) does not change in the crisp transportation at time period \( T \).

With this period, the transportation plan does not execute once and in eqns. (3.3), (3.4) the amount of supply in the \( i^{th} \) origin may not be a fixed conditions. So we fuzzified it by \( a_i \) to \( \tilde{a}_i \) and we assume the membership grade of \( a_i \) lies in interval \([\lambda, 1]\) where \( 0 < \lambda < 1 \)

\[ \tilde{a}_i = [(a_{L_i} - \theta_{3i}, a_i, a_{R_i} + \theta_{4i}; \lambda), (a_i - \theta_{4i}, a_i, a_i + \theta_{2i}; 1)] \quad \text{...(3.6)} \]

where \( 0 < \theta_{3i} < \theta_{1i} < a_i \) and \( 0 < \theta_{4i} < \theta_{2i} \quad \forall \ i = 1, 2, 3, \ldots, m \)

Now we can fuzzify \( b_j \) to the level \([\lambda, 1]\) be the fuzzy number.

\[ \tilde{b}_j = [(b_{L_j} - \delta_{3j}, b_j, b_{R_j} + \delta_{4j}; \lambda), (b_{L_j} - \delta_{1j}, b_j, b_{R_j} + \delta_{2j}; 1)] \quad \text{...(3.7)} \]

where, \( 0 < \delta_{3j} < \delta_{1j} < b_j, \quad 0 < \delta_{4j} < \delta_{2j} \quad \forall \ j = 1, 2, 3, \ldots, n \)

Now we let \( \tilde{1} \overset{1}{=} [(1,1,1; \lambda), (1,1,1; 1)] \)

So we formulate the fuzzy multi-objective transportation problem

\[ \text{Min.} \quad Z^k = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij}^{k} x_{ij}^k \quad \text{...(3.8)} \]

\[ \sum_{j=1}^{n} x_{ij}^k \tilde{1} = [\tilde{a}_L, \tilde{a}_R], i = 1, 2, 3, \ldots, m \]

\[ \text{s.t.} \quad \sum_{i=1}^{m} x_{ij}^k \tilde{1} = [\tilde{b}_L, \tilde{b}_R], j = 1, 2, 3, \ldots, n \quad \text{...(3.9)} \]
\[ x^k_{ij} \geq 0 \quad \forall \quad i = 1, 2, 3, \ldots, m, j = 1, 2, 3, \ldots, n \]

therefore we have

\[ \sum_{i=1}^{m} [\tilde{a}_{Li}^i, \tilde{a}_{Ri}^i] = \sum_{j=1}^{n} [\tilde{b}_{Lj}^j, \tilde{b}_{Rj}^j] \quad \ldots \text{(3.10)} \]

From equations (3.6—3.10) we have the fuzzy transportation problem in the fuzzy manner

Min. \[ Z^k = \sum_{i=1}^{m} \sum_{j=1}^{n} C^k_{ij} x^k_{ij} \]

s.t.

\[ \begin{cases} 
\sum_{j=1}^{n} x^k_{ij} = a_i + \frac{1}{16} [\theta_4 i - \theta_3 i + (4 - 3\lambda)(\theta_2 i - \theta_1 i)], i = 1, 2, 3, \ldots, m \\
\sum_{i=1}^{m} x^k_{ij} = b_j + \frac{1}{16} [\delta_4 j - \delta_3 j + (4 - 3\lambda)(\delta_2 j - \delta_1 j)], j = 1, 2, 3, \ldots, n 
\end{cases} \]

\[ x^k_{ij} \geq 0 \quad \forall \quad i = 1, 2, 3, \ldots, m \quad \text{&} \quad j = 1, 2, 3, \ldots, n \quad \ldots \text{(3.11)} \]

due to consistency,

\[ \sum_{i=1}^{m} [\theta_4 i - \theta_3 i + (4 - 3\lambda)(\theta_2 i - \theta_1 i)] = \sum_{j=1}^{n} [\delta_4 j - \delta_3 j + (4 - 3\lambda)(\delta_2 j - \delta_1 j)] \]

\[ \ldots \text{(3.12)} \]

Since the source (origin) parameter lies between left limit \( a_{Li} \) and right limit \( a_{Ri} \) and the destination parameter lies between left limit \( b_{Lj} \) and right limit \( b_{Rj} \) let this type of problem may be considered as follows
Chapter 3...

Min.  \( Z^k = \sum C^k_{ij} x^k_{ij} \)  \( \begin{align*} \sum_i x_{ij} &= a_i \\
\sum_j x_{ij} &= b_j \\
x_{ij} &\geq 0 \end{align*} \)  

\[ \underline{3.13} \]

\( \sum_i a_i = \sum_j b_j \quad \forall \ i & \& j \)

Where, \( Z \in R^k \) and \( C^k_{ij} = [C^{1}_{L_{ij}}, C^{k}_{R_{ij}}] \)

as \( C^{L_{ij}} = (C^{1}_{L_{ij}}, C^{2}_{L_{ij}}, \ldots, C^{k}_{L_{ij}}) \)

\( C^{R_{ij}} = (C^{1}_{R_{ij}}, C^{2}_{R_{ij}}, \ldots, C^{k}_{R_{ij}}) \)

represents the left bound and right bound of \( C^k_{ij} \).

3.3 FORMULATION OF CRISP CONSTRAINT

Consider the following multi-objective transportation problem

Minimize \( Z^k = \sum_{i=1}^{m} \sum_{j=1}^{n} C^k_{ij} x^k_{ij} \)

s.t. \( \sum_{j=1}^{n} x_{ij} \leq a_{R_i}, \sum_{j=1}^{n} x_{ij} \geq a_{L_i} \)

\( \sum_{i=1}^{m} x_{ij} \leq b_{R_j}, \sum_{i=1}^{m} x_{ij} \geq b_{L_j} \)

with \( \sum_{i=1}^{m} a_{R_i} = \sum_{j=1}^{n} b_{R_j}, \sum_{i=1}^{m} a_{L_i} = \sum_{j=1}^{n} b_{L_j} \)

\( x_{ij} \geq 0, \ i = 1, 2, 3\ldots m, \ j = 1, 2, 3\ldots n \)

where \( a_{L_i}, b_{L_j}, a_{R_i} \) and \( b_{R_j} \) are left and right end point of \( a_i \) and \( b_j \) respectively.
3.4 TYPES OF MULTI-OBJECTIVE INTERVAL TRANSPORTATION PROBLEMS

The multi-objective interval transportation problem can be described as following types.

1. The source and destinations are in the form of parameter $a_i$ and $b_j$ and the objective function $C_{ij}^k$ are deterministic

$$
\text{Min. } Z^k = \sum_{i=1}^{m} \sum_{j=1}^{n} [C_{L_{ij}}^k, C_{R_{ij}}^k] x_{ij} \forall k = 1, 2, 3, \ldots K \quad \ldots(3.15)
$$

s.t. \hspace{1cm} \sum_{j=1}^{n} x_{ij} = a_i, \sum_{i=1}^{m} x_{ij} = b_j

$$
x_{ij} \geq 0 \forall i = 1, 2, 3, \ldots m; j = 1, 2, 3, \ldots n
$$

$$
\Rightarrow \sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j
$$

let $C_{ij}^k$ is the centre and $C_{h_{ij}}^k$ is the half width interval of the coefficient $C_{ij}^k$ of $Z^k(x)$ then

$$
\text{Min. } Z_{R}^k(x) = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{c_{ij}}^k x_{ij} + \sum_{i=1}^{m} \sum_{j=1}^{n} C_{h_{ij}}^k x_{ij} \quad \ldots(3.16)
$$

$$
\text{Min. } Z_{C}^k(x) = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{c_{ij}}^k x_{ij}, \quad k = 1, 2, 3, \ldots K
$$
2. When the coefficients $C_{ij}^k$ are crisp and origin (source) parameter $a_i$ and destination parameters $b_j$ are in the form of interval, the multi-objective transportation problem can be represented as follows:

$$\text{Min. } Z^k = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij}^k x_{ij}$$

$$\text{s.t. } \sum_{j=1}^{n} x_{ij} = [a_{L_i}, a_{R_i}], \sum_{i=1}^{m} x_{ij} = [b_{L_j}, b_{R_j}]$$

$$x_{ij} \geq 0, i=1,2,3,...m, j=1,2,3,...n$$

$$\sum_{i=1}^{m} a_{L_i} = \sum_{j=1}^{n} b_{L_j} \quad \text{and} \quad \sum_{i=1}^{m} a_{R_i} = \sum_{j=1}^{n} b_{R_j}$$

the equivalent deterministic multi-objective transportation problem is

$$\text{minimize } Z^k = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij}^k x_{ij}, k=1,2,3,...K$$

$$\text{s.t. } \sum_{j=1}^{n} x_{ij} \leq a_{R_i}, \sum_{i=1}^{m} x_{ij} \geq a_{L_i}$$

$$\text{and } \sum_{i=1}^{m} x_{ij} \leq b_{R_j}, \sum_{i=1}^{m} x_{ij} \geq b_{L_j}$$

when $C_{ij}^k$ is in the form of an interval

$$\text{Minimize } Z^k = \sum_{i=1}^{m} \sum_{j=1}^{n} [C_{L_{ij}}^k, C_{R_{ij}}^k] x_{ij}, k=1,2,3,...K$$
s.t. \( \sum_{j=1}^{n} x_{ij} = [a_{L_i}, a_{R_i}], \sum_{i=1}^{m} x_{ij} = [b_{L_j}, b_{R_j}] \)

\[ x_{ij} \geq 0, \quad i = 1, 2, 3, \ldots, m, \quad j = 1, 2, 3, \ldots, n \]

\[ \sum_{i=1}^{m} a_{L_i} = \sum_{j=1}^{n} b_{L_j} \quad \text{and} \quad \sum_{i=1}^{m} a_{R_i} = \sum_{j=1}^{n} b_{R_j} \]

If we have \( C_{c_{ij}}^k \) be the centre and \( C_{h_{ij}}^k \) be the half width interval of the cost coefficient \( C_{ij}^k \) of \( Z^k \) then multi-objective deterministic transportation problem as

\[
\text{Minimize } Z_{R}^k = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{c_{ij}}^k x_{ij} + \sum_{i=1}^{m} \sum_{j=1}^{n} C_{h_{ij}}^k x_{ij} \quad \text{...(3.21)}
\]

\[
\text{Minimize } Z_{c}^k = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{c_{ij}}^k x_{ij}, \quad k = 1, 2, 3, \ldots, K
\]

\[
\text{s.t. } \sum_{j=1}^{n} x_{ij} \leq a_{R_i}, \quad \sum_{j=1}^{n} x_{ij} \geq a_{L_i}
\]

\[ \text{and } \sum_{i=1}^{m} x_{ij} \leq b_{R_j}, \sum_{i=1}^{m} x_{ij} \geq b_{L_j} \]

### 3.5 FUZZY PROGRAMMING TECHNIQUES FOR SOLVING THE MULTI-OBJECTIVE TRANSPORTATION PROBLEM

Let the problem is characterized by the membership function

\[ \mu_k = (F^k(x)) = \text{Min. } (\mu(F_1^k(x)), \mu(F_2^k(x))) \quad \text{...(3.22)} \]
and to define the membership function of multi-objective transportation problem, let $L_k$ and $U_k$ be the lower and upper bounds of the objective function $F^k(x)$. These values are determined as follows.

Calculate the individual minimum of each objective function as a single objective transportation problem subject to the given set of constraints. Let $X^1, X^2, X^3,...,X^k$ be the optimal solutions for $k$ different transportation problems, then multi-objective transportation problem can be formulated as

$$
\mu_k(F^k(x)) = \begin{cases} 
1, & \text{if } F^k(x) \leq L_k \\
U_k - F^k(x), & \text{if } L_k < F^k(x) < U_k \\
0, & \text{if } F^k(x) \geq U_k 
\end{cases} \quad \text{...(3.23)}
$$

where, $L_k \neq U_k, k = 1, 2, 3, ..., K$

If $L_k = U_k$ then $\mu_k(F^k(x)) = 1$ for any value of $k$ and the equivalent linear programming problem for the vector minimum problem may be written as maximize $\lambda$,

$$\text{Subject to } \lambda \leq \left( \frac{U_k - F^k(x)}{U_k - L_k} \right) \text{ for all value of k}$$

And for $\lambda \geq 0$, where $\lambda = \min \{ \mu_F(F^k(x)) \}$ \quad \text{...(3.24)}

This linear programming problem can be written as

Maximize $\lambda$ ,

Subject to $F^k(x) + \lambda[U_k - L_k] \leq U_k$
3.6 NUMERICAL ILLUSTRATION

A company has two factories $F_1$, $F_2$ and three retail stores $W_1$, $W_2$ and $W_3$. The production quantities per month $F_1$ and $F_2$ are 10 and 8 tons respectively. The demands per month for $W_1$, $W_2$ and $W_3$ are 5, 6 and 7 tons respectively. The transportation cost per ton $C_{ij}$, where $i = 1, 2$ and $j = 1, 2, 3$ are following $C_{11} = 16$, $C_{12} = 15$, $C_{13} = 25$, $C_{21} = 19$, $C_{22} = 24$, $C_{23} = 12$.

In our notation $a_1 = 10$, $a_2 = 8$, $b_1 = 5$, $b_2 = 6$ and $b_3 = 7$

**Crisp Case** :

$$\text{Min } Z = 16x_{11} + 15x_{12} + 25x_{13} + 19x_{21} + 24x_{22} + 12x_{23}$$

s.t. $x_{11} + x_{12} + x_{13} = 10$

$x_{21} + x_{22} + x_{23} = 8$

$x_{11} + x_{21} = 5$

$x_{12} + x_{22} = 6$

$x_{13} + x_{23} = 7$

$x_{ij} \geq 0$, $i = 1, 2$ and $j = 1, 2, 3$

Now with the help of North West Corner Rule we will obtain the minimum transportation cost:
We obtain the optimal $x_{11} = 4, x_{12} = 6, x_{13} = 0, x_{21} = 1, x_{22} = 0, x_{23} = 7$ and the optimal transportation cost is $Z_0 = 64 + 90 + 19 + 84 = 257$

**Fuzzy Case 1.** Let $\tilde{a}_1 = (10 - 4, 10, 10+8)$

$$\tilde{a}_2 = (8 - 2, 8, 8+6)$$

$$\tilde{b}_1 = (5 - 2, 5, 5+6)$$

$$\tilde{b}_2 = (6 - 2, 6, 6+10)$$ and $\tilde{b}_3 = (7 - 6, 7, 7+2)$

Min. $Z = 16x_{11} + 15x_{12} + 25x_{13} + 19x_{21} + 24x_{22} + 12x_{23}$

s.t. $x_{11} + x_{12} + x_{13} = 11$

$x_{21} + x_{22} + x_{23} = 9$

$x_{11} + x_{21} = 6$

$x_{12} + x_{22} = 8$

$x_{13} + x_{23} = 6$

$x_{ij} \geq 0, \ i=1, 2, j=1, 2, 3$
Now with north west corner rule

\[\begin{array}{ccc|c}
W_1 & W_2 & W_3 & \text{Supply (Available)} \\
\hline
3(16) & 8(15) & 0(25) & 11 \\
3(19) & 0(24) & 6(12) & 9 \\
\end{array}\]

Requirement (demand) \[\begin{array}{ccc|c}
6 & 8 & 6 & 20 \\
\end{array}\]

\[\therefore \text{the optimal solution is}\]

\[x_{11} = 3, x_{12} = 8, x_{13} = 0, x_{21} = 3, x_{22} = 0, x_{23} = 6\]

\[\therefore \text{the optimal transportation cost } Z_1 = 48 + 120 + 57 + 72 \]

\[= 297\]

**Fuzzy Case 2.** Let

\[\tilde{a}_1 = (10 - 0.6, 10, 10+9), \tilde{a}_2 = (8 - 0.4, 8, 8+1.4)\]

\[\tilde{b}_1 = (5 - 0.5, 5, 5+4.5), \tilde{b}_2 = (6 - 0.6, 6, 6+1) \text{ and}\]

\[\tilde{b}_3 = (7 - 0.4, 7, 7+5.4)\]

Min. \[Z = 16x_{11} + 15x_{12} + 25x_{13} + 19x_{21} + 24x_{22} + 12x_{23}\]

s.t. \[x_{11} + x_{12} + x_{13} = 12.1\]

\[x_{21} + x_{22} + x_{23} = 8.25\]

\[x_{11} + x_{21} = 6\]

\[x_{12} + x_{22} = 6.1\]

\[x_{13} + x_{23} = 8.25\]

\[X_{ij} \geq 0, i=1, 2, j=1, 2, 3\]
Chapter 3…

So by North West Corner Method

\[
\begin{array}{ccc}
W_1 & W_2 & W_3 \\
\hline
6 (16) & 6.1 (15) & 0 (25) \\
0 (19) & 0 (24) & 8.25 (12) \\
\hline
\end{array}
\]

Supply (Available) \hspace{1cm} 12.1 \\
\hspace{1cm} 8.25 \\

Requirement \rightarrow \hspace{1cm} 6 \hspace{1cm} 6.1 \hspace{1cm} 8.25 \hspace{1cm} 20.26

Hence we obtain the optimal solution \( x_{11} = 6, \ x_{12} = 6.1, \ x_{13} = 0, \)
\( x_{21} = 0, \ x_{22} = 0, \ x_{23} = 8.25 \) and the optimal transportation cost
\[ Z_2 = 96 + 91.5 + 99 = 286.5 \]

**Fuzzy Case 3.** Let \( \tilde{a}_1^R = (10 - 4, 10, 10+8, 1) \), \( \tilde{a}_2^U = (8 - 2, 8+6; 1) \)
\( \tilde{b}_1^U = (5 - 2, 5, 5+6, 1) \), \( \tilde{b}_2^U = (6 - 2, 6, 6+10; 1) \) and
\( \tilde{b}_3^U = (7 - 6, 7, 7+2; 1) \)

Let \( \tilde{a}_1^L = (10 - 1, 10, 10+1; 0.9) \), \( \tilde{a}_2^L = (8 - 1, 8, 8+5; 0.9) \)
\( \tilde{b}_1^L = (5 - 1, 5, 5+2; 0.9) \), \( \tilde{b}_2^L = (6 - 1, 6, 6+7; 0.9) \) and
\( \tilde{b}_3^L = (7 - 4, 7, 7+1; 0.9) \)

Consider \( \tilde{a}_i = [a_{L_i}, \ a_{R_i}], \ i=1,2 \) and \( \tilde{b}_j = [\tilde{b}_{L_j}, \ \tilde{b}_{R_j}], \ j=1,2,3 \)

Min. \( Z = 16x_{11} + 15x_{12} + 25x_{13} + 19x_{21} + 24x_{22} + 12x_{23} \)

s.t. \( x_{11} + x_{12} + x_{13} = 10.325 \)
\( x_{21} + x_{22} + x_{23} = 8.575 \)
\( x_{11} + x_{21} = 5.3875 \)

77
Now we will obtain optimal transportation cost

\[
\begin{array}{c|c|c|c}
F_1 & W_1 & W_2 & W_3 \\
\hline
3.3(16) & 7.0250(15) & 0(25) & 10.325 \\
\hline
2.0875(19) & 0(24) & 5.4875(12) & 8.575 \\
\hline
5.3875 & 7.0250 & 6.4875 & 18.900 \\
\end{array}
\]

\[\text{Supply (Available)} \]

\[\text{Requirement (demands)} \]

\[\text{\therefore We get } x_{11} = 3.3, x_{12} = 7.025, x_{13} = 0, x_{21} = 2.0875, x_{22} = 0, x_{23} = 6.4875 \text{ and the optimal transportation cost is }\]

\[Z_3 = 3.3 \times 16 + 7.025 \times 15 + 2.0875 \times 19 + 5.4875 \times 12 = 275.6875\]

### 3.7 CONCLUSION

The present chapter proposes a solution procedure of the transportation cost is significant whenever the fluctuation is large in the fuzzy manner and the transportation cost is close to the crisp case whenever the variation is also small in the fuzzy manner, and the solution procedure of the interval multi-objective transportation problem, where the co-efficient of the objective functions and the source and destination parameters have been considered as interval, and initially, the problem has been converted into a classical multi-objective transportation problem where the objectives which are the right limit and centre of the interval objective
functions are minimized and to obtain the solution of the transformed multi-objective transportation problem, the fuzzy programming technique has been used. In this chapter we approached a method for solving the multi-objective transportation problem in which the objective function is in the form of interval with \((\lambda, 1)\) as a fuzzy numbers and the decision maker’s preference between interval cost are defined for minimization problems. Since it is cleared that the cost of every alternatives lies in the corresponding interval which represents the multi-objective transportation problem with cost coefficients of the objective function, source and destination parameter have been expressed.