Fuzzy theory based solution of multi objective Interval based resource allocation problem: A case study of food factory

Kirti Patel*
*Research Scholar, UTU, Bardoli, Gujarat. India

Mukesh Patel**
** UTU, Bardoli, Gujarat. India

Jayesh M. Dhodiya***
***S.V.National Institute of Technology, Surat, Gujarat. India

Abstract: In today’s competitive market cost evaluation is basics need which indirectly affects the final selling price of the product. Cost of raw products varies on daily basis, so the cost of the product varies according but the selling price is kept constant to survive in market. This scenario affects the profit margin of the entrepreneur. Here in this paper we have taken cost on interval basis i.e. minimum to maximum possible cost of the raw product in a calendar year. We have use a formula that will check the sensitivity of the problem. And then later on we have applied various fuzzy linear membership and exponential membership functions on the various solutions obtained during sensitivity analysis. We also have deployed LINGO15 to solve linear programming problem.

Key words: linear Programming, multi objective, resource allocation, interval objective, fuzzy membership function.

1.0 INTRODUCTION

Generally, in this competitive world each and every company is interested to make the best product at the minimum cost. It is the prime objective to minimize the cost and sensitivity is the tool which help them to decide which raw material to be used in the final product to maintain standard and to compete in market.

In most of the developing country before a decade car was dream for people, now a day’s car is trend. Mr rattan Tata was the first man on earth to produce cheapest car in the world. That became the bench mark for other company to make the car at the affordable price. Now a day’s many cars are available which are rich in luxury, fuel efficiency, comfort and most important feature is price.

It is not that only car industry has taken up revolution but many industries like electronics, computer, food etc have taken up massive revolution in last few decades. This analysis of minimize cost will be the trend for the coming decades. The demand is increasing day by day and quality with affordable price will be the demand at the peak in next many decades.

Here we have taken one case study of food manufacturing units which face the problem of price variation on daily basis. Due to competition selling price cannot be increased or decreased on daily basis. They need to give the best price which can help them to survive against the change in price. we have adepted linear programming for formulating the problem.

Linear programming is a mathematical tool that handles the optimization of a linear objective function subject to linear constraints. Linear programming is an important area in applied mathematics which has many applications in industries. When realistic problems are formulated, a set of intervals may appear as coefficients in the objective function or the constraints of a linear programming problem.

Cost of raw product price usually fluctuate with in certain boundary for that it is very necessary to designe problem with inverval constraint or interval objective function. Various methods are used to solve interval problem on linear programming, then the generalization of ordinary arithmetic to closed intervals is known as interval arithmetic [14] is used to develop algorithm for interval linear programming problem with interval constraints. The problem of intervals ordering is an important problem because of its direct relevance to real world optimization problems. Therefore, the comparison of intervals is necessary when we have to make choice in practical applications. Numerous definitions of the comparison relation on intervals exist [14]. Based on the idea of the so called best-
and worst- optimum problem, interval constraints are used [15]. The basic interval arithmetic, the statistical function were the tools used for interval linear programming [16]. paper will follow following flow chart.

**Figure:1** process of formulation and method used

### 2.0 Single objective linear programming resource all location problem on interval

Some entrepreneur aims for single objective at a time, such single objective recourse allocation problem can be formulated in LPP as follows [7]

Minimum $Z = \sum_{i=1}^{n} [c_i C_i] x_i$

Subject to

$$\sum_{i=1}^{m} a_i x_i (\le, =, \ge) B_j, \quad j = 1,2,3,...n$$

(n such constraints)

Where $x_i \ge 0$ ............................................ (1)

Where $c_{ij}$ = associated cost vector, $B_j$ = resource vector, $a_i$ = associated quantity of resource required for production of $x_i$

This single objective linear programming base resource allocation problem has constraint which can be either in equality or inequality form.

### 3.0 Multi objective linear programming problem cost and risk are in interval

Most of the entrepreneur now a day’s do not have a aim of single objective but they wish to target multi objective i.e they not only try to minimize cost but try to minimize some recourse so that their business can grow in best of manner. In competitive world entrepreneur need to be aware of competition and should monopolised business. Their important objective could be to minimize risk using the same set of constraints. Such general multi objective linear programming problem can be defined as under [8].

Minimum $z_r = \sum_{i=1}^{n} [c_i^{r}, C_i^{r}] x_i \quad , \quad r = 1, 2, 3, 4 ...k$
Subject to

\[ \sum_{i=1}^{m} a_i x_i \ (\leq, =, \geq) B_j, \quad j = 1, 2, 3 \ldots n \] (n such constraints)

Where, \( x_i \geq 0 \) ..................................................... (2)

Here in objective \( c_i^r \) is minimum cost or risk for \( i^{th} \) object

\( c_i^r \) is maximum cost or risk for \( i^{th} \) object

4.0 Method to solve interval linear programming problem

Step-1: Write your Multiobjective LPP with interval. (for first objective)

Step-2: Convert each interval objective of LPP in fixed single valued LPP by using formula

\[
\left[ 0.5(a + b) + \varepsilon (b - a) \right]
\]

where interval is given by in the form of \([a, b]\) and \( a < b \). \( \varepsilon \) is parameter. Here \(-0.5 \leq \varepsilon \leq 0.5\).

Using this we can generate sensitivity and for different value of \( \varepsilon \) we can get different objective

<table>
<thead>
<tr>
<th>Value of ( \varepsilon )</th>
<th>( c_i )</th>
<th>( r_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>( c_0 )</td>
<td>( r_0 )</td>
</tr>
<tr>
<td>-0.1</td>
<td>( c_{-0.1} )</td>
<td>( r_{-0.1} )</td>
</tr>
<tr>
<td>-0.2</td>
<td>( c_{-0.2} )</td>
<td>( r_{-0.2} )</td>
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<tr>
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<td>( r_{-0.3} )</td>
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<tr>
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<td>( c_{-0.4} )</td>
<td>( r_{-0.4} )</td>
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<tr>
<td>-0.5</td>
<td>( c_{-0.5} )</td>
<td>( r_{-0.5} )</td>
</tr>
</tbody>
</table>

Table 1: values of cost and risk factor associated with \( \varepsilon \)

Where \( c_i \) = the cost associated with \( i^{th} \) value of \( \varepsilon \) for individual product

\( r_i \) = the risk associated with \( i^{th} \) value of \( \varepsilon \) for individual product

5.0 Method to solve LPP using fuzzy linear and exponential membership function:

Step 1: The formulated linear programming problem first solve by using single objective function. Here we have use LINGO15 software to solve this single objective LPP and derive optimal solution say \( f(x_1, x_2, x_3 \ldots x_n) \) for first objective \( Z_1 \) and then obtain other objective value with the same solution. Procedure repeats same for \( Z_2 \ldots \ldots Z_k \).

Step 2: Corresponding to above data we can construct matrix which can give various alternate optimal value.

<table>
<thead>
<tr>
<th></th>
<th>( Z_1 )</th>
<th>( Z_2 )</th>
<th>( \ldots \ldots \ldots )</th>
<th>( Z_k )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f_j(x_1, x_2, \ldots x_n) )</td>
<td>( Z_{j1} )</td>
<td>( Z_{j2} )</td>
<td>( \ldots \ldots \ldots )</td>
<td>( Z_{jk} )</td>
</tr>
<tr>
<td>( f_j(x_1, x_2, \ldots x_n) )</td>
<td>( Z_{j1} )</td>
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</tr>
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<td>( f_j(x_1, x_2, \ldots x_n) )</td>
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<td>( f_j(x_1, x_2, \ldots x_n) )</td>
<td>( Z_{j1} )</td>
<td>( Z_{j2} )</td>
<td>( \ldots \ldots \ldots )</td>
<td>( Z_{jk} )</td>
</tr>
</tbody>
</table>

Table 2: pay off matrix for various optimal solution

Here,

\( Z_{ij} \) indicated optimal solution of objective \( i \) using solution of objective \( j \), \( i = 1, 2, \ldots, k \) and \( j=1,2,3\ldots n \).

Here two different membership functions are utilized to find efficient solution of this multi-objective resource allocation problem.

Fuzzy linear membership function is defined as follows [8]
\[ \mu_l(z_k) = \begin{cases} 
0, & \text{if } z_k \leq L_k \\
1 - \frac{z_k - L_k}{U_k - L_k}, & \text{if } L_k < z_k < U_k \\
1, & \text{if } z_k \geq U_k 
\end{cases} \]

Here for any \( Z_k \), minimum \( (Z_{k1}, Z_{k2}, \ldots, Z_{kn}) = L_k \) and Maximum \( (Z_{k1}, Z_{k2}, \ldots, Z_{kn}) = U_k \)

Corresponding to data adjustment parameter: \( \sigma \) can be obtained which will give us degree of satisfaction of both the objectives.

By using linear membership function The LPP described in (3) can be converted into crisp model as follows

Maximum \( \sigma \)

Subject to

\[ Z_k + \sigma (U_k - L_k) \leq U_k \]

\[ \sum_{i=1}^{m} a_i x_i (\leq, =, \geq) B_j, \quad j = 1, 2, 3 \ldots n \quad (n \text{ such constraints}) \quad \text{Where } x_i \geq 0 \]

Where \( x_{ij} \geq 0 \)

fuzzy exponential membership function is defined as follows [8]

\[ \mu_l(z_k) = \begin{cases} 
1, & \text{if } z_k \leq L_k \\
\left(\frac{e^{-\beta_k(x)} - e^{-\sigma}}{1 - e^{-\sigma}}\right), & \text{if } L_k < z_k < U_k \\
0, & \text{if } z_k \geq U_k 
\end{cases} \]

Where \( \beta_k(x) = \frac{z_k - L_k}{U_k - L_k}, k = 1, 2, 3 \ldots, K \)

Corresponding to this exponential membership function the linear programming problem will be as under

Maximum = \( \sigma \)

Subject to

\[ e^{-\beta_k(x)} - (1 - e^{-\sigma}) \sigma \geq e^{-\sigma} \]

\[ \sum_{i=1}^{m} a_i x_i (\leq, =, \geq) B_j, \quad j = 1, 2, 3 \ldots n \quad (n \text{ such constraints}) \quad \text{Where } x_i \geq 0 \]

Solution of this model will give you an efficient solution with respect to different shape parameters.

6.0 FORMULATION RESOURCE ALLOCATION PROBLEM OF SANDWICH FACTORY IN MOILPP

In the following sections, the considered sandwich factory resource allocation problem and formulated in Multi objective linear programming problem on interval. First the process system of sandwich industry is introduced. Then the objective as well as constraints are stated, in this paper we have checked the degree of satisfaction of all the constraint. For production, certain resource like man power, material, machinery is required and it should be available before production. Also some pre-production is also requiring before the production which we have to assume that, it is available before production. Here we can apply inventory control models for inventory which needs to be stored before preproduction, in production we have applied linear programming problem and solved it using LINGO.

6.1 Mathematical Formulation:

For mathematical formulation, we assume that sandwich industry is producing ‘n’ product and it require some resource like man power, machine power, and material to make such n product. Here we assume that

\( X_1 = \) product 1

\( X_2 = \) Product2

...
Xn= Product n

c_j, r_j j= 1, 2, ..., n, associated minimum cost vectors

(Cost, Risk)

Cj, Rj j= 1, 2, 3, ..., n, associated maximum

(cost, Risk)

Bj be the associated resource vector

(Like Bread, Tomato, Cheese, etc.)

Here we assume that the costs associated to produce such product are c_j, r_j j= 1, 2, ..., n, and Bj be the associated resource vector then the Objective function: cost function Z1 and risk function Z2 for ‘n’ product can be formulated as follows:

Min Z1= [c_1, C_1]x_1 + [c_2, C_2]x_2 + ... + [c_n, C_n]x_n

Mini Z= [r_1, R_1]x_1 + [r_2, R_2]x_2 + ... + [r_n, R_n]x_n

Other all the constrain associated with different resources can be formulated as follows

Subject to constraints are

Bread constraint

\[ \sum_{i=1}^{n} a_i x_i \leq B_1 \]

a_1 x_1 + a_2 x_2 + ... + a_n x_n \leq B_1  \text{(Bread constraints)}

Here, a_i is amount of bread required x_i here

B_1 = total amount of bread required for total production

Tomato constraint

\[ \sum_{i=1}^{n} b_i x_i \leq B_2 \]

b_1 x_1 + b_2 x_2 + ... + b_n x_n \leq B_2  \text{(Tomato constraints)}

Here, b_i is amount of tomato required x_i here

B_2 = total amount of tomato required for total production

Cheese constraints

\[ \sum_{i=1}^{n} c_i x_i \leq B_3 \]

c_1 x_1 + c_2 x_2 + ... + c_n x_n \leq B_3  \text{(Cheese constraints)}

Here, c_i is amount of cheese required x_i here

B_3 = total amount of cheese required for total production

Potato constraints

\[ \sum_{i=1}^{n} d_i x_i \leq B_4 \]

d_1 x_1 + d_2 x_2 + ... + d_n x_n \leq B_4  \text{(Potato constraints)}

Here, d_i is amount of bread required x_i here
\[ B_s = \text{total amount of bread required for total production} \]

**Tiki constraints**

\[
\sum_{i=1}^{n} e_i x_i \leq B_s
\]

Here, \( e_i \) is amount of Tiki required \( x_i \) here.

\[ B_s = \text{total amount of tiki required for total production} \]

**Manpower constraints**

\[
\sum_{i=1}^{n} f_i x_i \leq B_6
\]

Here, \( f_i \) is amount of man power required \( x_i \) here.

\[ B_6 = \text{total amount of man power required for total production} \]

**Machine constraints**

\[
\sum_{i=1}^{n} g_i x_i \leq B_7
\]

Here, \( g_i \) is amount of bread required \( x_i \) here.

\[ B_7 = \text{total amount of bread required for total production} \]

**Chicken constraints**

\[
\sum_{i=1}^{n} h_i x_i \leq B_8
\]

Here, \( h_i \) is amount of chicken required \( x_i \) here.

\[ B_8 = \text{total amount of chicken required for total production} \]

Where

\[ x_1, x_2, ..., x_n \geq 0 \]

So the general multi-objective mathematical model for the sandwich factory can be written as

**Min**

\[ Z_1 = [c_1, C_1] x_1 + [c_2, C_2] x_2 + \cdots + [c_n, C_n] x_n \]

**Min**

\[ Z = [r_1, R_1] x_1 + [r_2, R_2] x_2 + \cdots + [r_n, R_n] x_n \]

Subject to constraints are
\[ \sum_{i=1}^{n} a_i x_i (\leq, =, \geq) B_1 \]

i.e.
\[ a_1 x_1 + a_2 x_2 + \cdots + a_n x_n \leq, =, \geq B_1 \] (Bread constraints)

\[ \sum_{i=1}^{n} b_i x_i (\leq, =, \geq) B_2 \]

i.e.
\[ b_1 x_1 + b_2 x_2 + \cdots + b_n x_n \leq, =, \geq B_2 \] (tomato constraints)

\[ \sum_{i=1}^{n} c_i x_i (\leq, =, \geq) B_3 \]

i.e.
\[ c_1 x_1 + c_2 x_2 + \cdots + c_n x_n \leq, =, \geq B_3 \] (cheese constraints)

\[ \sum_{i=1}^{n} d_i x_i (\leq, =, \geq) B_4 \]

i.e.
\[ d_1 x_1 + d_2 x_2 + \cdots + d_n x_n \leq, =, \geq B_4 \] (Potato constraints)

\[ \sum_{i=1}^{n} e_i x_i (\leq, =, \geq) B_5 \]

i.e.
\[ e_1 x_1 + e_2 x_2 + \cdots + e_n x_n \leq, =, \geq B_5 \] (tiki constraints)

\[ \sum_{i=1}^{n} f_i x_i (\leq, =, \geq) B_6 \]

i.e.
\[ f_1 x_1 + f_2 x_2 + \cdots + f_n x_n \leq, =, \geq B_6 \] (manpower constraints)

\[ \sum_{i=1}^{n} g_i x_i (\leq, =, \geq) B_7 \]

i.e.
\[ g_1 x_1 + g_2 x_2 + \cdots + g_n x_n \leq, =, \geq B_7 \] (machine constraints)

\[ \sum_{i=1}^{n} h_i x_i (\leq, =, \geq) B_8 \]

i.e.
\[ h_1 x_1 + h_2 x_2 + \cdots + h_n x_n \leq, =, \geq B_8 \] (chicken constraints)

\[ \sum_{i=1}^{n} i_i x_i (\leq, =, \geq) B_9 \]

i.e.
\[ i_1 x_1 + i_2 x_2 + \cdots + i_n x_n \leq, =, \geq B_9 \] (miscellaneous constraints)

\[ \sum_{i=1}^{n} j_i x_i (\leq, =, \geq) B_{10} \]

i.e.
\[ j_1 x_1 + j_2 x_2 + \cdots + j_n x_n \leq, =, \geq B_{10} \] (rent constraints)

\[ x_1, x_2, \ldots, x_n \geq 0 \]

Where

7.0 Problem of sandwich factory.

In this paper, we have taken the case study of a sandwich factory XYZ. This factory has production capacity of 200000 sandwich per day and it requires tremendous amount of resource like manpower, machine power, material, money and proper method to achieve target per day. This factory is divided into units and each unit is divided into lines. So, in total approximate 30 lines require 1000 people and huge amount of machinery to achieve daily target. Here we have taken the data from 1 line and similarly we can get the data for 30 lines. One line that work in two shifts require manpower, machine power, material following data have been collected.
Table 3: maximum and minimum cost of the product

<table>
<thead>
<tr>
<th>Product</th>
<th>Max cost</th>
<th>Min cost</th>
<th>Cost per unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheese s/w</td>
<td>30</td>
<td>17.5</td>
<td>20</td>
</tr>
<tr>
<td>Cheese burger</td>
<td>37</td>
<td>25.5</td>
<td>30</td>
</tr>
<tr>
<td>Allotiki</td>
<td>24</td>
<td>16.5</td>
<td>20</td>
</tr>
<tr>
<td>Chicken pasta</td>
<td>53</td>
<td>37.5</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 4: Amount of product require for single unit.

<table>
<thead>
<tr>
<th>Product</th>
<th>Bread</th>
<th>Tomato</th>
<th>Potato</th>
<th>Cheese</th>
<th>Tiki</th>
<th>Chicken</th>
<th>Pasta</th>
<th>Manpower</th>
<th>Machine</th>
<th>Miscall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheese s/w</td>
<td>2-4</td>
<td>1.5-4</td>
<td>1-3</td>
<td>3-5</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>2-3</td>
<td>2-3</td>
<td>3-5</td>
</tr>
<tr>
<td>Cheese burger</td>
<td>6-8</td>
<td>1-2</td>
<td>0</td>
<td>4-6</td>
<td>2</td>
<td>4.6-6</td>
<td>0</td>
<td>0</td>
<td>2-4</td>
<td>3-4</td>
</tr>
<tr>
<td>Allotiki</td>
<td>3-5</td>
<td>1.5-3</td>
<td>0</td>
<td>4-6</td>
<td>2</td>
<td>3-5</td>
<td>0</td>
<td>0</td>
<td>2-3</td>
<td>0</td>
</tr>
<tr>
<td>Chicken pasta</td>
<td>9-11</td>
<td>1.5-3</td>
<td>0</td>
<td>4-6</td>
<td>2</td>
<td>0</td>
<td>9-11</td>
<td>4-6</td>
<td>3-5</td>
<td>3-4</td>
</tr>
</tbody>
</table>

Table 5: Quantity requires in product with its units

By considering all this data, the MOLPP can be formulated as follows

\[ x_1 = \text{Number of Chess s/w sandwich} \]

\[ x_2 = \text{Number of Cheese burger sandwich} \]

\[ x_3 = \text{Number of Allotiki sandwich} \]

\[ x_4 = \text{Number of Chicken pasta sandwich} \]

By using this variables objectives related with cost and risk can be formulated as follows

### 7.1 Method to Solve Interval Linear Programming Problem

**Step-1:** Write your MOITP with interval. (for first objective)

**Step-2:** Convert each interval objective of transportation problem in fixed single valued transportation problem by using formula \([0.5(a + b)] + \epsilon \cdot (b - a)\) where interval is given by in the form of \([a, b]\) and \(a < b\). \(\epsilon\) is parameter. Here \(-0.5 \leq \epsilon \leq 0.5\). Using this we can generate sensitivity and for different value of \(\epsilon\) we can get different objective.
For product 1

<table>
<thead>
<tr>
<th>Value of $\epsilon$</th>
<th>$c_i$</th>
<th>$r_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.5</td>
<td>17.5</td>
<td>18</td>
</tr>
<tr>
<td>-0.4</td>
<td>18.75</td>
<td>18.5</td>
</tr>
<tr>
<td>-0.3</td>
<td>20.0</td>
<td>19</td>
</tr>
<tr>
<td>-0.2</td>
<td>21.25</td>
<td>19.5</td>
</tr>
<tr>
<td>-0.1</td>
<td>22.25</td>
<td>20</td>
</tr>
<tr>
<td>0</td>
<td>23.75</td>
<td>20.5</td>
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<tr>
<td>0.1</td>
<td>25</td>
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<td>0.3</td>
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<td>0.4</td>
<td>28.75</td>
<td>22.5</td>
</tr>
<tr>
<td>0.5</td>
<td>30.0</td>
<td>23.0</td>
</tr>
</tbody>
</table>

Table 6: value of cost and risk factor for product 1

For product 2

<table>
<thead>
<tr>
<th>Value of $\epsilon$</th>
<th>$c_i$</th>
<th>$r_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.5</td>
<td>25.5</td>
<td>15.5</td>
</tr>
<tr>
<td>-0.4</td>
<td>26.65</td>
<td>15.9</td>
</tr>
<tr>
<td>-0.3</td>
<td>27.8</td>
<td>16.3</td>
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<td>-0.2</td>
<td>28.95</td>
<td>16.7</td>
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<tr>
<td>-0.1</td>
<td>30.1</td>
<td>17.1</td>
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<tr>
<td>0</td>
<td>31.25</td>
<td>17.5</td>
</tr>
<tr>
<td>0.1</td>
<td>32.4</td>
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</tr>
<tr>
<td>0.2</td>
<td>33.55</td>
<td>18.3</td>
</tr>
<tr>
<td>0.3</td>
<td>34.7</td>
<td>18.7</td>
</tr>
<tr>
<td>0.4</td>
<td>35.85</td>
<td>19.1</td>
</tr>
<tr>
<td>0.5</td>
<td>37</td>
<td>19.5</td>
</tr>
</tbody>
</table>

Table 7: value of cost and risk factor for product 2

For product 3

<table>
<thead>
<tr>
<th>Value of $\epsilon$</th>
<th>$c_i$</th>
<th>$r_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.5</td>
<td>16.5</td>
<td>5</td>
</tr>
<tr>
<td>-0.4</td>
<td>17.25</td>
<td>5.4</td>
</tr>
<tr>
<td>-0.3</td>
<td>18</td>
<td>5.8</td>
</tr>
<tr>
<td>-0.2</td>
<td>18.75</td>
<td>6.2</td>
</tr>
<tr>
<td>-0.1</td>
<td>19.5</td>
<td>6.6</td>
</tr>
<tr>
<td>0</td>
<td>20.25</td>
<td>7</td>
</tr>
<tr>
<td>0.1</td>
<td>21</td>
<td>7.4</td>
</tr>
<tr>
<td>0.2</td>
<td>21.75</td>
<td>7.8</td>
</tr>
<tr>
<td>0.3</td>
<td>22.5</td>
<td>8.2</td>
</tr>
<tr>
<td>0.4</td>
<td>23.25</td>
<td>8.6</td>
</tr>
<tr>
<td>0.5</td>
<td>24</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 8: value of cost and risk factor for product 3

For product 4

<table>
<thead>
<tr>
<th>Value of $\epsilon$</th>
<th>$c_i$</th>
<th>$r_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.5</td>
<td>37.5</td>
<td>8</td>
</tr>
<tr>
<td>-0.4</td>
<td>39.05</td>
<td>8.4</td>
</tr>
<tr>
<td>-0.3</td>
<td>40.6</td>
<td>8.8</td>
</tr>
<tr>
<td>-0.2</td>
<td>42.15</td>
<td>9.2</td>
</tr>
<tr>
<td>-0.1</td>
<td>43.7</td>
<td>9.6</td>
</tr>
<tr>
<td>0</td>
<td>45.25</td>
<td>10</td>
</tr>
<tr>
<td>0.1</td>
<td>46.8</td>
<td>10.4</td>
</tr>
<tr>
<td>0.2</td>
<td>48.35</td>
<td>10.8</td>
</tr>
<tr>
<td>0.3</td>
<td>49.9</td>
<td>11.2</td>
</tr>
</tbody>
</table>
Now for above all values of cost and risk we will formulate the linear programming problem for individual value of $\varepsilon$, by following method.

For $\varepsilon = 0$ LPP will be

For $\varepsilon = 0$ LPP will be

$$\begin{align*}
\text{Min } z_1 &= 23.75x_1 + 31.25x_2 + 20.25x_3 + 45.25x_4 \\
\text{Min } z_2 &= 20.5x_1 + 17.5x_2 + 7.0x_3 + 10x_4
\end{align*}$$

All the constraints of the problem related with resource can be written as

\[
\begin{align*}
x_1 + x_2 + x_3 + x_4 &\leq 210 \\
30x_1 + 30x_2 + 50x_3 + 50x_4 &\geq 4000 \\
20x_1 + 25x_2 + 25x_3 + 25x_4 &\geq 4000 \\
30x_1 &\leq 15000 \\
0x_1 + 1x_2 + 1x_3 + 0.0x_4 &\leq 110 \\
3x_1 + 3x_2 + 3x_3 + 3x_4 &\leq 960 \\
2x_1 + 2x_2 + 2x_3 + 2x_4 &\leq 600 \\
0.04x_4 &\leq 4000 \\
0.025x_4 &\leq 3000 \\
x_1 &\geq 20 \\
x_2 &\geq 20 \\
x_3 &\geq 20 \\
x_4 &\geq 20 \\
x_1 &, x_2 &, x_3 &, x_4 &\geq 0
\end{align*}
\]

Solution Methods:

By using LINGO solution of 1st and 2nd objective individually can be obtained as follows

Global optimal solution found.

Objective Min $Z_1$: 4243.12 where $x_1$ = 37.50, $x_2$ = 20, $x_3$ = 90, $x_4$ = 20

Objective Min $Z_2$: 1730.0 where $x_1$ = 20, $x_2$ = 20, $x_3$ = 90, $x_4$ = 34

Using this method described above we can find matrix which can give various alternate optimal value as follows

<table>
<thead>
<tr>
<th>$z_k$</th>
<th>$x_1 = 23.75x_1 + 31.25x_2 + 20.25x_3 + 45.25x_4$ (cost)</th>
<th>$x_2 = 20.5x_1 + 17.5x_2 + 7.0x_3 + 10x_4$; (minimum risk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_1(37,20,90,20)$</td>
<td>4243.50</td>
<td>1948.75</td>
</tr>
<tr>
<td>$f_1(20,20,90,34)$</td>
<td>4461</td>
<td>1730</td>
</tr>
</tbody>
</table>

Table 10: Pay off matrix between optimal solution and objective function
Table 11: payoff matrix between optimal solution and objective function with upper and lower value

Using the linear membership function, we get the following model with additional constraints as follows

Maximum: $\sigma$
Subject to

\[
\begin{align*}
23.75x_1 + 31.25x_2 + 20.25x_3 + 45.25x_4 + \sigma(217.5) & \leq 4461; \quad (Z_1 + \sigma(U_1 - L_1) \leq U_1) \\
20.5x_1 + 17.5x_2 + 7.0x_3 + 10x_4 + \sigma(218.7) & \leq 1948.75; (Z_2 + \sigma(U_2 - L_2) \leq U_2)
\end{align*}
\]

Subject to the constraints

\[
\begin{align*}
x_1 + x_2 + x_3 + x_4 & \leq 210 & \quad \text{(Bread constraint)} \\
30x_1 + 30x_2 + 50x_3 + 50x_4 & \geq 4000 & \quad \text{(tomato constraint)} \\
20x_1 + 25x_2 + 25x_3 + 25x_4 & \geq 4000 & \quad \text{(cheese constraint)} \\
30x_1 & \leq 15000 & \quad \text{(potato constraint)} \\
0.04x_4 & \leq 4000 & \quad \text{(chicken constraint)} \\
0.025x_4 & \leq 3000 & \quad \text{(Bread constraint)} \\
x_1 & \geq 20 & \quad \text{(minimum constraint)} \\
x_2 & \geq 20 & \quad \text{(minimum constraint)} \\
x_3 & \geq 20 & \quad \text{(minimum constraint)} \\
x_4 & \geq 20 & \quad \text{(minimum constraint)} \\
x_1, x_2, x_3, x_4 & \geq 0
\end{align*}
\]

By using LINGO15 solution can be obtain as follows

Objective value $\sigma$: 0.500488, $x_1 = 28.7434$, $x_2 = 20$, $x_3 = 90$, $x_4 = 27.00523$

Using this exponential membership function and solving it with lingo we get following LPP

Maximum $= \sigma$
Subject to

\[
\begin{align*}
e^{-1\left(\frac{23.75x_1 + 31.25x_2 + 20.25x_3 + 45.25x_4 - 4243.125}{217.875}\right)} - (1 - e^{-1})\sigma & \geq e^{-1} \\
e^{-1\left(\frac{20.5x_1 + 17.5x_2 + 7.0x_3 + 10x_4 - 1730}{218.75}\right)} - (1 - e^{-1})\sigma & \geq e^{-1}
\end{align*}
\]

Subject to

\[
\begin{align*}
x_1 + x_2 + x_3 + x_4 & \leq 210 & \quad \text{(Bread constraint)} \\
30x_1 + 30x_2 + 50x_3 + 50x_4 & \geq 4000 & \quad \text{(tomato constraint)} \\
20x_1 + 25x_2 + 25x_3 + 25x_4 & \geq 4000 & \quad \text{(cheese constraint)} \\
30x_1 & \leq 15000 & \quad \text{(potato constraint)} \\
0.04x_4 + 1x_2 + 1x_3 + 0.0x_4 & \leq 110 & \quad \text{(tiki constraint)}
\end{align*}
\]
Solution of this LPP will be given by

Objective value: $\sigma = 0.6224600$

$x_1 = 28.75, \quad x_2 = 20, x_3 = 90, x_4 = 27.00$

Similarly solving for all the value of $\varepsilon$, following solutions are derived

<table>
<thead>
<tr>
<th>Value of $\varepsilon$</th>
<th>Min $z_k$</th>
<th>Solution using linear membership function $\sigma$</th>
<th>Solution using exponential membership function $\sigma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$z_1 = 4243.125$</td>
<td>$x_1 = 28, x_2 = 20, x_3 = 90, x_4 = 27.00$</td>
<td>$x_1 = 28.75, x_2 = 20, x_3 = 90, x_4 = 27$</td>
</tr>
<tr>
<td>0.1</td>
<td>$z_1 = 4411.50$</td>
<td>$x_1 = 28.75, x_2 = 20, x_3 = 90, x_4 = 27.00$</td>
<td>$x_1 = 28.75, x_2 = 20, x_3 = 90, x_4 = 27$</td>
</tr>
<tr>
<td>0.2</td>
<td>$z_1 = 4579.879$</td>
<td>$x_1 = 29.032, x_2 = 20, x_3 = 26.7743$, $x_4 = 27$</td>
<td>$x_1 = 28.75, x_2 = 20, x_3 = 90, x_4 = 27$</td>
</tr>
<tr>
<td>0.3</td>
<td>$z_1 = 4748.240$</td>
<td>$x_1 = 28.7502, x_2 = 20, x_3 = 26.999, x_4 = 27$</td>
<td>$x_1 = 28.75, x_2 = 20, x_3 = 90, x_4 = 27$</td>
</tr>
<tr>
<td>0.4</td>
<td>$z_1 = 4976.625$</td>
<td>$x_1 = 27.34, x_2 = 20, x_3 = 28.127, x_4 = 27$</td>
<td>$x_1 = 28.3407, x_2 = 20, x_3 = 90, x_4 = 27$</td>
</tr>
<tr>
<td>0.5</td>
<td>$z_1 = 5085$</td>
<td>$x_1 = 28.80161, x_2 = 20, x_3 = 26.9581, x_4 = 27$</td>
<td>$x_1 = 28.75, x_2 = 20, x_3 = 90, x_4 = 27$</td>
</tr>
<tr>
<td>-0.1</td>
<td>$z_1 = 4074.75$</td>
<td>$x_1 = 28.819, x_2 = 20, x_3 = 26.9443, x_4 = 27$</td>
<td>$x_1 = 28.819, x_2 = 20, x_3 = 90, x_4 = 27$</td>
</tr>
<tr>
<td>-0.2</td>
<td>$z_1 = 3906.375$</td>
<td>$x_1 = 28.60849, x_2 = 20, x_3 = 27.113, x_4 = 27$</td>
<td>$x_1 = 28.60849, x_2 = 20, x_3 = 90, x_4 = 27$</td>
</tr>
<tr>
<td>-0.3</td>
<td>$z_1 = 3738.00$</td>
<td>$x_1 = 28.74582, x_2 = 20, x_3 = 27.00, x_4 = 27$</td>
<td>$x_1 = 28.74582, x_2 = 20, x_3 = 90, x_4 = 27$</td>
</tr>
<tr>
<td>-0.4</td>
<td>$z_1 = 3569.625$</td>
<td>$x_1 = 28.79900, x_2 = 20$</td>
<td>$x_1 = 28.79900, x_2 = 20$</td>
</tr>
</tbody>
</table>
8.0 CONCLUSION

This paper conclude that solving resource allocation based linear programming problem of multi objective by fuzzy programming technique we provide higher degree of satisfaction as per requirement of decision maker with exponential membership function compare to linear membership function.

9.0 REFERENCES


[16] A. ABBASI MOLAI** AND E. KHORRAM ,LINEAR PROGRAMMING PROBLEM WITH INTERVAL COEFFICIENTS AND AN INTERPRETATION FOR ITS CONSTRAINT , Faculty of Mathematics and Computer Science, Amirkabir University of Technology, Hafez Avenue, Tehran, I. R. of Iran Emails: abbsi54@aut.ac.ir, eskhor@aut.ac.ir


Table 12: solution for various value of ε