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

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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.

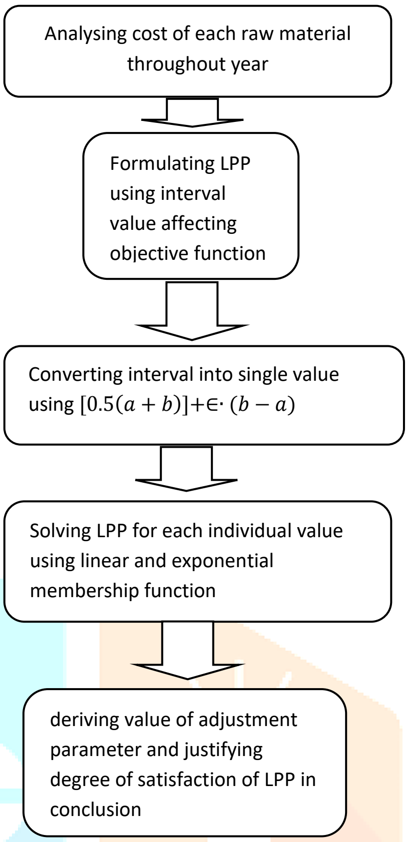

Figure:1 process of formulation and method used

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

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

(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 fi.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=$\sum_{i=1}^{n}[c_i^r, C_i^r]x_i$, *r=1, 2, 3, 4 ...k*

Subject to

$\sum_{i=1}^{m} a_i x_i \ (\leq, =, \geq) B_j, \ \ j = 1,2,3 \ldots n$ (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 $[0.5(a+b)]$+∈· $(b-a)]$ where interval is given by in the form of $[a, b]$ and $a < b$.∈ is parameter. Here $-0.5 \leq \in \leq 0.5$.

Using this we can generate sensitivity and for different value of `∈' we can get different objective

Value of ∈	c_i	r_i
0	c_0	r_0
0.1	$c_{0.1}$	$r_{0.1}$
0.2	$c_{0.2}$	$r_{0.2}$
0.3	$c_{0.3}$	$r_{0.3}$
0.4	$c_{0.4}$	$r_{0.4}$
0.5	$c_{0.5}$	$r_{0.5}$
-0.1	$c_{-0.1}$	$r_{-0.1}$
-0.2	$c_{-0.2}$	$r_{-0.2}$
-0.3	$c_{-0.3}$	$r_{-0.3}$
-0.4	$c_{-0.4}$	$r_{-0.4}$
-0.5	$c_{-0.5}$	$r_{-0.5}$

Table 1: values of cost and risk factor associated with ∈

Where c_i = the cost associated with i^{th} value of ∈ for individual product

r_i = the riskassociated with i^{th} value of ∈ 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 $f_1(x_1, x_2, x_3 \ldots\ldots x_n)$, 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.

	Z_1	Z_2	....	Z_k
$f_1(x_1, x_2, x_3 \ldots\ldots x_n)$	Z_{11}	Z_{21}	....	Z_{k1}
$f_2(x_1, x_2, x_3 \ldots\ldots x_n)$	Z_{12}	Z_{22}	....	Z_{2k}
......			....	
$f_n(x_1, x_2, x_3 \ldots\ldots x_n)$	Z_{1n}	Z_{2n}	....	Z_{kn}

Table 2: pay off matrix for various optimal solutiuon

Here,

Zij: indicated optimal solution of objective i using solution of objective j, i= 1, 2, ..., k and j=1,2,3...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]

$$\mu^l(z_k)=\begin{cases} 0, & if \quad z_k \le L_k \\ 1-\frac{z_k-L_k}{U_k-L_k}, & if \quad L_K < Z_k < U_k \\ 1, & if \quad z_k \ge U_k \end{cases}$$

Here for any Z_k, minimum (Z_{k1}, Zk_2........, Z_{kn}) = L_k and Maximum (Z_{k1}, Zk_2, ...,Z_{kn}) = U_k

Corresponding to data adjustment parameter: σ 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 σ

Subject to

$Z_k + \sigma(U_k - L_k) \le U_k$

$\sum_{i=1}^{m} a_i x_i\ (\le, =, \ge) B_j,\ j = 1,2,3 \ldots n$ (n such constraints) Where $x_i \ge 0$

Where $x_{ij} \ge 0$

fuzzy exponential membership function is defined as follows [8]

$$\mu^l(z_k)=\begin{cases} 1, & if \quad z_k \le L_K \\ \frac{e^{-s\beta_k(x)}-e^{-s}}{1-e^{-s}}, & if \quad L_K < Z_k < U_k \\ 0, & if \quad z_k \ge U_k \end{cases}$$

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 = σ

Subject to

$$e^{-s\beta_k(x)} - (1-e^{-s})\sigma \ge e^{-s})$$

$\sum_{i=1}^{m} a_i x_i\ (\le, =, \ge) B_j,$ $j = 1,2,3 \ldots n$ (n such constraints) Where $x_i \ge 0$

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

X1= product 1

X2= Product2

. .

. .

Xn= Product n

c_j, r_j j= 1,2 ...,n, associatedminimum cost vectors (Cost, Risk)

C_j, R_j $j = 1,2,3 \dots n, associated\ maximum$ $(cost, Risk)$

$B_j$be the associated resource vector (Like Bread, Tomato, Cheese, etc.)

Here we assume that the costs associated to produce such product arec_j, r_j j= 1, 2 ..., n, and$B_j$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= $[c_1, C_1]x_1 + [c_2, C_2]x_2 + \cdots + [c_n, C_n]x_n$

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

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

Subject to constraints are

Bread constraint

$$\sum_{i}^{n} a_i x_i \leq B_1$$

$a_1x_1 + a_1x_2 + \cdots + a_nx_n (\leq, =, \geq)$ B_1(Bread constraints)

Here, a_i $is\ amount\ of\ bread\ required\ x_i$ here

$B_1 = total\ amount\ of\ bread\ requied\ for\ total\ production$

Tomato constraint

$$\sum_{i}^{n} b_i x_i \leq B_2$$

$b_1x_1 + b_2x_2 + \cdots + b_nx_n \leq, =, \geq$ B_2(Tomato constraints)

Here, b_i $is\ amount\ of\ tomato\ required\ x_i$ here

$B_2 = total\ amount\ of\ tomato\ requied\ for\ total\ production$

Cheese constraints

$$\sum_{i}^{n} c_i x_i \leq B_3$$

$c_1x_1 + c_2x_2 + \cdots + c_nx_n \leq, =, \geq$ B_3(Cheese constraints)

Here, c_i $is\ amount\ of\ cheese\ required\ x_i$ here

$B_3 = total\ amount\ of\ cheese\ requied\ for\ total\ production$

Potato constraints

$$\sum_{i}^{n} d_i x_i \leq B_4$$

$d_1x_1 + dx_2 + \cdots + d_nx_n \leq, =, \geq$ B_4(Potato constraints)

Here, d_i $is\ amount\ of\ bread\ required\ x_i$ here

$B_4 = total\ amount\ of\ bread\ requied\ for$

$total\ production$

Tiki constraints

$$\sum_{i}^{n} e_i x_i \leq B_5$$

$e_1x_1 + e_2x_2 + \cdots + e_nx_n \leq, =, \geq\ B_5$(tiki constraints)

Here, $e_i\ is\ amount\ of\ Tiki\ required\ x_i$ here

$B_5 = total\ amount\ of\ tiki\ requied\ for\ total\ production$

manpower constraints

$$\sum_{i}^{n} f_i x_i \leq B_6$$

$f_1x_1 + f_2x_2 + \cdots + f_nx_n \leq, =, \geq\ B_6$(manpower constraints)

Here, $f_i\ is\ amount\ of\ man\ power\ required\ x_i$ here

$B_6 = total\ amount\ of\ man\ power\ requied\ for$

$total\ production$

machine constraints

$$\sum_{i}^{n} g_i x_i \leq B_7$$

$g_1x_1 + g_2x_2 + \cdots + a_nx_n \leq, =, \geq\ B_7$(machine constraints)

Here, $g_i\ is\ amount\ of\ bread\ required\ x_i$ here

$B_7 = total\ amount\ of\ bread\ requied\ for\ total$

$production$

chicken constraints

$$\sum_{i}^{n} h_i x_i \leq B_8$$

$h_1x_1 + h_2x_2 + \cdots + h_nx_n \leq, =, \geq\ B_8$(Chicken constraints)

Here, $h_i\ is\ amount\ of\ chicken\ required\ x_i$ here

$B_8 = total\ amount\ of\ chicken\ requied\ for\ total\ production$

Where

$x_1, x_2, \ldots \ldots, x_n \geq 0$

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

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

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

Subject to constraints are

$$\sum_{i}^{n} a_i x_i (\leq, =, \geq) B_1$$
i.e.
$a_1x_1 + a_2x_2 + \cdots + a_nx_n \leq, =, \geq\ B_1$ (Bread constraints)

$$\sum_{i}^{n} b_i x_i (\leq, =, \geq) B_2$$
i.e.
$b_1x_1 + b_2x_2 + \cdots + b_nx_n \leq, =, \geq\ B_2$ (tomato constraints)

$$\sum_{i}^{n} c_i x_i (\leq, =, \geq) B_3$$
i. e.
$c_1x_1 + c_2x_2 + \cdots + c_nx_n \leq, =, \geq\ B_3$ (cheese constraints)

$$\sum_{i}^{n} d_i x_i (\leq, =, \geq) B_4$$
i. e.
$d_1x_1 + dx_2 + \cdots + d_nx_n \leq, =, \geq\ B_4$ (Potato constraints)

$$\sum_{i}^{n} e_i x_i (\leq, =, \geq) B_5$$
i. e
$e_1x_1 + e_2x_2 + \cdots + e_nx_n \leq, =, \geq\ B_5$ (tikiconstraints)

$$\sum_{i}^{n} f_i x_i (\leq, =, \geq) B_6$$
i. e.
$f_1x_1 + f_2x_2 + \cdots + f_nx_n \leq, =, \geq\ B_6$ (manpower constraints)

$$\sum_{i}^{n} g_i x_i (\leq, =, \geq) B_7 \quad \text{i. e.}$$
$g_1x_1 + g_2x_2 + \cdots + a_nx_n \leq, =, \geq\ B_7$(machine constraints)

$$\sum_{i}^{n} h_i x_i (\leq, =, \geq) B_8 \quad \text{i. e}$$
$h_1x_1 + h_2x_2 + \cdots + h_nx_n \leq, =, \geq\ B_8$ (chicken constraints)

$\sum_{i}^{n} i_i x_i (\leq, =, \geq) B_9$ i. e.
$i_1x_1 + i_2x_2 + \cdots + i_nx_n \leq, =, \geq\ B_9$ (miscellaneous constraints)

$$\sum_{i}^{n} j_i x_i (\leq, =, \geq) B_{10}$$
i.e.
$j_1x_1 + j_2x_2 + \cdots + j_nx_n \leq, =, \geq\ B_{10}$ (rent constraints)
$x_1, x_2, \dots \dots, x_n \geq 0$Where
.... (3)

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 in to units and each unit are 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.

Product	Max cost	Min cost	Cost per unit
Cheese s/w	30	17.5	20
Cheese burger	37	25.5	30
Allotiki	24	16.5	20
Chicken pasta	53	37.5	40

Table 3: maximum and minimum cost of the product

Product	Bread	Tomato	Potato	Cheese	Rent	Tiki	Chicken	Pasta	Manpower	Machine	Other
Cheese s/w	2-4	1.5-4	1-3	3-5	3	0	0	0	2-3	2-3	3-5
Cheese burger	6-8	1-2	0	4-6	2	4.6-6	0	0	2-4	3-4	3-5
Allotiki	3-5	1.5-3	0	4-6	2	3-5	0	0	2-3	0	1-2
Chicken pasta	9-11	1.5-3	0	4-6	2	0	9-11	4-6	3-5	3-4	2-5

Table-4: Amount of product require for single unit.

Product	Bread	Tomato	Potato	Cheese	Tiki	Chicken	Pasta	Manpower	Machine	Miscall
Cheese s/w	1	30	30	20	0	0	0	3	2	50
Cheese burger	1	30	0	25	50	0	0	3	2	50
Allotiki	1	50	0	25	50	0	0	3	0	50
Chicken pasta	1	50	0	25	0	40	25	3	2	50
avaibility	210	4000	15000	4000	110	4000	3000	960	600	210

Table 5:Quantity requires in product with its units

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

x_1= Number of Chess s/w sandwich

x_2 = Number of Cheese burger sandwich

x_3 = Number of Allotiki sandwich

x_4 =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 $[0.5(a+b)]+\in\cdot(b-a)$ where interval is given by in the form of $[a,b]$ and $a<b.\in$ is parameter. Here $-0.5\leq\in\leq 0.5$.Using this we can generate sensitivity and for different value of∈' we can get different objective

For product 1

Value of ∈	c_i	r_i
-0.5	17.5	18
-0.4	18.75	18.5
-0.3	20.0	19
-0.2	21.25	19.5
-0.1	22.25	20
0	23.75	20.5
0.1	25	21
0.2	26.25	21.5
0.3	27.5	22
0.4	28.75	22.5
0.5	30.0	23.0

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

For product 2

Value of ∈	c_i	r_i
-0.5	25.5	15.5
-0.4	26.65	15.9
-0.3	27.8	16.3
-0.2	28.95	16.7
-0.1	30.1	17.1
0	31.25	17.5
0.1	32.4	17.9
0.2	33.55	18.3
0.3	34.7	18.7
0.4	35.85	19.1
0.5	37	19.5

Table 7value of cost and risk factor for product 2

For product 3

Value of ∈	c_i	r_i
-0.5	16.5	5
-0.4	17.25	5.4
-0.3	18	5.8
-0.2	18.75	6.2
-0.1	19.5	6.6
0	20.25	7
0.1	21	7.4
0.2	21.75	7.8
0.3	22.5	8.2
0.4	23.25	8.6
0.5	24	9

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

For product 4

Value of ∈	c_i	r_i
-0.5	37.5	8
-0.4	39.05	8.4
-0.3	40.6	8.8
-0.2	42.15	9.2
-0.1	43.7	9.6
0	45.25	10
0.1	46.8	10.4
0.2	48.35	10.8
0.3	49.9	11.2

0.4	51.45	11.6
0.5	53	12

Table 9: value of cost and risk factor for product 4

Now for above all values of cost and risk we will formulate the linear programming problem for individual value of ∈, by following method.

For ∈= *0* LPP will be

For ∈= 0 LPP will be

$$Min\ z_1 = 23.75x_1 + 31.25x_2 + 20.25x_3 + 45.25x_4$$

$$Min\ z_2 = 20.5x_1 + 17.5x_2 + 7.0\ x_3 + 10x_4$$

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

$x_1 + x_2 + x_3 + x_4 <= 210$ (Bread constraint)
$30x_1 + 30x_2 + 50x_3 + 50x_4 >= 4000$ (tomato constraint)
$20x_1 + 25x_2 + 25x_3 + 25x_4 >= 4000$ (cheese constraint)
$30x_1 <= 15000$ (potato constraint)
$0x_1 + 1x_2 + 1x_3 + 0.0x_4 < =110$ (tiki constraint)
$3x_1 + 3x_2 + 3x_3 + 3x_4 < =960$ (manpower constraint)
$2x_1 + 2x_2 + 2x_3 + 2x_4 < =600$ (machine constraint)
$0.04x_4 <= 4000$ (chicken constraint)
$0.025x_4 <= 3000$ (Bread constraint)
$x_1 >= 20$ (minimum constraint)
$x_2 >= 20$ (minimum constraint)
$x_3 >= 20$ (minimum constraint)
$x_4 >= 20$ (minimum constraint)
$x_1 >= 0,\ x_2 >= 0,\ x_3 >= 0,\ x_4 >= 0$

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

z_k / $f_i(x_1, x_2, x_3 \ldots x_n)$	$z_1 = 23.75x_1 + 31.25x_2 + 20.25x_3 + 45.25x_4$ (cost)	$z_2 = 20.5x_1 + 17.5x_2 + 7.0\ x_3 + 10x_4$; (minimum risk)
$f_1(37,20,90,20)$	4243.50	1948.75
$f_1(20,20,90,34)$	4461	1730

Table 10: pay off matrix between optimal solution and objective function

By considering maximum and minimum value objective function of cost and minimum

z_k / $f_i(x_1, x_2, x_3 \ldots x_n)$	$z_1 = 23.75x_1 + 31.25x_2 + 20.25x_3 + 45.25x_4$ (cost)	$z_2 = 20.5x_1 + 17.5x_2 + 7.0\ x_3 + 10x_4$; (minimum risk)
$f_1(37,20,90,20)$	4243.50 (L_1)	1948.75 (u_2)
$f_1(20,20,90,34)$	4461 (u_1)	1730 (L_2)

Table 11: pay off 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: σ

Subject to

$\mathbf{23.75x_1 + 31.25x_2 + 20.25x_3 + 45.25x_4} + \sigma(217.5) \leq 4461$; $(Z_1 + \sigma(U_1 - L_1) \leq U_1)$

$\mathbf{20.5x_1 + 17.5x_2 + 7.0\,x_3 + 10x_4} + \sigma(218.7) \leq 1948.75$;$(Z_2 + \sigma(U_2 - L_2) \leq U_2)$

Subject to the constraints

$x_1 + x_2 + x_3 + x_4 <= 210$ (Bread constraint)

$30x_1 + 30x_2 + 50x_3 + 50x_4 >= 4000$ (tomato constraint)

$20x_1 + 25x_2 + 25x_3 + 25x_4 >= 4000$ (cheese constraint)

$30x_1 <= 15000$ (potato constraint)

$0x_1 + 1x_2 + 1x_3 + 0.0x_4 < =110$ (tiki constraint)

$3x_1 + 3x_2 + 3x_3 + 3x_4 < =960$ (manpower constraint)

$2x_1 + 2x_2 + 2x_3 + 2x_4 < =600$ (machine constraint)

$0.04x_4 <= 4000$ (chicken constraint)

$0.025x_4 <= 3000$ (Bread constraint)

$x_1 >= 20$ (minimum constraint)

$x_2 >= 20$ (minimum constraint)

$x_3 >= 20$ (minimum constraint)

$x_4 >= 20$ (minimum constraint)

$x_1 >= 0$, $x_2 >= 0$, $x_3 >= 0$, $x_4 >= 0$

By using LINGO15 solution can be obtain as follows

Objective value σ: 0.500488, x_1= 28.7434, x2=20, x3= 90,x_4= 27.00523

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

Maximum $= \sigma$

Subject to

$$e^{-1\left(\frac{\mathbf{23.75x_1+31.25x_2+20.25x_3+45.25x_4}-4243.125)}{217.875}\right)} - (1 - e^{-1})\sigma \geq e^{-1},$$

$$e^{-1\left(\frac{\mathbf{20.5x_1+17.5x_2+7.0\,x_3+10x_4}-1730)}{218.75}\right)} - (1 - e^{-1})\sigma \geq e^{-1}$$

$x_1 + x_2 + x_3 + x_4 <= 210$ (Bread constraint)
$30x_1 + 30x_2 + 50x_3 + 50x_4 >= 4000$ (tomato constraint)
$20x_1 + 25x_2 + 25x_3 + 25x_4 >= 4000$ (cheese constraint)
$30x_1 <= 15000$ (potato constraint)
$0x_1 + 1x_2 + 1x_3 + 0.0x_4 < =110$ (tiki constraint)

$3x_1 + 3x_2 + 3x_3 + 3x_4 <= 960$ (manpower constraint)
$2x_1 + 2x_2 + 2x_3 + 2x_4 <= 600$ (machine constraint)
$0.04x_4 <= 4000$ (chicken constraint)
$0.025x_4 <= 3000$ (Bread constraint)
$x_1 >= 20$ (minimum constraint)
$x_2 >= 20$ (minimum constraint)
$x_3 >= 20$ (minimum constraint)
$x_4 >= 20$ (minimum constraint)
$x_1 >= 0;\ x_2 >= 0;\ x_3 >= 0;\ x_4 >= 0$

Solution of this LPP will be given by

Objective value: $\sigma = 0.6224600$

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

similarly solving for all the value of ∈, following solutions are derived

Value of ∈	Min z_k	Solution using linear membership function	Solution using exponential membership function
0	$z_1 = 4243.125$ $z_2 = 1730.0$	$\sigma = 0.500488$ $x_1 = 28$ $x_2 = 20$, $x_3 = 90$ $x_4 = 27.00$	$\sigma = 0.6224600$ $x_1 = 28.75$, $x_2 = 20$, $x_3 = 90$ $x_4 = 27$
0.1	$z_1 = 4411.50$ $z_2 = 1797.60$	$\sigma = 0.50$ $x_1 = 28.75$ $x_2 = 20$, $x_3 = 90$ $x_4 = 27.00$	$\sigma = 0.6224600$ $x_1 = 28.75$, $x_2 = 20$, $x_3 = 90$ $x_4 = 27$
0.2	$z_1 = 4579.879$ $z_2 = 1865.2$	$\sigma = 0.5161$ $x_1 = 29.032$ $x_2 = 20$, $x_3 = 90$ $x_4 = 26.77433$	$\sigma = 0.6224600$ $x_1 = 28.75$, $x_2 = 20$, $x_3 = 90$ $x_4 = 27$
0.3	$z_1 = 4748.240$ $z_2 = 1932.800$	$\sigma = 0.4999$ $x_1 = 28.7502$ $x_2 = 20$, $x_3 = 90$ $x_4 = 26.999$	$\sigma = 0.622489$ $x_1 = 28.75$, $x_2 = 20$, $x_3 = 90$ $x_4 = 26.999$
0.4	$z_1 = 4976.625$ $z_2 = 2000.400$	$\sigma = 0.579558$ $x_1 = 27.34$ $x_2 = 20$, $x_3 = 90$ $x_4 = 28.127$	$\sigma = 0.695837$ $x_1 = 28.3407$ $x_2 = 20$, $x_3 = 90$ $x_4 = 28.127$
0.5	$z_1 = 5085$ $z_2 = 2058$	$\sigma = 0.50$ $x_1 = 28.80161$ $x_2 = 20$, $x_3 = 90$ $x_4 = 26.9581$	$\sigma = 0.62246$ $x_1 = 28.75$, $x_2 = 20$ $x_3 = 90$ $x_4 = 27$
-0.1	$z_1 = 4074.75$ $z_2 = 1665.8$	$\sigma = 0.503973$ $x_1 = 28.819$ $x_2 = 20$, $x_3 = 90$ $x_4 = 26.9443$	$\sigma = 0.626252$ $x_1 = 28.819$, $x_2 = 20$, $x_3 = 90$ $x_4 = 26.9443$
-0.2	$z_1 = 3906.375$ $z_2 = 1587.80$	$\sigma = 0.49187$ $x_1 = 28.60849$ $x_2 = 20$ $x_3 = 90$ $x_4 = 27.113$	$\sigma = 0.61463$ $x_1 = 28.60849$ $x_2 = 20$ $x_3 = 90$ $x_4 = 27.113$
-0.3	$z_1 = 3738.00$ $z_2 = 1527.20$	$\sigma = 0.4997612$ $x_1 = 28.74582$ $x_2 = 20$, $x_3 = 90$ $x_4 = 27.00$	$\sigma = 0.62222308$ $x_1 = 28.74582$ $x_2 = 20$ $x_3 = 90$ $x_4 = 27$
-0.4	$z_1 = 3569.625$ $z_2 = 1459.600$	$\sigma = 0.500007$ $x_1 = 28.74990$ $x_2 = 20$	$\sigma = 0.6224654$ $x_1 = 28.74990$ $x_2 = 20$

		x_3= 90 x_4 = 27.00	x_3= 90 x_4 = 27
-0.5	z_1 = 3401 z_2 = 1392	σ = 0.4650 x_1 = 28.148 x_2 = 20, x_3= 90 x_4 = 27.48	σ = 0.6221859 x_1 = 28.7550 x_2 = 20, x_3= 90 x_4 =26.9960

Table 12: solution for various value of ∈

8.0 CONCLUSION

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

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