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A Fuzzy Production Inventory Model with Wastage item under Two Constraints using Regular Weighted Point of Lotus Petal Fuzzy Number

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Abstract— **In this paper, a fuzzy production inventory model with wastage item and two warehouse under two constraints have been considered. In this model the deterioration rate and demand rate considered as random variable and the production rate depends directly on demand rate. The lotus petal fuzzy number is defined and its properties are given. The parameters involved in this model are represented by lotus petal fuzzy number. The expected average total cost is defuzzified by the regular weighted point technique. The analytical expressions for expected inventory level of temporary warehouse, maximum inventory (sugar and wastage item) levels are derived. The optimum values of time are determined by using nonlinear programming technique. A numerical example is presented to illustrate the results.**

Keyword- **lotus petal fuzzy number, regular weighted point technique, temporary warehouse cost constraint, machine time constraint.**
AMS Subject Classification (2010): **90B05, 03E72.**

I. INTRODUCTION

Inventory problems are common in manufacturing, service and business operations in general. Some inventory models were formulated in a static environment where the demand is assumed to be constant and steady over a finite planning horizon. Many items of inventory such as electronic products, fashionable clothes, tasty food products etc.,

Most of the existing inventory models in the literature assume that items can be stored indefinitely to meet the future demands. However, certain types of commodities either deteriorate or become obsolete in the course of time and hence are unstable. Therefore, if the rate of deterioration is not sufficiently low, its impact on modelling of such an inventory model cannot be ignored. In this connections, inventory problems for deteriorating items have been studied extensively by many researchers [3],[6],[7] and [9] from time to time. Research in this area started with the work of Whitin [10], who considered fashion goods deteriorating at the end of prescribed storage period. Goyal and Giri [5] gave recent trends of modelling in deteriorating item inventory. The inventory model for variable demand and production is given in [1]. A production inventory model for variable demand and production is explained in [2]. Samantha and Ajanta roy work based on realistic production lot-size inventory model for deteriorating items is given in [8].

In conventional inventory models, uncertainties are treated as randomness and are handled by probability theory. Furthermore, when addressing real world problems, frequently the parameters are imprecise numerical quantities. However, in certain situations, uncertainties are due to fuzziness and in such cases the fuzzy set theory introduced by Zadeh [11] is applicable. A. Faritha Asma and E.C. Henry Amirtharaj analized multi objective inventory model of deteriorating items with two constraints using fuzzy optimization technique [4].

In the real situation, at the time of production the deterioration rate and demand rate are varied. So that the deterioration rate and demand rate are considered as a random variable which follows rayleigh distribution and bounded pareto distribution respectively.

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In the existing inventory models, they used only rented warehouse and own warehouse. When using the rented warehouse the transportation cost, rental and maintenance cost are all high. Here, the model newly constructed with permanent warehouse and temporary warehouse.

As warehouse is a key factor in production inventory model, so these days researcher are paying more rent in stored the goods. The temporary warehouse used for reducing the rented amount and maintenance cost.

This paper is organized as follows:

In section 2, assumptions and notations for the fuzzy production inventory model under consideration are given. The mathematical formulation for the proposed model is explained in crisp environment under section 3. In section 4, lotus petal fuzzy number is defined and its properties are given. To defuzzify the model, the regular weighted point of lotus petal fuzzy number is determined in section 5. In section 6, the mathematical model is explained in fuzzy environment. In section 7, an application of this model is given in both environment.

II. ASSUMPTIONS AND NOTATIONS

The following assumptions and notations are used throughout this paper:

Assumptions

1. Demand rate for inventory(sugar and wastage item) are taken as a random variable which follows bounded pareto distribution.
2. Production rate is demand dependent that is $p = cd$, $0 < c < n$, n is a finite number.
3. Deterioration rate for inventory(sugar and wastage item) are taken as a random variable which follows reyleigh distribution.
4. First, the goods(sugar) are stored in permanent warehouse then the remaining goods(sugar) are stored in temporary warehouse.
5. The goods(sugar) of permanent warehouse are consumed only after consuming the goods(sugar) kept in temporary warehouse.
6. The permanent warehouse has a fixed capacity of I_P units.
7. The inventory(suger and wastage item) levels depleted due to demand and deterioration.
8. Shortages are not allowed.

Notations

$I_1(t)$ – the level of inventory(sugar) at time t, $0 \leq t \leq t_1$.

$I_2(t)$ - the level of inventory(sugar) in temporary warehouse at time t, $t_1 \leq t \leq t_2$.

$I_3(t)$ – the level of inventory(sugar) in permanent warehouse at time t, $t_1 \leq t \leq t_4$.

$W_1(t)$ - the level of inventory(wastage item) at time t, $0 \leq t \leq t_1$.

$W_2(t)$ – the level of inventory(wastage item) at time t, $t_1 \leq t \leq t_3$.

I_P – fixed capacity for permanent warehouse at time t_1.

I_m – expected maximum inventory(sugar) level at time t_1. (decision variable)

I_w - expected maximum inventory(wastage item) level at time t_1. (decision variable)

I_T – expected maximum inventory(sugar) level of temporary warehouse at time t_1.(decision variable)

p – production rate for inventory (sugar).

D – demand rate for inventory(sugar).

θ - deterioration rate for inventory(sugar).

d_1 – demand rate for inventory(wastage item).

θ_1 - deterioration rate for inventory(wastage item).

t_1 - machine time available for product.

TC – expected average total cost per cycle.

$\tilde{S}_c$ - fuzzy setup cost per cycle.

$\tilde{h}_c$ - fuzzy holding cost for inventory(sugar) per unit per unit time.

$\tilde{d}_c$ - fuzzy deteriorating cost for inventory(sugar) per unit per unit time.

$\tilde{h}_w$ - fuzzy holding cost for inventory(wastage item) per unit per unit time.

$\tilde{d}_w$ - fuzzy deteriorating cost for inventory(wastage item) per unit per unit time.

$\tilde{T}_{wc}$ - fuzzy cost for 1 square feet of temporary warehouse.

$\tilde{T}_{ws}$ - fuzzy total space for temporary warehouse.

$\tilde{T}_{twc}$ - fuzzy total temporary warehouse cost.

$\tilde{T}_m$ - fuzzy machine time consumed per month.

$\tilde{m}$ - fuzzy number of months for production.

III. MATHEMATICAL FORMULATION AND SOLUTION

The proposed inventory model is formulated to minimize the average total cost, which includes setup cost,

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holding cost, deterioration cost and temporary warehouse cost. The rate of change of the inventory during the following periods are governed by the following differential equations:

$$\frac{dI_1(t)}{dt} + \theta I_1(t) = p - d \qquad 0 \le t \le t_1 \qquad (1)$$

with boundary condition $I_1(t) = 0$ at $t = 0$

$$\frac{dI_2(t)}{dt} + \theta I_2(t) = -d \qquad t_1 \le t \le t_2 \qquad (2)$$

with boundary conditions $I_2(t) = 0$ at $t = t_2$ and $I_2(t) = I_T$ at $t = t_1$

$$\frac{dI_3(t)}{dt} + \theta I_3(t) = 0 \qquad t_1 \le t \le t_2 \qquad (3)$$

with boundary conditions $I_3(t) = I_P$ at $t = t_1$

$$\frac{dI_3(t)}{dt} + \theta I_3(t) = -d \qquad t_2 \le t \le t_4 \qquad (4)$$

with boundary condition $I_3(t) = 0$ at $t = t_4$

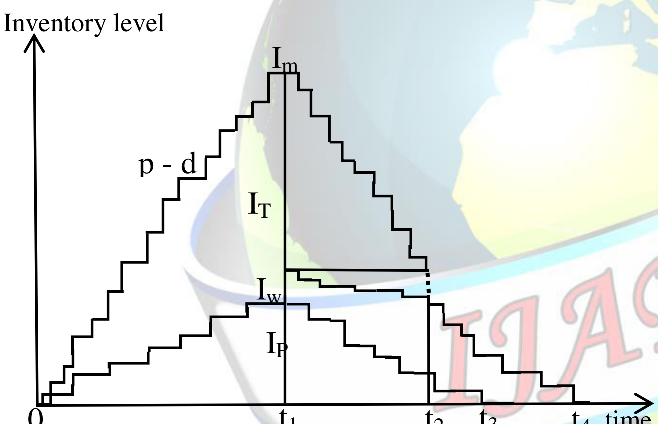

Fig 1: Graphical representation of the state of inventory system

$$\frac{dW_1(t)}{dt} + \theta W_1(t) = -d \qquad 0 \le t \le t_1 \qquad (5)$$

with boundary condition $W_1(t) = 0$ at $t=0$

$$\frac{dW_2(t)}{dt} + \theta W_2(t) = -d \qquad t_1 \le t \le t_3 \qquad (6)$$

with boundary condition $W_2(t) = 0$ at $t = t_3$ and $W_2(t) = I_w$ at $t = t_1$

From (1) $$I_1(t) = \frac{p-d}{\theta}\left(1 - e^{-\theta t}\right) \qquad (7)$$

From (2) $$I_2(t) = \frac{d}{\theta}\left(e^{\theta(t_2 - t)} - 1\right)$$

using the boundary condition $I_2(t) = I_T$ at $t = t_1$

$$I_T = \frac{d}{\theta}\left(e^{\theta(t_2 - t_1)} - 1\right) \qquad (8)$$

From (3) $$I_3(t) = I_p\, e^{\theta(t_1 - t)} \qquad (9)$$

From (4) $$I_3(t) = \frac{d}{\theta}\left(e^{\theta(t_4 - t)} - 1\right) \qquad (10)$$

From (5) $$W_1(t) = \frac{d_1}{\theta_1}\left(e^{-\theta_1 t} - 1\right) \qquad (11)$$

From (6) $$W_2(t) = \frac{d_1}{\theta_1}\left(e^{\theta_1(t_3 - t)} - 1\right)$$

using the boundary condition $W_2(t) = I_w$ at $t = t_1$

$$I_w = \frac{d_1}{\theta_1}\left(e^{\theta_1(t_3 - t_1)} - 1\right) \qquad (12)$$

The maximum inventory(sugar) level per cycle is

$$I_m = I_T + I_P \qquad (13)$$

Expected demand rate for inventory(sugar) is

$$E(d) = \frac{L^{\alpha}}{1 - \left(\frac{L}{H}\right)^{\alpha}}\left(\frac{\alpha}{\alpha - 1}\right)\left(\frac{1}{L^{\alpha-1}} - \frac{1}{H^{\alpha-1}}\right)$$

Expected deterioration rate for inventory(sugar) is

$$E(\theta) = \sigma\sqrt{\frac{\pi}{2}}$$

Expected demand rate for inventory(wastage item) is

$$E(d_1) = \frac{L_1^{\alpha_1}}{1 - \left(\frac{L_1}{H_1}\right)^{\alpha}}\left(\frac{\alpha_1}{\alpha_1 - 1}\right)\left(\frac{1}{L_1^{\alpha_1-1}} - \frac{1}{H_1^{\alpha_1-1}}\right)$$

Expected deterioration rate for inventory(wastage item) is

$$E(\theta_1) = \sigma_1\sqrt{\frac{\pi_1}{2}}$$

$$Expected\ \ average\ \ total\ \ cost$$

$$= \frac{1}{t_4}\begin{bmatrix} setup\ cost + E(holding\ \ cost) \\ + E(deterioration\ \ cost) \\ + temporary\ \ warehouse\ \ cost \end{bmatrix} \qquad (14)$$

where,

Setup cost = S_c

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Holding cost = Holding cost for inventory(sugar) (HC_S)

+Holding cost for inventory(wastage item) (HC_W)

$$HC_S = h_c \left\{ \int_0^{t_1} I_1(t)\,dt + \int_{t_1}^{t_2} (I_2(t)+I_3(t))\,dt + \int_{t_2}^{t_4} I_3(t)\,dt \right\}$$

$$= h_c \left\{ \begin{array}{l} \frac{p-d}{\theta^2}\left(e^{-\theta t_1}-1\right)+ \\ \frac{d}{\theta^2}\left(e^{\theta(t_2-t_1)}+e^{\theta(t_4-t_2)}-2+\theta t_1-\theta t_4\right) \\ +I_p\left(\frac{1-e^{\theta(t_1-t_2)}}{\theta}\right) \end{array} \right\}$$

$$HC_W = h_w \left\{ \int_0^{t_1} W_1(t)\,dt + \int_{t_1}^{t_3} W_2(t)\,dt \right\}$$

$$= h_w \frac{d_1}{\theta_1}\left\{\left(\frac{e^{\theta_1(t_3-t_1)}-e^{-\theta_1 t_1}}{\theta_1}-t_3\right)\right\}$$

Deterioration cost = deteriorationcost for inventory (sugar) (DC_S) + deterioration cost for inventory(wastage item) (DC_W)

$$DC_S = d_c\left\{\int_0^{t_1} I_1(t)\,dt - \int_{t_1}^{t_4} d\,dt\right\}$$

$$= d_c\left\{\frac{p-d}{\theta^2}\left(e^{-\theta t_1}+\theta t_1-1\right)-d(t_4-t_1)\right\}$$

$$DC_W = d_w\left\{\int_0^{t_1} W_1(t)\,dt - \int_{t_1}^{t_3} d_1\,dt\right\}$$

$$= d_w\left\{\frac{d_1}{\theta_1^2}\left(1-e^{-\theta_1 t_1}-\theta_1 t_1\right)-d_1(t_3-t_1)\right\}$$

Temporary warehouse cost = temporary warehouse cost for inventory (sugar) (TWC_S)

$$TWC_S = T_{wc} \times T_{ws}$$

$$Min\ E(TC(t_1,t_2,t_3,t_4)) =$$

$$\frac{1}{t_4}\left[\begin{array}{l} S_c + h_c\left\{\begin{array}{l} \frac{c\,E(d)-E(d)}{E(\theta)^2}\left(e^{-E(\theta)t_1}-1\right) \\ +\frac{E(d)}{E(\theta)^2}\left(e^{E(\theta)(t_2-t_1)}+e^{E(\theta)(t_4-t_2)}-2+E(\theta)t_1-E(\theta)t_4\right) \\ +I_p\left(\frac{1-e^{E(\theta)(t_1-t_2)}}{E(\theta)}\right) \end{array}\right\} \\ +h_w\frac{d_1}{\theta_1}\left\{\left(\frac{e^{\theta_1(t_3-t_1)}-e^{-\theta_1 t_1}}{\theta_1}-t_3\right)\right\} \\ +d_c\left\{\frac{c\,E(d)-E(d)}{E(\theta)^2}\left(e^{-E(\theta)t_1}+E(\theta)t_1-1\right)-E(d)(t_4-t_1)\right\} \\ +d_w\left\{\frac{d_1}{\theta_1^2}\left(1-e^{-\theta_1 t_1}-\theta_1 t_1\right)-d_1(t_3-t_1)\right\}+T_{wc}\,T_{ws} \end{array}\right]$$

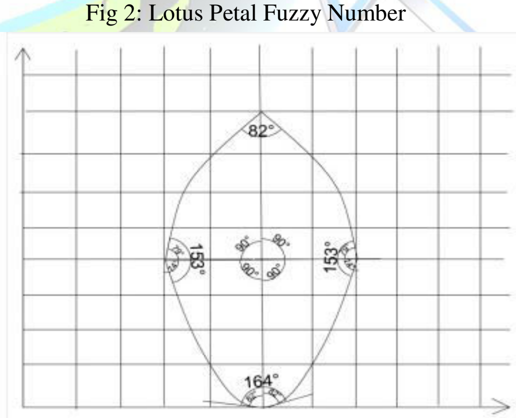
$$\text{subject to}: T_{wc}\,T_{ws} \le T_{twc},\ T_m\,m \le t_1 \tag{15}$$

Solve the objective function using MATLAB software, the values of t_1^*, t_2^*, t_3^* and t_4^* are obtained. Substituting t_1^*, t_2^*, t_3^* and t_4^* in (8), (12), (13) and (15), the optimum values I_T^*, I_W^*, I_m^* and TC^* are obtained.

IV LOTUS PETAL FUZZY NUMBER AND ITS PROPERTIES

DEFINITION: LOTUS PETAL FUZZY NUMBER

Fig 2: Lotus Petal Fuzzy Number



A Lotus petal fuzzy number $\tilde{A}$ described as a normalized convex fuzzy subset on the real line R whose membership function $\mu_{\tilde{A}}(x)$ is defined as follows:

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$$\mu_{\tilde{A}}(x)=\begin{cases}\frac{1}{2} & at \quad x=a,c\\ \frac{1}{2}\left[1+\sqrt{\frac{x-a}{b-a}}\right] & at \quad a\le x\le b\\ \frac{1}{2}\left[1+\sqrt{\frac{c-x}{c-b}}\right] & at \quad b\le x\le c\\ \frac{1}{2}\left[\left(1-\frac{c-x}{c-b}\right)^2\right] & at \quad c\ge x\ge b\\ \frac{1}{2}\left[\left(1-\frac{x-a}{b-a}\right)^2\right] & at \quad b\ge x\ge a\\ 0\,\&\,1 & at \quad x=b\end{cases}$$

This type of fuzzy number be denoted as $\tilde{A}$ = [a, b, c], whose membership function $\mu_{\tilde{A}}(x)$ satisfies the following conditions:

1. $\mu_{\tilde{A}}(x)$ is a continuous mapping from R to the closed interval [0,1]
2. $\mu_{\tilde{A}}(x)$ is a convex function.
3. $\mu_{\tilde{A}}(x) = 0$ & 1 at x=b.
4. $\mu_{\tilde{A}}(x) = \frac{1}{2}$ at x= a & c.
5. $\mu_{\tilde{A}}(x)$ is strictly decreasing as well as increasing and continuous on [a,b] and [b,c].

Properties:

1. Left and right opposite angles are equal.
2. The horizontal and vertical diagonal bisect each other and meet at 90°.
3. The lower angle is twice that of the upper angle.

IV. REGULAR WEIGHTED POINT OF LOTUS PETAL FUZZY NUMBER

For the Lotus petal fuzzy number $\tilde{A}$ =[a, b, c] , the α -cut is $\tilde{A}_\alpha = [L_{\tilde{A}}(\alpha), R_{\tilde{A}}(\alpha)]$ and the regular weighted point for $\tilde{A}$ is given by,

$$r_w(\tilde{A})=\frac{\int_0^1 \frac{L_{\tilde{A}}(\alpha)+R_{\tilde{A}}(\alpha)}{2} f_1(\alpha)\,d\alpha}{\int_0^1 f(\alpha)\,d\alpha}$$

$$=\int_0^1 \left[L_{\tilde{A}}(\alpha)+R_{\tilde{A}}(\alpha)\right] f_1(\alpha)\,d\alpha$$

where,

$$f(\alpha)=\begin{cases}(1-2\alpha) & when \quad \alpha\in\left[0,\frac{1}{2}\right]\\ (2\alpha-1) & when \quad \alpha\in\left[\frac{1}{2},1\right]\end{cases}$$

$$f_1(\alpha)=\begin{cases}\omega(1-2\alpha) & when \quad \alpha\in\left[0,\frac{1}{2}\right]\\ (1+\omega)(2\alpha-1) & when \quad \alpha\in\left[\frac{1}{2},1\right]\end{cases} \quad 0<\omega<1.$$

The regular weighted point of a lotus petal fuzzy number is of the form

$$r_w(\tilde{A})=\omega\left(\frac{31a+58b+31c}{120}\right)+\left(\frac{a+2b+c}{8}\right)$$

V. INVENTORY MODEL IN FUZZY ENVIRONMENT

The proposed inventory model in fuzzy environment is

$$Min\,E(\tilde{T}C(t_1,t_2,t_3,t_4))=$$

$$\frac{1}{t_4}\left[\begin{array}{l}\tilde{S}_c+\tilde{h}_c\left\{\begin{array}{l}\frac{c\,E(d)-E(d)}{E(\theta)^2}\left(e^{-E(\theta)\,t_1}-1\right)\\ +\frac{E(d)}{E(\theta)^2}\left(e^{E(\theta)\,(t_2-t_1)}+e^{E(\theta)\,(t_4-t_2)}-2+E(\theta)t_1-E(\theta)t_4\right)\\ +I_p\left(\frac{1-e^{E(\theta)\,(t_1-t_2)}}{E(\theta)}\right)\end{array}\right\}\\ +\tilde{h}_w\frac{E(d_1)}{E(\theta_1)}\left\{\left(\frac{e^{E(\theta_1)(t_3-t_1)}-e^{-E(\theta_1)t_1}}{E(\theta_1)}-t_3\right)\right\}\\ +\tilde{d}_c\left\{\frac{c\,E(d)-E(d)}{E(\theta)^2}\left(e^{-E(\theta)\,t_1}+E(\theta)t_1-1\right)-E(d)(t_4-t_1)\right\}\\ +\tilde{d}_w\left\{\frac{E(d_1)}{E(\theta_1)^2}\left(1-e^{-E(\theta_1)\,t_1}-E(\theta_1)t_1\right)-E(d_1)(t_3-t_1)\right\}+\tilde{T}_{wc}\,\tilde{T}_{ws}\end{array}\right] \quad (16)$$

subject to : $\tilde{T}_{wc}\ \tilde{T}_{ws} \le \tilde{T}_{twc},\ \tilde{T}_m\ \tilde{m} \le t_1$

where ~ represents for fuzzification of the parameters.

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$\tilde{S}_c = (S_{c1}, S_{c2}\, S_{c3})$, $\tilde{h}_c = (h_{c1}, h_{c2}, h_{c3})$, $\tilde{h}_w = (h_{w1}, h_{w2}, h_{w3})$,

$\tilde{d}_w = (d_{w1}, d_{w2}, d_{w3})$, $\tilde{T}_{wc} = (T_{wc1}, T_{wc2}\, T_{wc3})$,

$\tilde{d}_c = (d_{c1}, d_{c2}, d_{c3})$, $\tilde{T}_{ws} = (T_{ws1}, T_{ws2}, T_{ws3})$,

$\tilde{T}_{twc} = (T_{twc1}, T_{twc2}, T_{twc3})$, $\tilde{T}_m = (T_{m1}, T_{m2}, T_{m3})$,

$\tilde{m} = (m_1, m_2, m_3)$.

Now using the technique, regular weighted point of lotus petal fuzzy number, the above model is defuzzified as follows

$$Min\, E(r_w(TC(t_1,t_2,t_3,t_4)))$$

$$= \frac{1}{t_4}\left[\begin{array}{l} r_w(S_c) + r_w(h_c)\left\{\begin{array}{l} \dfrac{c\,E(d) - E(d)}{E(\theta)^2}\left(e^{-E(\theta)\,t_1} - 1\right) \\ + \dfrac{E(d)}{E(\theta)^2}\left(e^{E(\theta)\,(t_2 - t_1)} + e^{E(\theta)\,(t_4 - t_2)} - 2 + E(\theta)t_1 - E(\theta)t_4\right) \\ + I_p\left(\dfrac{1 - e^{E(\theta)\,(t_1 - t_2)}}{E(\theta)}\right) \end{array}\right\} \\ + r_w(h_w)\dfrac{E(d_1)}{E(\theta_1)}\left\{\left(\dfrac{e^{E(\theta_1)(t_3 - t_1)} - e^{-E(\theta_1)t_1}}{E(\theta_1)} - t_3\right)\right\} \\ + r_w(d_c)\left\{\dfrac{c\,E(d) - E(d)}{E(\theta)^2}\left(e^{-E(\theta)\,t_1} + E(\theta)t_1 - 1\right) - E(d)(t_4 - t_1)\right\} \\ + r_w(d_w)\left\{\dfrac{E(d_1)}{E(\theta_1)^2}\left(1 - e^{-E(\theta_1)\,t_1} - E(\theta_1)t_1\right) - E(d_1)(t_3 - t_1)\right\} + r_w(T_{wc})\; r_w(T_{ws}) \end{array}\right] \quad (17)$$

Subject to : $r_w(T_{wc})\; r_w(T_{ws}) \le r_w(T_{twc})$,
$r_w(T_m)\; r_w(m) \le t_1$

Solve the objective function using MATLAB software, the values of t_1^*, t_2^*, t_3^* and t_4^* are obtained. Substituting t_1^*, t_2^*, t_3^* and t_4^* in (8), (12), (13) and (17), the optimum values I_T^*, I_w^*, I_m^* and TC^* are obtained.

VI. NUMERICAL EXAMPLES

In sugar factory, there are two warehouse (permanent and temporary). In permanent warehouse it has constant capacity, but in temporary warehouse holds its inventory(sugar) in constainers. The wastage item is sold at the time of manufacturing.

The following values of the parameter in proper unit were considered as input for the numerical result of the above problem.

L = 100, H = 1000, α = 0.5, c = 2, σ = 5, π = 3.14, L_1 = 50, H_1 = 500, α_1 = 0.25, σ_1 = 2.5, π_1 = 3.14, I_p = 50000 Ton.

All costs are taken in rupees.

$\tilde{S}_c$ = (1000000, 2000000, 3000000), $\tilde{h}_c$ = (5000, 6000, 7000), $\tilde{d}_c$ = (500, 600, 700), $\tilde{h}_w$ = (1000, 2000, 3000),

$\tilde{d}_w$ = (100, 200, 300), $\tilde{T}_{twc}$ = (500000,600000,700000),

$\tilde{T}_{wc}$ = (200, 250, 300), $\tilde{T}_{ws}$ =(2000,2050,2100) in sqft,

$\tilde{T}_m$ = (25,27,29) in days, $\tilde{m}$ = (3,4,5) in months.

Using MATLAB software, the optimum values I_T^*, I_m^*, I_w^* and TC^* are tabulated below:

COMPARISON TABLE 7.1

Model	t_1^* /month	t_2^* /month	t_3^* /month	t_4^* /month	I_T^* /Ton	I_m^* /Ton	I_w^* /Ton	TC^* Rs
Crisp 1	3.0567	4.2073	4.2825	5.3105	68,134	1,18,130	16,327	2,77,66,000
Crisp 2	3.6509	4.7895	4.8052	5.8798	63,196	1,13,200	11,399	2,80,54,000
Crisp 3	4.6492	5.7856	5.7998	6.8746	62,330	1,12,330	11,189	2,78,78,000
Fuzzy	4.9635	6.1486	6.2104	7.2878	84,586	1,34,590	18,152	2,56,91,000

OBSERVATION

From the above table, it should be noted that compared to crisp model, the fuzzy model is very effective

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method, because of the time consuming in fuzzy analysis and the optimal results are obtained easily.

i. The average total cost is obtained in fuzzy model is less than the crisp model.

ii. The optimal values I_T^*, I_m^*, I_w^* in fuzzy model are higher than the crisp model.

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