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An Inventory Model with Logarithmic Demand and Degradation over Season in Fuzzy Sense

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Abstract. In this work we have studied an backlog model for damaged products with logarthimic stipulation rate for the optimal stock of commodities which may be either constant or vary with time. This paradigmatic is developed to find the fuzzy total cost of the inventory system so as to get the lower expenditure. Time dependent deterioration of time is considered. For defuzzification the proposed model is dealt with heptagonal fuzzy numbers .Numeric illustration is dispensed to exhibit the evaluation of suggested layout.

Keywords: logarithmic period sensitive demand rate, time-critical opportunity cost, heptogonal fuzzy number, defuzzification

1.Introduction:

Inventory management is a critical resource for every activities because it determines how much inventory to keep on hand and how regularly to reorder. Stockpile refers to the commodities or resources used by a commercial organisation for inventory purposes. The impact of degradation on the inventory process is critical. When developing appropriate inventory suggestions for merchandise such as fruits, vegetables, chemicals, and so on, the deprivation of reserve due to degradation cannot be ignored. Manish Pande and Gautam[11] developed an stock management pattern using a cost-cutting technique for determining the best stock, time, and total cost for fixed degradation and integrated sales rates. By tolerating a scarcity, deterministic demand instances were considered. They were given beginning inventory, total number of deteriorating pieces, and approximate expression. They came up with a rough formula for initial inventory and overall variety of deteriorated units. Dutta and Kumar[2] created a backlog model with no deficiency using trapezoidal fuzzy numbers in a hazy environment. The best overall cost and order quantity were defined utilising trapezoidal fuzzy numbers. The signed distance method was used for defuzzification.Ranganathan and Thirunavukarasu[14] developed a fuzzy resource type with continuous depreciation. Balarama Murthy, Kartigeyan, and Pragathi[1] investigated a fuzzy backlog control problem with logarithmic demand and weibull deterioration rate. Karthigeyan, Balarama murthy, and Saranya [8] developed a fuzzy-optimized production pattern that accounts for economic order quantity and allows for shortages. Senbagam and Kokilamani [16] investigated an inventory model in a fuzzy setting for gompertz degrading commodities with quadratic demand and constant holding cost.Meenakshi Sundaram ,Harikrishnan and Sivan[12] introduced an deteriorating inventory model of EOQ with betadistributed quadratic time function demand and fully backlogged with shortages.

In this article, we looked at the logarithmic ratio of demand and damage over time. The end goal is to find a fuzzy optimal solution by differential mean integration using heptagonal fuzzy number . To represent the estimations of the proposed model, numerical examples were used.

2.Premise and Symbols:

The presumptions for the arithmetical representation are

(a)The stockpile ratio is logarithmic behaviour of time (i.e) $D(t)= \log(1+ t)$

(b) The delivery time is nil.

(c) The reload rate is interminable.

(d) Rate of decline is time dependent.

(e) I (t) is the supply at spell .

(f) H is the possibility price in step with unit price.

(g) A is the rarity value per order unit.

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(h) C is the per unit value of deterioration.

(i) Q is the overall quantity of stock on the begin of every period.

(j) S is the starting stock after fulfillment of back orders.

(k) $\tilde{A}$ is the fuzzy shortage cost.

(l) $\tilde{H}$ is the fuzzy opportunity cost.

(m) $\tilde{C}$ is the fuzzy deteriorated cost.

3.Concepts of fuzzy[17]:

(i) The trapezoidal fuzzy number is defined as A = (a_1, a_2 , a_3, a_4) where a_1, a_2 , $a_3, a_4$are defined on R, if the membership function of A is given by

$$\mu\tilde{A} = \begin{cases} \frac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ 1, & a_2 \le x \le a_3 \\ \frac{x-a_3}{a_4-a_3}, & a_3 \le x \le a_4 \\ 0, & x \ge a_4 \end{cases}$$

(ii).A heptagonal fuzzy number $\tilde{A} = (a_1, a_2, a_3, a_4, a_5, a_6, a_7)$ are represented with membership function $\mu_{\tilde{A}}(x)$ as:

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ \frac{x-a_2}{a_3-a_2}, & a_2 \le x \le a_3 \\ \frac{x-a_4}{a_4-a_3}, & a_3 \le x \le a_4 \\ 1, & x = a_4 \\ \frac{a_5-x}{a_5-a_4}, & a_4 \le x \le a_5 \\ \frac{a_6-x}{a_6-a_5}, & a_5 \le x \le a_6 \\ \frac{a_7-x}{a_7-a_6}, & a_6 \le x \le a_7 \\ 0 & \text{otherwise.} \end{cases}$$

(iii).Graded Mean Representation integration:

A generalized heptagonal fuzzy number $\tilde{A} = (a_1, a_2, a_3, a_4, a_5, a_6, a_7)$ is defuzzified by graded mean integration representation [17] and is defined by

$$P(\tilde{A}) = \frac{a_1+3a_2+3a_3+4a_4+3a_5+3a_6+a_7}{18}$$

4. Mathematical Formulation

Let I(t) denote on-hand inventory at time (0,T) then the differential equation below determines the inventory of variation with regard to time T is

$$\frac{dI(t)}{dt} + \theta t\, I(t) = -\log(1+t), \quad 0 \le t \le t_1 \qquad (1)$$

$$\frac{dI(t)}{dt} = -\log(1+t), \quad t_1 \le t \le T \qquad (2)$$

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The result of equation (1) is

$$I(t)= [\frac{t^3}{6} - \frac{t^2}{2} - \frac{t^4}{12} - \theta(\frac{t^4}{8} - \frac{t^5}{20} + \frac{t^6}{36})]e^{\frac{-\theta t^2}{2}} + Ce^{\frac{-\theta t^2}{2}}$$

With the limiting condition t=0, I(t)=S implies S=C,therefore

$$I(t)= [\frac{t^3}{6} - \frac{t^2}{2} - \frac{t^4}{12} - \theta(\frac{t^4}{8} - \frac{t^5}{20} + \frac{t^6}{36})]e^{\frac{-\theta t^2}{2}} + Se^{\frac{-\theta t^2}{2}} \quad (3)$$

The result of (2) is given by the limiting condition $t= t_1$, I(t)=0,

$$I(t)= (1+ t_1) \log(1+ t_1) – (1+t)\log(1+t) + t - t_1 \quad (4)$$

From (3) we obtain

$$S= \frac{t_1^2}{2} - \frac{t_1^3}{6} + \frac{t_1^4}{12} + \theta(\frac{t_1^4}{8} - \frac{t_1^5}{20} + \frac{t_1^6}{36}) \quad (5)$$

Hence the unit deteriorated is given by

$$D= S- \int_0^{t_1} \log(1 + t)dt$$

$$= \frac{t_1^2}{2} - \frac{t_1^3}{6} + \frac{t_1^4}{12} + \theta(\frac{t_1^4}{8} - \frac{t_1^5}{20} + \frac{t_1^6}{36}) - (1+ t_1) \log(1+ t_1) +t_1 \quad (6)$$

Total average inventory is given by

$$I_1(t_1) = \frac{1}{T} \int_0^{t_1} I(t)dt$$

$$= \frac{1}{T} [\frac{t_1^3}{3} - \frac{t_1^4}{8} - \frac{t_1^5}{15} - \theta(\frac{t_1^4}{40} - \frac{11t_1^5}{120} + \frac{t_1^6}{36} - \frac{t_1^7}{63})] \quad (7)$$

Average shortage cost is given by

$$I_2(t_1) = \frac{1}{T} \int_{t_1}^{T} I(t)dt$$

$$= \frac{1}{T} [\frac{(1+T)^2}{2} (\log(1+T) - \frac{1}{2})+ (1+ t_1) \log(1+ t_1) (\frac{t_1-1}{2} -T)+ \frac{(1+t_1)^2}{4} - \frac{t_1^2}{2} - \frac{T^2}{2} +T t_1] \quad (8)$$

Therefore the total cost per unit time is given by

$$TC= \frac{1}{T} [\text{ Carrying cost + Deficit cost +Depreciation cost}]$$

$$= \frac{1}{T} [H(\frac{t_1^3}{3} - \frac{t_1^4}{8} - \frac{t_1^5}{15} - \theta(\frac{t_1^4}{40} - \frac{11t_1^5}{120} + \frac{t_1^6}{36} - \frac{t_1^7}{63})) +A(\frac{(1+T)^2}{2} (\log(1+T) - \frac{1}{2})+ (1+ t_1) \log(1+ t_1) (\frac{t_1-1}{2}$$

$$– T) + \frac{(1+t_1)^2}{4} - \frac{t_1^2}{2} - \frac{T^2}{2} +T t_1)+C(\frac{t_1^2}{2} - \frac{t_1^3}{6} + \frac{t_1^4}{12} + \theta(\frac{t_1^4}{8} - \frac{t_1^5}{20} + \frac{t_1^6}{36}) – (1+ t_1) \log(1+ t_1) +t_1)] \quad (9)$$

The conditions required to minimize the total cost are as follows

$$\frac{\partial (TC)}{\partial t_1} = 0 \quad (10)$$

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Subject to the competent situation $\frac{\partial^2(TC)}{\partial t_1^2} > 0$

$$\frac{H}{T}[(t_1^2 - \frac{t_1^3}{2} - \frac{t_1^4}{3}) - \theta(\frac{t_1^3}{10} - \frac{11t_1^4}{24} + \frac{t_1^5}{6} + \frac{t_1^6}{9})] + \frac{A}{T}[\log(1+t_1)(t_1-T)] + \frac{C}{T}[t_1 - \frac{t_1^2}{2} + \frac{t_1^3}{3} + \theta(\frac{t_1^3}{2} - \frac{t_1^4}{4} + \frac{t_1^5}{6}) + \log(1+t_1)] = 0 \quad (11)$$

5.Fuzzy Model:

Let $\widetilde{A} = (\widetilde{a_1}, \widetilde{a_2}, \widetilde{a_3}, \widetilde{a_4}, \widetilde{a_5}, \widetilde{a_6}, \widetilde{a_7})$, $\widetilde{C} = (\widetilde{c_1}, \widetilde{c_2}, \widetilde{c_3}, \widetilde{c_4}, \widetilde{c_5}, \widetilde{c_6}, \widetilde{c_7})$, $\widetilde{H} = (\widetilde{h_1}, \widetilde{h_2}, \widetilde{h_3}, \widetilde{h_4}, \widetilde{h_5}, \widetilde{h_6}, \widetilde{h_7})$ are the heptagonal fuzzy numbers. The total cost per unit time in a fuzzy context is calculated using the above heptagonal fuzzy numbers

$$\widetilde{TC} = \frac{1}{18T}\{[\widetilde{h_1} \otimes (\frac{t_1^3}{3} - \frac{t_1^4}{8} - \frac{t_1^5}{15} - \theta(\frac{t_1^4}{40} - \frac{11t_1^5}{120} + \frac{t_1^6}{36} - \frac{t_1^7}{63})) + \widetilde{a_1} \otimes (\frac{(1+T)^2}{2}(\log(1+T) - \frac{1}{2}) + (1+t_1)\log(1+t_1)(\frac{t_1-1}{2} - T) + \frac{(1+t_1)^2}{4} - \frac{t_1^2}{2} - \frac{T^2}{2} + T\,t_1) + \widetilde{c_1} \otimes (\frac{t_1^2}{2} - \frac{t_1^3}{6} + \frac{t_1^4}{12} + \theta(\frac{t_1^4}{8} - \frac{t_1^5}{20} + \frac{t_1^6}{36}) - (1+t_1)\log(1+t_1) + t_1)] + 3 \otimes [\widetilde{h_2} \otimes (\frac{t_1^3}{3} - \frac{t_1^4}{8} - \frac{t_1^5}{15} - \theta(\frac{t_1^4}{40} - \frac{11t_1^5}{120} + \frac{t_1^6}{36} - \frac{t_1^7}{63})) + \widetilde{a_2} \otimes (\frac{(1+T)^2}{2}(\log(1+T) - \frac{1}{2}) + (1+t_1)\log(1+t_1)(\frac{t_1-1}{2} - T) + \frac{(1+t_1)^2}{4} - \frac{t_1^2}{2} - \frac{T^2}{2} + T\,t_1) + \widetilde{c_2} \otimes (\frac{t_1^2}{2} - \frac{t_1^3}{6} + \frac{t_1^4}{12} + \theta(\frac{t_1^4}{8} - \frac{t_1^5}{20} + \frac{t_1^6}{36}) - (1+t_1)\log(1+t_1) + t_1)] + 3 \otimes [\widetilde{h_3} \otimes (\frac{t_1^3}{3} - \frac{t_1^4}{8} - \frac{t_1^5}{15} - \theta(\frac{t_1^4}{40} - \frac{11t_1^5}{120} + \frac{t_1^6}{36} - \frac{t_1^7}{63})) + \widetilde{a_3} \otimes (\frac{(1+T)^2}{2}(\log(1+T) - \frac{1}{2}) + (1+t_1)\log(1+t_1)(\frac{t_1-1}{2} - T) + \frac{(1+t_1)^2}{4} - \frac{t_1^2}{2} - \frac{T^2}{2} + T\,t_1) + \widetilde{c_3} \otimes (\frac{t_1^2}{2} - \frac{t_1^3}{6} + \frac{t_1^4}{12} + \theta(\frac{t_1^4}{8} - \frac{t_1^5}{20} + \frac{t_1^6}{36}) - (1+t_1)\log(1+t_1) + t_1)] + 4 \otimes [\widetilde{h_4} \otimes (\frac{t_1^3}{3} - \frac{t_1^4}{8} - \frac{t_1^5}{15} - \theta(\frac{t_1^4}{40} - \frac{11t_1^5}{120} + \frac{t_1^6}{36} - \frac{t_1^7}{63})) + \widetilde{a_4} \otimes (\frac{(1+T)^2}{2}(\log(1+T) - \frac{1}{2}) + (1+t_1)\log(1+t_1)(\frac{t_1-1}{2} - T) + \frac{(1+t_1)^2}{4} - \frac{t_1^2}{2} - \frac{T^2}{2} + T\,t_1) + \widetilde{c_4} \otimes (\frac{t_1^2}{2} - \frac{t_1^3}{6} + \frac{t_1^4}{12} + \theta(\frac{t_1^4}{8} - \frac{t_1^5}{20} + \frac{t_1^6}{36}) - (1+t_1)\log(1+t_1) + t_1)] + 3 \otimes [\widetilde{h_5} \otimes (\frac{t_1^3}{3} - \frac{t_1^4}{8} - \frac{t_1^5}{15} - \theta(\frac{t_1^4}{40} - \frac{11t_1^5}{120} + \frac{t_1^6}{36} - \frac{t_1^7}{63})) + \widetilde{a_5} \otimes (\frac{(1+T)^2}{2}(\log(1+T) - \frac{1}{2}) + (1+t_1)\log(1+t_1)(\frac{t_1-1}{2} - T) + \frac{(1+t_1)^2}{4} - \frac{t_1^2}{2} - \frac{T^2}{2} + T\,t_1) + \widetilde{c_5} \otimes (\frac{t_1^2}{2} - \frac{t_1^3}{6} + \frac{t_1^4}{12} + \theta(\frac{t_1^4}{8} - \frac{t_1^5}{20} + \frac{t_1^6}{36}) - (1+t_1)\log(1+t_1) + t_1)] + 3 \otimes [\widetilde{h_6} \otimes (\frac{t_1^3}{3} - \frac{t_1^4}{8} - \frac{t_1^5}{15} - \theta(\frac{t_1^4}{40} - \frac{11t_1^5}{120} + \frac{t_1^6}{36} - \frac{t_1^7}{63})) + \widetilde{a_6} \otimes (\frac{(1+T)^2}{2}(\log(1+T) - \frac{1}{2}) + (1+t_1)\log(1+t_1)(\frac{t_1-1}{2} - T) + \frac{(1+t_1)^2}{4} - \frac{t_1^2}{2} - \frac{T^2}{2} + T\,t_1) + \widetilde{c_6} \otimes (\frac{t_1^2}{2} - \frac{t_1^3}{6} + \frac{t_1^4}{12} + \theta(\frac{t_1^4}{8} - \frac{t_1^5}{20} + \frac{t_1^6}{36}) - (1+t_1)\log(1+t_1) + t_1)] + [\widetilde{h_7} \otimes (\frac{t_1^3}{3} - \frac{t_1^4}{8} - \frac{t_1^5}{15} - \theta(\frac{t_1^4}{40} -$$

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$\frac{11t_1^5}{120} + \frac{t_1^6}{36} - \frac{t_1^7}{63})) + \widetilde{a_7} \otimes (\frac{(1+T)^2}{2}$ (log(1+T) - $\frac{1}{2}$) + (1+ t_1) log(1+ t_1) $(\frac{t_1-1}{2} - T) + \frac{(1+t_1)^2}{4} - \frac{t_1^2}{2} - \frac{T^2}{2}$

$+T\, t_1) + \widetilde{c_7} \otimes (\frac{t_1^2}{2} - \frac{t_1^3}{6} + \frac{t_1^4}{12} + \theta(\frac{t_1^4}{8} - \frac{t_1^5}{20} + \frac{t_1^6}{36}) - (1+t_1)\log(1+t_1) + t_1)]\}\ \}$ (9)

for minimization of the entire cost ,the optimal value of t_1 can be obtained by solving

$\frac{1}{18}\{[\frac{\widetilde{h_1}}{T} \otimes [(t_1^2 - \frac{t_1^3}{2} - \frac{t_1^4}{3}) - \theta(\frac{t_1^3}{10} - \frac{11t_1^4}{24} + \frac{t_1^5}{6} + \frac{t_1^6}{9})] + \frac{\widetilde{a_1}}{T} \otimes [\log(1+t_1)(t_1-T)] + \frac{\widetilde{c_1}}{T} \otimes [t_1 - \frac{t_1^2}{2} + \frac{t_1^3}{3} + \theta(\frac{t_1^3}{2} - \frac{t_1^4}{4} + \frac{t_1^5}{6}) + \log(1+t_1)]] + 3 \otimes [\frac{\widetilde{h_2}}{T} \otimes [(t_1^2 - \frac{t_1^3}{2} - \frac{t_1^4}{3}) - \theta(\frac{t_1^3}{10} - \frac{11t_1^4}{24} + \frac{t_1^5}{6} + \frac{t_1^6}{9})] + \frac{\widetilde{a_2}}{T} \otimes [\log(1+t_1)(t_1-T)] + \frac{\widetilde{c_2}}{T} \otimes [t_1 - \frac{t_1^2}{2} + \frac{t_1^3}{3} + \theta(\frac{t_1^3}{2} - \frac{t_1^4}{4} + \frac{t_1^5}{6}) + \log(1+t_1)]] + 3 \otimes \{[\frac{\widetilde{h_3}}{T} \otimes [(t_1^2 - \frac{t_1^3}{2} - \frac{t_1^4}{3}) - \theta(\frac{t_1^3}{10} - \frac{11t_1^4}{24} + \frac{t_1^5}{6} + \frac{t_1^6}{9})] + \frac{\widetilde{a_3}}{T} \otimes [\log(1+t_1)(t_1-T)] + \frac{\widetilde{c_3}}{T} \otimes [t_1 - \frac{t_1^2}{2} + \frac{t_1^3}{3} + \theta(\frac{t_1^3}{2} - \frac{t_1^4}{4} + \frac{t_1^5}{6}) + \log(1+t_1)]] + 4 \otimes \{[\frac{\widetilde{h_4}}{T} \otimes [(t_1^2 - \frac{t_1^3}{2} - \frac{t_1^4}{3}) - \theta(\frac{t_1^3}{10} - \frac{11t_1^4}{24} + \frac{t_1^5}{6} + \frac{t_1^6}{9})] + \frac{\widetilde{a_4}}{T} \otimes [\log(1+t_1)(t_1-T)] + \frac{\widetilde{c_4}}{T} \otimes [t_1 - \frac{t_1^2}{2} + \frac{t_1^3}{3} + \theta(\frac{t_1^3}{2} - \frac{t_1^4}{4} + \frac{t_1^5}{6}) + \log(1+t_1)]] + 3 \otimes [\frac{\widetilde{h_5}}{T} \otimes [(t_1^2 - \frac{t_1^3}{2} - \frac{t_1^4}{3}) - \theta(\frac{t_1^3}{10} - \frac{11t_1^4}{24} + \frac{t_1^5}{6} + \frac{t_1^6}{9})] + \frac{\widetilde{a_5}}{T} \otimes [\log(1+t_1)(t_1-T)] + \frac{\widetilde{c_5}}{T} \otimes [t_1 - \frac{t_1^2}{2} + \frac{t_1^3}{3} + \theta(\frac{t_1^3}{2} - \frac{t_1^4}{4} + \frac{t_1^5}{6}) + \log(1+t_1)]] + 3 \otimes [\frac{\widetilde{h_6}}{T} \otimes [(t_1^2 - \frac{t_1^3}{2} - \frac{t_1^4}{3}) - \theta(\frac{t_1^3}{10} - \frac{11t_1^4}{24} + \frac{t_1^5}{6} + \frac{t_1^6}{9})] + \frac{\widetilde{a_6}}{T} \otimes [\log(1+t_1)(t_1-T)] + \frac{\widetilde{c_6}}{T} \otimes [t_1 - \frac{t_1^2}{2} + \frac{t_1^3}{3} + \theta(\frac{t_1^3}{2} - \frac{t_1^4}{4} + \frac{t_1^5}{6}) + \log(1+t_1)]] + [\frac{\widetilde{h_7}}{T} \otimes [(t_1^2 - \frac{t_1^3}{2} - \frac{t_1^4}{3}) - \theta(\frac{t_1^3}{10} - \frac{11t_1^4}{24} + \frac{t_1^5}{6} + \frac{t_1^6}{9})] + \frac{\widetilde{a_7}}{T} \otimes [\log(1+t_1)(t_1-T)] + \frac{\widetilde{c_7}}{T} \otimes [t_1 - \frac{t_1^2}{2} + \frac{t_1^3}{3} + \theta(\frac{t_1^3}{2} - \frac{t_1^4}{4} + \frac{t_1^5}{6}) + \log(1+t_1)]]\} = 0$

6.Numerical Example:

Crisp Model: Let H= 40, A=200 ,C=400, γ = 0.9, T= 12 we get t_1 = 1.6516,TC = 1557.4.

Fuzzy model: Let $\widetilde{H}$ = (20,40,60,80,100,120,140) $\widetilde{A}$ = (40,80,120,160,200,240,280), $\widetilde{C}$ = (200,400,600,800,1000,1200,1400), γ = 0.9, T= 12, we get t_1 = 0.6123 ,TC =1347.

7.Conclusion:

A fuzzy resource model for time-varying degradation for logarthimic sale rate is discussed in this work. The framework is constructed in a precise and fuzzy environment. The optimal cost is defuzzified using heptagonal fuzzy integers and graded mean integration representation approach. The evaluation of the suggested model can be extended as nonlinear demand ,weibull deterioration rate, price discounts etc.

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