An EPQ Model For Products With Two Parameter Weibull Distribution Deterioration With Fuzzy And Decagonal Fuzzy Demand

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ABSTRACT:
The main objective of this paper is to compare EPQ inventory model for fuzzy and decagonal fuzzy demand under two parameter Weibull deterioration. It is assumed that an EPQ model in which inventory is depleted not only by demand but also by deterioration. Here we have taken a model for producer by assuming linear time dependent demand and is compared between crisp, fuzzy and decagonal fuzzy environment. The result is validated with the help of numerical example under fuzzy and decagonal fuzzy demand. The main purpose of this work is to find optimal cost under these constraints.

KEYWORDS: Inventory, Weibull deterioration, Fuzzy and Decagonal Fuzzy Demand.

INTRODUCTION:

In the production domain, there is a lot of complex scenario for productions. In large companies, the factors influencing any decision is always under complex situation needs to be made favoring the company. The factors like, raw material, customer demand, capacity of equipment etc. are the main reason for complex situation. It is possible to make suitable decision to get rid of these uncertainties with the help of mathematical model and optimize the objectives and results. For these kind of various critical situations, the fuzzy theory helps us to get optimal results. Fuzzy set theory has been applied to several fields like optimization and other areas. In the field of research, L. A. Zadeh [1] developed the fuzzy set theory which is used in several research in different fields like mathematics, statistics. Sen and Chakrabarti [2] introduced an EOQ model for healthcare industries with exponential demand pattern and time dependent delayed deterioration under fuzzy and neutrosophic fuzzy environment. Geetha and Reshma [3] proposed a model on An Analysis on Fuzzy Inventory Model without Deficits Using Decagonal Fuzzy Numbers. Henrietta, Mary, et al [4] suggested a model an investigation of inventory optimization by using geometric programming technique with decagonal fuzzy number representation. Chakrabarti, Giri and Chaudhury [5] promoted an EOQ model for items with Weibull distribution deterioration, shortages and trended demand: an extension of Philip's model. Singh, Gupta and Bansal [6] developed an EOQ model with volume agility, variable demand rate, Weibull deterioration rate and inflation. Sen and Chakrabarti [7] also developed an industrial production inventory model with deterioration under neutrosophic fuzzy optimization. Chaudhury and Tripathi [8] proposed an Inflationary induced EOQ model for Weibull distribution deterioration and trade credits. Tripathy and Mishra [9] suggested an EOQ model with time dependent Weibull deterioration and ramp type demand. Singh and Pattnayak [10] introduced an EOQ inventory model for deteriorating items with varying trapezoidal type demand rate and Weibull distribution deterioration. Shee and Chakrabarti [11] put forward Fuzzy inventory Model for deteriorating items in a supply chain system with time dependent demand rate. Soni and Shah [12] modeled Optimal ordering policy for stock dependent demand under progressive payment.

Zita [13] proposed a Fuzzy inventory model with allowable shortages and backorder. Kundu and Chakrabarti [14] also developed an EOQ model for deteriorating items with fuzzy demand and fuzzy partial backlogging. Saha and Chakrabarti [15] also schemed A Fuzzy inventory model for deteriorating items with linear price dependent demand in a supply chain. Wang, Tang and Zhao [16] developed model on fuzzy economic order quantity inventory model without backordering. Mullai et al [17] suggested A single valued Neutrsophic inventory Model with Neutrosophic Random Variable. Shah, Pandey, and Soni [18] developed an Optimal ordering policies for Weibull distribution deterioration with associated salvage value under scenario of progressive credit periods. Sarkar and Chakrabarti [19] modified an EPQ Model with Two-Component Demand under Fuzzy Environment and Weibull Distribution Deterioration with Shortages. Saha and Chakrabarti [20] initiated a Fuzzy EOQ model for time dependent deteriorating items and time dependent demand and shortages. Chakraborty, Shee and Chakrabarti [21] evolve with an idea of A Fuzzy Production Inventory Model for Deteriorating Items with Shortages.

Here we discuss the basics of Fuzzy, mainly triangular fuzzy and decagonal fuzzy with defuzzification under signed distance method.

BASIC PRELIMINERIES:
Fuzzy Set
A Fuzzy Set A is defined by a membership function $\mu_A(x)$ which maps each and every element of X to [0, 1]. i.e. $\mu_A(x) \rightarrow [0,1]$, where X is the underlying set. In simple, a fuzzy set is a set whose boundary is not clear. On the other hand, a fuzzy set is a set whose element are characterized by a membership function as above.
A triangular fuzzy number is a fuzzy set. It is denoted by $A = \langle a, b, c \rangle$ and is defined by the following membership function:

$$\mu_A(x) = \begin{cases} 0, & a \le x, \\ \dfrac{x-a}{b-a}, & a \le x \le b, \\ \dfrac{c-x}{c-b}, & b \le x \le c, \\ 0, & x \ge c, \end{cases}$$

Defuzzification of Triangular fuzzy number
Defuzzification under Signed distance for $A = \langle a, b, c \rangle$, a triangular fuzzy number, the signed distance of A measured from O_1 is given by

$$d(A, O_1) = \tfrac{1}{4}(a + 2b + c)$$

Decagonal fuzzy number:
A fuzzy number $\widetilde{A} = \langle a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9, a_{10}, \rangle$ is represent with membership function $\mu_{\widetilde{A}}(x)$ as:

$$\mu_{\widetilde{A}}(x) = \begin{cases} \dfrac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2, \\ \dfrac{x-a_2}{a_3-a_2}, & a_2 \le x \le a_3 \\ \dfrac{x-a_3}{a_4-a_3}, & a_3 \le x \le a_4 \\ \dfrac{x-a_4}{a_4-a_3}, & a_4 \le x \le a_5 \\ 1, & a_5 \le x \le a_6 \\ \dfrac{a_7-x}{a_7-a_6}, & a_6 \le x \le a_7 \\ \dfrac{a_8-x}{a_8-a_7}, & a_7 \le x \le a_8 \\ \dfrac{a_9-x}{a_9-a_8}, & a_8 \le x \le a_9 \\ \dfrac{a_{10}-x}{a_{10}-a_9}, & a_9 \le x \le a_{10} \\ 0, & \text{otherwise.} \end{cases}$$

Defuzzification of Decagonal fuzzy number
Defuzzification under Signed distance for $\widetilde{A} = \langle a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9, a_{10}, \rangle$, a decagonal fuzzy number, is given by:

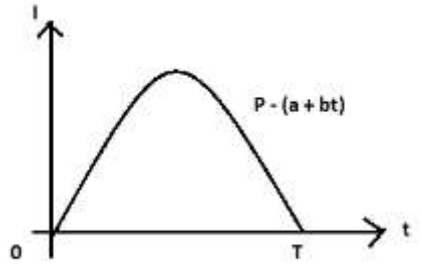
$$d(\widetilde{A}, \tilde{0}) = \frac{1}{16}(a_1 + 2a_2 + 2a_3 + 2a_4 + a_5 + a_6 + 2a_7 + 2a_8 + 2a_9 + a_{10})$$

ASSUMPTIONS AND NOTATIONS:
Demand is dependent on time and is linear i.e. $D(t) = a + bt$, where a and b are constants.
a and b are first considered as crisp then fuzzy and then decagonal fuzzy.

i. Rate of deterioration is following two parameter Weibull Distribution $\alpha\beta t^{\beta-1}$
ii. Replenishment is instantaneous and lead time is zero.
iii. The cycle time is uncertain.
iv. Shortages are not allowed.
v. There is no initial stock level at the beginning of every inventory.

vi. The total deterioration items is D.
vii. T is the length of a cycle.
viii. I(t) is the inventory level at any time t.
ix. h is the holding cost per unit time.
x. A is the setup cost per cycle.
xi. C is the deterioration cost per unit.
xii. TAC is the total inventory cost.
xiii. $TAC^{\#}$ is the total fuzzy inventory cost.
xiv. $TAC^{\#\#}$ is the total octagonal fuzzy inventory cost.

MATHEMATICAL MODEL:
The inventory level is 0 at time t = 0. Then the productions starts at rate P and inventory level decreases due to demand and deterioration and reaches to zero at t = T.



The change in the inventory level can be described by the following differential equation:

Case 1 (Crisp Model)
$I'(t) + \alpha\beta t^{\beta-1} I = P - [a + bt]$ $\quad 0 \le t \le T$
With boundary condition I(0) = 0 and I(T) = 0
The solution of the above differential equation is given by

$$I(t) = (P - a)(t + \frac{\alpha t^{\beta+1}}{\beta+1}) - b(\frac{t^2}{2} + \frac{\alpha t^{\beta+2}}{\beta+2}) - \alpha(P - a)t^{\beta+1} + \frac{\alpha\beta t^{\beta+2}}{2} \quad \text{[neglecting O(α)]}$$

The inventory in a cycle is given by:

$$I_T = \int_0^T I(T)\,dt$$
$$= (P - a)\frac{T^2}{2} + (P - a)\frac{\alpha T^{\beta+2}}{(\beta+1)(\beta+2)} - b\,[\frac{T^3}{6} + \frac{\alpha T^{\beta+3}}{(\beta+3)(\beta+2)}] - \alpha(P - a)\,\frac{\alpha T^{\beta+2}}{(\beta+2)} + \frac{\alpha\beta T^{\beta+3}}{2(\beta+3)}$$

Total deterioration is a cycle is given by

$$D = \int_0^T \alpha\beta t^{\beta-1}\, I(t)\,dt$$
$$= \alpha\beta(P - a)\frac{t^{\beta+1}}{\beta+1} - b\frac{\alpha\beta t^{\beta+2}}{\beta+2} \quad \text{[neglecting O(α)]}$$

Average cost of the system is given by

$$TAC = \frac{1}{T}\,[A + C.D + hI_T]$$
$$= \frac{1}{T}\,[A + C(\,\alpha\beta(P - a)\frac{t^{\beta+1}}{\beta+1} - b\frac{\alpha\beta t^{\beta+2}}{\beta+2}) + h\{(P - a)\frac{T^2}{2} + (P - a)\frac{\alpha T^{\beta+2}}{(\beta+1)(\beta+2)} - b\,[\frac{T^3}{6} + \frac{\alpha T^{\beta+3}}{(\beta+3)(\beta+2)}]$$
$$- \alpha(P - a)\,\frac{\alpha T^{\beta+2}}{(\beta+2)} + \frac{\alpha\beta T^{\beta+3}}{2(\beta+3)}\}]$$

Case 2 (Fuzzy Model, when a and b of demand is Fuzzy)
$I'(t) + \alpha\beta t^{\beta-1} I = P - [\tilde{a} + \tilde{b}t]$ $\quad 0 \le t \le T$
With boundary condition I(0) = 0 and I(T) = 0
The solution of the above differential equation is given by

$$I(t) = (P - \tilde{a})(t + \frac{\alpha t^{\beta+1}}{\beta+1}) - \tilde{b}\,(\frac{t^2}{2} + \frac{\alpha t^{\beta+2}}{\beta+2}) - \alpha(P - \tilde{a})t^{\beta+1} + \frac{\alpha\beta t^{\beta+2}}{2} \quad \text{[neglecting O(α)]}$$

The inventory in a cycle is given by:

$$I_T = \int_0^T I(T)\,dt$$
$$= (P - \tilde{a})\frac{T^2}{2} + (P - \tilde{a})\frac{\alpha T^{\beta+2}}{(\beta+1)(\beta+2)} - \tilde{b}\,[\frac{T^3}{6} + \frac{\alpha T^{\beta+3}}{(\beta+3)(\beta+2)}] - \alpha(P - \tilde{a})\,\frac{\alpha T^{\beta+2}}{(\beta+2)} + \frac{\alpha\beta T^{\beta+3}}{2(\beta+3)}$$

Total deterioration is a cycle is given by

$$D = \int_0^T \alpha\beta t^{\beta-1} I(t)\ dt$$
$$= \alpha\beta(P - \tilde{a})\frac{t^{\beta+1}}{\beta+1} - \tilde{b}\,\frac{\alpha\beta t^{\beta+2}}{\beta+2} \qquad \text{[neglecting } O(\alpha)]$$

Average cost of the system is given by

$$TAC^{\#} = \frac{1}{T}\,[A + C.D + hI_T\,]$$
$$= \frac{1}{T}\,[A + C(\ \alpha\beta(P - \tilde{a})\frac{t^{\beta+1}}{\beta+1} - b\frac{\alpha\beta t^{\beta+2}}{\beta+2}) + h\{(P - \tilde{a})\frac{T^2}{2} + (P - \tilde{a})\frac{\alpha T^{\beta+2}}{(\beta+1)(\beta+2)} - \tilde{b}\,[\frac{T^3}{6} + \frac{\alpha T^{\beta+3}}{(\beta+3)(\beta+2)}]$$
$$- \alpha(P - \tilde{a})\,\frac{\alpha T^{\beta+2}}{(\beta+2)} + \frac{\alpha\beta T^{\beta+3}}{2(\beta+3)}\}]$$
$$= \frac{1}{T}\,[A + C(\ \alpha\beta(P - \frac{(a_1+2a_2+a_3)}{4})\frac{t^{\beta+1}}{\beta+1} - \frac{(b_1+2b_2+b_3)}{4}\,\frac{\alpha\beta t^{\beta+2}}{\beta+2}) + h\{(P - \frac{(a_1+2a_2+a_3)}{4})\frac{T^2}{2}$$
$$+ (P - \frac{(a_1+2a_2+a_3)}{4})\frac{\alpha T^{\beta+2}}{(\beta+1)(\beta+2)} - \frac{(b_1+2b_2+b_3)}{4}\,[\frac{T^3}{6} + \frac{\alpha T^{\beta+3}}{(\beta+3)(\beta+2)}]\ - \alpha(P - \frac{(a_1+2a_2+a_3)}{4})\,\frac{\alpha T^{\beta+2}}{(\beta+2)} + \frac{\alpha\beta T^{\beta+3}}{2(\beta+3)}\}]$$

Case 3 (Decagonal Fuzzy Model, when a and b of demand is Decagonal Fuzzy)

$I'(t) + \alpha\beta t^{\beta-1}I = P - [\tilde{a} + \tilde{b}t] \qquad 0 \le t \le T$

With boundary condition I(0) = 0 and I(T) = 0

The solution of the above differential equation is given by

$$I(t) = (P - \tilde{a})(t + \frac{\alpha t^{\beta+1}}{\beta+1}) - \tilde{b}\,(\frac{t^2}{2} + \frac{\alpha t^{\beta+2}}{\beta+2}) - \alpha(P - \tilde{a})t^{\beta+1} + \frac{\alpha\beta t^{\beta+2}}{2} \qquad \text{[neglecting } O(\alpha)]$$

The inventory in a cycle is given by:

$$I_T = \int_0^T I(T)\ dt$$
$$= (P - \tilde{a})\frac{T^2}{2} + (P - \tilde{a})\frac{\alpha T^{\beta+2}}{(\beta+1)(\beta+2)} - b\,[\frac{T^3}{6} + \frac{\alpha T^{\beta+3}}{(\beta+3)(\beta+2)}] - \alpha(P - \tilde{a})\,\frac{\alpha T^{\beta+2}}{(\beta+2)} + \frac{\alpha\beta T^{\beta+3}}{2(\beta+3)}$$

Total deterioration is a cycle is given by

$$D = \int_0^T \alpha\beta t^{\beta-1} I(t)\ dt$$
$$= \alpha\beta(P - \tilde{a})\frac{t^{\beta+1}}{\beta+1} - b\frac{\alpha\beta t^{\beta+2}}{\beta+2} \qquad \text{[neglecting } O(\alpha)]$$

Average cost of the system is given by

$$TAC^{\#\#} = \frac{1}{T}\,[A + C.D + hI_T\,]$$
$$= \frac{1}{T}\,[A + C(\ \alpha\beta(P - \tilde{a})\frac{t^{\beta+1}}{\beta+1} - \tilde{b}\,\frac{\alpha\beta t^{\beta+2}}{\beta+2}) + h\{(P - \tilde{a})\frac{T^2}{2} + (P - \tilde{a})\frac{\alpha T^{\beta+2}}{(\beta+1)(\beta+2)} - \tilde{b}\,[\frac{T^3}{6} + \frac{\alpha T^{\beta+3}}{(\beta+3)(\beta+2)}]$$
$$- \alpha(P - \tilde{a})\,\frac{\alpha T^{\beta+2}}{(\beta+2)} + \frac{\alpha\beta T^{\beta+3}}{2(\beta+3)}\}]$$
$$= \frac{1}{T}\,[A + C(\ \alpha\beta(P - \frac{1}{16}\,(a_1 + 2a_2 + 2a_3 + 2a_4 + a_5 + a_6 + 2a_7 + 2a_8 + 2a_9 + a_{10}))\frac{t^{\beta+1}}{\beta+1} -$$
$$\frac{1}{16}\,(b_1 + 2b_2 + 2b_3 + 2b_4 + b_5 + b_6 + 2b_7 + 2b_8 + 2b_9 + b_{10})\,\frac{\alpha\beta t^{\beta+2}}{\beta+2}) + h$$
$$\{(P - \frac{1}{16}\,(a_1 + 2a_2 + 2a_3 + 2a_4 + a_5 + a_6 + 2a_7 + 2a_8 + 2a_9 + a_{10}))\frac{T^2}{2} +$$
$$(P - \frac{1}{16}\,(a_1 + 2a_2 + 2a_3 + 2a_4 + a_5 + a_6 + 2a_7 + 2a_8 + 2a_9 + a_{10}))\frac{\alpha T^{\beta+2}}{(\beta+1)(\beta+2)} -$$
$$\frac{1}{16}\,(b_1 + 2b_2 + 2b_3 + 2b_4 + b_5 + b_6 + 2b_7 + 2b_8 + 2b_9 + b_{10})\,[\frac{T^3}{6} + \frac{\alpha T^{\beta+3}}{(\beta+3)(\beta+2)}] -$$
$$\alpha(P - \frac{1}{16}\,(a_1 + 2a_2 + 2a_3 + 2a_4 + a_5 + a_6 + 2a_7 + 2a_8 + 2a_9 + a_{10}))\,\frac{\alpha T^{\beta+2}}{(\beta+2)} + \frac{\alpha\beta T^{\beta+3}}{2(\beta+3)}\}]$$

PROBLEM AND SOLUTION METHOD:

The problem is to minimize TAC, $TAC^{\#}$, $TAC^{\#\#}$

Here the Lingo Software is used for optimization.

ILLUSTRATIVE EXAMPLES:

For Crisp Model: A = 50, C = 5, α = 0.15, β = 3, h = 10, P = 220, a = 2, b = 7

For Fuzzy Model: A = 50, C = 5, α = 0.15, β = 3, h = 10, P = 220, a = <1.5, 2, 2.4>, b = <6, 7, 8>

For Decagonal Fuzzy Model: A = 50, C = 5, α = 0.15, β = 3, h = 10, P = 220,
a = <1.4, 1.6, 1.7, 1.8, 1.9, 2, 2.3, 2.6, 2.8, 3>,
b = <4, 4.5, 5, 5.6, 6, 7, 7.6, 8, 8.6, 9>

COMPARISON OF MODEL:

TAC = 5412.06 at T = 7.369
TAC$^{\#}$ = 5406.15 at T = 7.362
TAC$^{\#\#}$ = 5399.23 at T = 7.359

SENSITIVITY ANALYSIS:

Parameters	% Change	TAC	TAC$^{\#}$	TAC$^{\#\#}$
A	- 50 %	5374.26	5378.65	5354.25
	- 25 %	5387.69	5381.49	5371.71
	+ 25 %	5431.87	5419.33	5429.23
	+ 50 %	5444.78	5427.87	5446.57
P	- 50 %	5276.29	5380.89	5355.99
	- 25 %	5390.11	5383.22	5374.02
	+ 25 %	5334.12	5422.47	5431.26
	+ 50 %	5447.01	5429.49	5448.19
α	- 50 %	5373.98	5378.26	5353.91
	- 25 %	5387.47	5380.94	5371.10
	+ 25 %	5431.15	5418.78	5428.75
	+ 50 %	5443.99	5426.81	5445.96
β	- 50 %	5374.01	5377.98	5353.74
	- 25 %	5387.12	5380.83	5371.16
	+ 25 %	5430.99	5418.68	5428.71
	+ 50 %	5444.17	5427.29	5445.97
C	- 50 %	5409.37	5402.22	5389.34
	- 25 %	5410.99	5404.27	5393.87
	+ 25 %	5413.23	5407.34	5406.29
	+ 50 %	5415.03	5410.16	5411.37
h	- 50 %	5407.25	5400.05	5387.35
	- 25 %	5409.71.	5401.49	5331.62
	+ 25 %	5412.07	5406.01	5404.93
	+ 50 %	5413.98	5408.36	5409.50

It is clear that the change in inventory cost due to cost parameters setup cost (A) and deterioration parameters(α, β) and Production rate (P) are highly sensitive and inventory cost due to holding cost (h) and deterioration cost (C) are less sensitive with respect to all the three models.

Conclusion:

We have progressed with an inventory model for time dependent Weibull deteriorating items with Production and linear time dependent demand under crisp, fuzzy and decagonal fuzzy environment. This model doesn't count for any shortages. Here the comparison of the model has been illustrated with its crisp, fuzzy and decagonal demands and hence its cost. For the fuzzy and decagonal fuzzy model, we have used signed distance method for defuzzification techniques and hence we have obtain the minimum cost for each case. We also observe that the result is quite impressive with decagonal fuzzy parameters and is much cost effective when compared to its crisp and fuzzy model. In the present situation, the fuzziness occurs in the different parameters which affects to the whole inventory management.

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