International Journal of Aquatic Science
ISSN: 2008-8019
Vol 12, Issue 02, 2021

Production Inventory Models For Deterioration Items Using Penalty, Transportation And Shortage Cost: A Fuzzy Approach

Jayanthi J [1], Reshmaa Raaj M.R[2], Sri Ram Siddarth M[3], Surendhar M[4], Shyamala Devi V[5], Ruthra R [6]

[1]*Department of Mathematics, Periyar Maniammai Institute of Science & Technology, Thanjavur – 3, India.*
[2,3,4,5] *U.G students, Department of Mathematics, Periyar Maniammai Institute of Science & Technology, Thanjavur – 3, India.*

E-mail: [1]jayanthij@pmu.edu

Abstract: In this paper, we formulate a production inventory model for deteriorating items with shortages, transportation cost and lead time using penalty cost in a crisp and fuzzy sense. We have to resolve the optimum time, the optimal order quantity and the optimal total cost using this proposed inventory model. To achieve this type of technique, we have been establishing the trapezoidal fuzzy numbers. The working out of economic order quantity (EOQ) is conceded out during defuzzification process. Graded mean integration method is used for defuzzification process. To exemplify the results of this proposed model, we give an example and sensitivity analysis.

Keywords:
Production Model, Defuzzification, Deteriorating Items, Graded Mean Integration Method, Lead Time, Transportation Cost, Penalty Cost, Shortage Cost, Trapezoidal Fuzzy Numbers.

1. INTRODUCTION

Inventory Management is a significant feature of any flourishing business. It is the course of management and scheming the flow of inventory units a business uses in the production or manufacture of goods for sale or distribution. Inventories are usually made up of a combination of goods, raw materials, semi finished and finished products, and effective management of these items is necessary to ensure optimal stock levels and to maximize the earning potential of the company. It also allows a business to prevent or mitigate any inventory-associated losses.

The right stock, at the right levels, in the right place, at the right time, and at the right cost. Inventory management is the branch of business management that
covers the planning and control of the inventory. Inventory management is the supervision of non-capitalized possessions and stock items. Inventory management is a multiplex process, particularly for larger organizations, but the basics are essentially the same in spite of the organization's size or type.

In 2012, Dutta and Pavan Kumar [2] contrived that fuzzy inventory model without shortages using trapezoidal fuzzy number with sensitivity analysis. Zadeh L.A [14] has first introduced the fuzzy sets. In 1983, Zimmerman [15] was first introduced the fuzzy sets in operational research. In 2020, Jayanthi and Yasotha Nandhini established that the fuzzy production inventory model for deterioration items with shortages and lead time using penalty cost. Yao and Lee [13] developed that the fuzzy inventory with or without backorder for fuzzy order quantity with trapezoidal fuzzy number in 1999. In 2020, Jayanthi and Yasotha Nandhini [5] illustrated a fuzzy production inventory model with allowed lead time and shortages using Yager ranking methods. Nalini Prava Behera and Pradip Kumar Tripathy [9] had formulated fuzzy EOQ model for time deteriorating items using penalty cost. In 2018, Maragatham, Ananthi and Jayanthi [7] recognized that the fuzzy inventory model for deteriorating items with shortages using penalty cost. In 2020, Jayanthi and Yasotha Nandhini [6] have coined that production inventory model with allowed shortages: A fuzzy approach. Aaditya Pevakar and Nagare [1] has recognized the inventory model for timely deteriorating products considering penalty cost and shortage cost. In 1993, Fujiwara and Perera [3] has initiated EOQ model for continuously deteriorating products using linear and exponential penalty cost. In 1987, Park [10] has visualized fuzzy sets theoretic interpretation of economic order quantity. In 2015, Mishra, Gupta, Yadav and Rawat [8] have predicted that optimization of fuzzified economic order quantity model allowing shortage and deterioration with full backlogging. In 2009, Srivastava and Gupta [12] has forecasted EOQ model for time-deteriorating items using penalty cost.

Here we develop a fuzzy production inventory model logically using penalty cost and transportation cost with shortages. We use graded mean integration method for defuzzification process. The annual total cost is derived and calculated as a function of seven variables (ie) holding cost, set up cost, transportation cost, shortage cost, penalty cost, screening cost and reworking cost.

2. METHODOLOGY

2.1 Fuzzy Numbers

Any fuzzy subset of the real line R, whose membership function μ_A satisfied the following conditions, is a generalized fuzzy number $\tilde{A}$.

(i) μ_A is a continuous mapping from R to the closed interval [0, 1].

(ii) $\mu_A = 0, -\infty < x \le a_1$,

(iii) $\mu_A =$ L(x) is strictly increasing on $[a_1, a_2]$

(iv) $\mu_A = w_A,\ a_2 \le x \le a_3$

(v) $\mu_A =$ R(x) is strictly decreasing on $[a_3, a_4]$

(vi) $\mu_A = 0,\ a_4 \le x < \infty$

where $0 < w_A \le 1$ and a_1, a_2, a_3 and a_4 are real numbers. Also this type of generalized fuzzy number be denoted as $\tilde{A} = (a_1, a_2, a_3, a_4 : w_A)_{LR}$; When $w_A = 1$, it can be simplified as $\tilde{A} = (a_1, a_2, a_3, a_4)_{LR}$.

2.2 Trapezoidal Fuzzy Number:

A trapezoidal fuzzy number $\tilde{A}$ = (a, b, c, d) is represented with membership function $\mu_{\tilde{A}}$ as follows:

$$\mu_A(x) = \begin{cases} 0, & x > d \\ \frac{x-a}{b-a}, & a \le x \le b \\ 1, & b \le x \le c \\ \frac{d-x}{d-c}, & c \le x \le \mathrm{d} \end{cases}$$

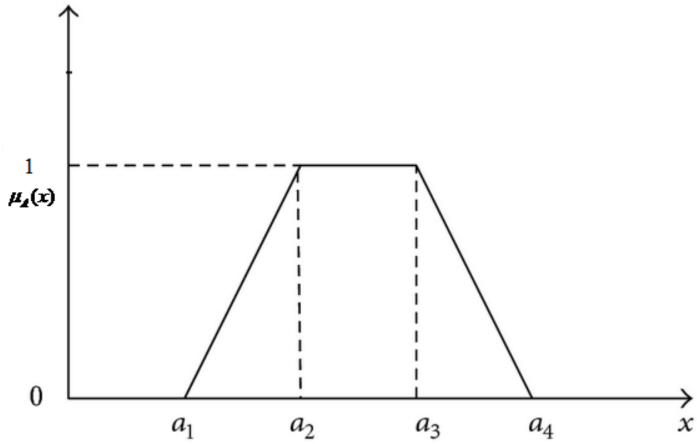

Figure 1 Trapezoidal Fuzzy Number

2.3 Graded Mean Integration Method

If $\tilde{A} = (a_1, a_2, a_3, a_4)$ is a trapezoidal fuzzy number then the graded mean integration representation of $\tilde{A}$ is,

$$p(\tilde{A}) = \frac{a_1 + 2a_2 + 2a_3 + a_4}{6}$$

2.4 Notations and Assumptions

The mathematical model of this paper is developed on the basis of the following notations and assumptions.

2.4.1 Notations

p : production cost
c : holding cost per unit quantity per unit time
s : set up or ordering cost per order
r : shortage cost or stock out cost per unit quantity per unit time
T : transportation cost
q : order quantity per cycle
L : lead time
$k\sigma\sqrt{L}$: safety stock
t : scheduling time period
z : order level
R : total demand over the planning time period [0, t]
μ : time period at which deterioration of product start.
α : screening cost per unit
β : reworking cost per unit
θ : percentage of defective items
TC : total annual cost for the period [0, t]

t^* : optimum time
q^* : optimal order quantity
TC^* : minimum total cost
$\tilde{p}$: fuzzy production cost
$\tilde{c}$: fuzzy holding cost per unit quantity per unit time
$\tilde{\alpha}$: fuzzy set up or ordering cost per order
$\tilde{\beta}$: fuzzy shortage cost per unit quantity per unit time
$\widetilde{TC}$: fuzzy total cost for the period [0, t]
$\tilde{t}^*$: fuzzy optimum time
$\tilde{q}^*$: fuzzy optimal order quantity
$T\tilde{C}^*$: fuzzy minimum total cost

2.4.2 Assumptions

- Demand rate is uniform and finite.
- Lead time crashing cost is related to the lead time by a function of the form $R(L) = a\,L^{-b}$, a > 0, 0 < b ≤ 0.5, where a and b are real constants.
- A single product is considered over a prescribed period of time.
- Shortages and lead time are allowed.
- Inventory is continuously reviewed.
- The replenishment occurs instantaneously at an infinite rate.
- Screening cost and reworking cost is constant.
- Production cost, holding cost, setup cost, transportation cost and shortage cost are taken as trapezoidal fuzzy numbers.
- q is the lot-size per cycle whereas z is the initial inventory level after fulfilling the back-logged quantity of previous cycle and q – z be the maximum shortage level.

3. MODEL FORMULATION

3.1 Proposed Inventory Model in Crisp Sense:

From the above notations and assumptions, we obtain the total annual cost for the inventory model for deterioration items using penalty cost with shortages in crisp environment.

Here penalty cost is taken as an exponential function. An exponential penalty cost function $P(t)=\alpha\left(e^{\beta(t-\mu)}-1\right), t \geq \mu$ which gives the cost of keeping one unit of product in stock until age t, where μ be the time period at which deterioration of product starts and α and β are constants.

The cost due to the deterioration of the product delivered during the period t is given by $\alpha\left(e^{\beta(t-\mu)}-1\right)R\,dt$.

The penalty cost due to the deterioration of the product delivered during the time interval (μ, t) is given by $\frac{\alpha R}{\beta t}\left[\left(e^{\beta(t-\mu)}-1\right)-\beta(t-\mu)\right]$.

The total cost for the period (0, t) is given by,

TC (t) = production cost + carrying cost + set up cost + transportation cost + shortage cost + lead time + penalty cost + screening cost + reworking cost

$$TC(t) = pRt + \left[\frac{cz^2}{2Rt} + ck\,\sigma\sqrt{L}\right] + \frac{s}{t} + TRt + \frac{r\,(Rt-z)^2}{2Rt} + \frac{\alpha R}{\beta t}\left[\left(e^{\beta(t-\mu)}-1\right) - \beta\left(t-\mu\right)\right] + \frac{R(L)}{t} + SRt + \gamma\theta Rt$$
(1)

By using second order approximation of the exponential term $e^{\beta(t-\mu)}$ in TC (t), we get

$$TC(t) = pRt + \left[\frac{crRt}{2(c+r)} + ck\,\sigma\sqrt{L}\right] + \frac{s}{t} + TRt\ \frac{\alpha\beta Rt}{2} - \alpha R\mu\beta + \frac{\alpha\beta\mu^2 R}{2t} + \frac{a\ L^{-b}}{t} + SRt + \gamma\theta Rt$$
(2)

and total cost in terms of 'q' is,

$$TC(q) = pq + \left[\frac{crq}{2(c+r)} + ck\,\sigma\sqrt{L}\right] + \frac{sR}{q} + Tq + \frac{\alpha\beta q}{2} - \alpha R\mu\beta + \frac{\alpha\beta\mu^2 R^2}{2q} + \frac{R}{q}a\,L^{-b} + Sq + \gamma\theta q$$
(3)

where $z = \frac{rRt}{c+r}$ and $q = Rt$

Partially differentiating equation (2) with respect to t, we get

$$\frac{\partial TC}{\partial t} = pR + \left[\frac{crR}{2(c+r)}\right] - \frac{s}{t^2} + TR + \frac{\alpha\beta R}{2} - \frac{\alpha\beta\mu^2 R}{2t^2} - \frac{a\ L^{-b}}{t^2} + SR + \gamma\theta R \tag{4}$$

The optimum $q*$ and $TC*$ can be obtained by equating the first partial derivative w.r.t to 't' of TC to zero.

(i.e) $\frac{\partial TC}{\partial t} = 0$ gives

Optimum time period:

$$t* = \sqrt{\frac{(2s+\alpha\beta\mu^2 R + 2aL^{-b})\ (c+r)}{2pR(c+r) + crR + 2TR(c+r) + \alpha\beta R(c+r) + 2SR(c+r) + 2\gamma\theta R(c+r)}} \tag{5}$$

Optimal order quantity:

$$q^* = Rt* = R\sqrt{\frac{(2s+\alpha\beta\mu^2 R + 2aL^{-b})\ (c+r)}{2pR(c+r) + crR + 2TR(c+r) + \alpha\beta R(c+r) + 2SR(c+r) + 2\gamma\theta R(c+r)}}$$

$$=> \quad q* = \sqrt{\frac{(2Rs+\alpha\beta\mu^2 R^2 + 2aL^{-b}R)\ (c+r)}{2p(c+r) + cr + 2T(c+r) + \alpha\beta(c+r) + 2S(c+r) + 2\gamma\theta(c+r)}} \tag{6}$$

Optimum total cost:

$$TC* = \sqrt{(2Rs+\alpha\beta\mu^2 R^2 + 2aL^{-b}R)\left[2p + \frac{cr}{c+r} + 2T + \alpha\beta + 2S + 2\gamma\theta\right]} - \alpha\beta\mu R + ck\sigma\sqrt{L}$$
(7)

3.2 Proposed Inventory Model in Fuzzy Sense:

Here, we consider the model in fuzzy environment. Since the holding cost, set up cost and shortage cost are fuzzy in nature, we represent them by trapezoidal fuzzy numbers.

Let $\tilde{p}$: fuzzy production cost per unit quantity per unit time

$\tilde{c}$: fuzzy carrying or holding cost per unit quantity per unit time

$\tilde{s}$: fuzzy set up or ordering cost per order

$\tilde{r}$: fuzzy shortage cost or stock out cost per unit quantity per unit time

$\tilde{T}$: fuzzy transportation cost

Now we fuzzify the total cost given in (2), we have,

$$\tilde{TC}(t) = \tilde{p}Rt + \left[\frac{\tilde{c}z^2}{2Rt} + \tilde{c}k\,\sigma\sqrt{L}\right] + \frac{\tilde{s}}{t} + \tilde{T}Rt + \frac{\tilde{r}\,(Rt-z)^2}{2Rt} + \frac{\alpha R}{\beta t}\left[\left(e^{\beta(t-\mu)}-1\right) - \beta\,(t-\mu)\right] + \frac{R(L)}{t} + SRt + \gamma\theta Rt$$

(8)

By using second order approximation of the exponential term $e^{\beta(t-\mu)}$ in $\tilde{TC}(t)$, we get

$$\tilde{TC}(t) = \tilde{p}Rt + \left[\frac{\tilde{c}\tilde{r}Rt}{2(\tilde{c}+\tilde{r})} + \tilde{c}k\,\sigma\sqrt{L}\right] + \frac{\tilde{s}}{t} + \tilde{T}Rt + \frac{\alpha\beta Rt}{2} - \alpha R\mu\beta + \frac{\alpha\beta\mu^2 R}{2t} + \frac{a\,L^{-b}}{t} + SRt + \gamma\theta Rt$$

(9)

and total cost in terms of 'q' is,

$$\tilde{TC}(q) = \tilde{p}q + \left[\frac{\tilde{c}\tilde{r}q}{2(\tilde{c}+\tilde{r})} + \tilde{c}k\,\sigma\sqrt{L}\right] + \frac{\tilde{s}R}{q} + \tilde{T}q + \frac{\alpha\beta q}{2} - \alpha R\mu\beta + \frac{\alpha\beta\mu^2 R^2}{2q} + \frac{R}{q}a\,L^{-b} + Sq + \gamma\theta q$$

(10)

where $z = \dfrac{\tilde{r}Rt}{\tilde{c}+\tilde{r}}$ and $q = Rt$

Partially differentiate equation (9) with respect to t, we get

$$\frac{\partial\tilde{TC}}{\partial t} = \tilde{p}R + \left[\frac{\tilde{c}\tilde{r}R}{2(\tilde{c}+\tilde{r})}\right] - \frac{\tilde{s}}{t^2} + \tilde{T}R + \frac{\alpha\beta R}{2} - \frac{\alpha\beta\mu^2 R}{2t^2} - \frac{a\,L^{-b}}{t^2} + SR + \gamma\theta R \qquad (11)$$

The optimum $\tilde{q^*}$ and $\tilde{TC^*}$ can be obtained by equating the first partial derivative w.r.t to 't' of $\tilde{TC}$ to zero.

(i.e) $\dfrac{\partial\tilde{TC}}{\partial t} = 0$ gives

Fuzzy optimum time period:

$$\tilde{t}* = \sqrt{\frac{(2\tilde{s} + \alpha\beta\mu^2 R + 2aL^{-b})\;(\tilde{c}+\tilde{r})}{2\tilde{p}R(\tilde{c}+\tilde{r}) + \tilde{c}\tilde{r}R + 2\tilde{T}R(\tilde{c}+\tilde{r}) + \alpha\beta R(\tilde{c}+\tilde{r}) + 2SR(\tilde{c}+\tilde{r}) + 2\gamma\theta R(\tilde{c}+\tilde{r})}}$$

(12)

Fuzzy optimal order quantity:

$$\tilde{q}^* = Rt* = R\sqrt{\frac{(2\tilde{s} + \alpha\beta\mu^2 R + 2aL^{-b})\;(\tilde{c}+\tilde{r})}{2\tilde{p}R(\tilde{c}+\tilde{r}) + \tilde{c}\tilde{r}R + 2\tilde{T}R(\tilde{c}+\tilde{r})(\tilde{c}+\tilde{r}) + \alpha\beta R(\tilde{c}+\tilde{r}) + 2SR(\tilde{c}+\tilde{r}) + 2\gamma\theta R(\tilde{c}+\tilde{r})}}$$

$$=> \quad \tilde{q^*} \quad = \sqrt{\frac{(2R\tilde{s} + \alpha\beta\mu^2 R^2 + 2aL^{-b}R)\;(\tilde{c}+\tilde{r})}{2\tilde{p}(\tilde{c}+\tilde{r}) + \tilde{c}\tilde{r} + 2\tilde{T}(\tilde{c}+\tilde{r}) + \alpha\beta(\tilde{c}+\tilde{r}) + 2S(\tilde{c}+\tilde{r}) + 2\gamma\theta(\tilde{c}+\tilde{r})}}$$

(13)

Fuzzy Optimum total cost:

$$\tilde{TC}* = \sqrt{(2R\tilde{s} + \alpha\beta\mu^2 R^2 + 2aL^{-b}R)\left[2\tilde{p} + \frac{\tilde{c}\tilde{r}}{\tilde{c}+\tilde{r}} + 2\tilde{T} + \alpha\beta + 2S + 2\gamma\theta\right]} - \alpha\beta\mu R + \tilde{c}k\sigma\sqrt{L}$$

(14)

4. NUMERICAL EXAMPLE:

4.1 Numerical Example in Crisp Sense:

The annual demand of an item is 1000 unit / year. Production cost is Rs. 800/ unit/year, annual inventory holding cost is Rs. 10 per unit, set up cost is Rs. 20 per unit, transportation cost is Rs. 20 unit / year and shortage cost is Rs. 4 unit / year. If there is 10 % defective items then the duplicate cost for the defective items is Rs. 2 / unit and the screening cost is Rs. 3 / unit. L = 0.5, k = 8, a = 1, b = 0.1, σ = 4. Also, μ = 3 days, α = 10, β = 0.9. Optimum time, economic order quantity and total annual cost are determined.

Sol:

4.1.1 Optimum Time:

$$t* = \sqrt{\frac{(2s+\alpha\beta\mu^2 R+2aL^{-b})\ (c+r)}{2pR(c+r)+crR + 2TR(c+r)+\alpha\beta R(c+r)+ 2SR(c+r)+2\gamma\theta R(c+r)}}$$

t^* = 0.22 days

4.1.2 Optimum Economic order quantity:

$$q* = \sqrt{\frac{(2Rs+\alpha\beta\mu^2 R^2+2aL^{-b}R)\ (c+r)}{2p(c+r)+cr+2T(c+r)+\alpha\beta(c+r)+2S(c+r)+2\gamma\theta(c+r)}}$$

= Rs. 221.07

4.1.3 Optimum Total annual cost:

$$TC* = \sqrt{(2Rs+\alpha\beta\mu^2 R^2+2aL^{-b}R)\left[2p+\frac{cr}{c+r}+2T+\alpha\beta+2S+2\gamma\theta\right]} - \alpha\beta\mu R + ck\sigma\sqrt{L}$$

= Rs. 339817.24

4.2 Numerical Example in Fuzzy Sense:

Let

R = 1000 unit / year

$\tilde{p}$ = Rs. (600, 700, 900, 1000) / unit / year

$\tilde{c}$ = Rs. (7, 9, 11, 13) / unit / year

$\tilde{r}$ = Rs. (2, 3, 5, 6) / unit / year

$\tilde{s}$ = Rs. (16, 19, 21, 24) / unit / year

$\tilde{T}$ = Rs. (16, 19, 21, 24) / unit / year

θ = 10 %

S = Rs. 3 / unit

γ = Rs. 2 / unit

μ = 3 days

α = 10

β = 0.9

L = 0.5

k = 8

a = 1

b = 0.1

σ = 4

4.2.1 Fuzzy Optimum Time:

$$\tilde{t}* = \sqrt{\frac{(2\tilde{s}+\alpha\beta\mu^2 R+2aL^{-b})\ (\tilde{c}+\tilde{r})}{2\tilde{p}R(\tilde{c}+\tilde{r})+\tilde{c}\tilde{r}R+2\tilde{T}R(\tilde{c}+\tilde{r})+\alpha\beta R(\tilde{c}+\tilde{r})+2SR(\tilde{c}+\tilde{r})+2\gamma\theta R(\tilde{c}+\tilde{r})}}$$

= (0.14, 0.18, 0.27, 0.37)

Graded mean integration method:

p ($\tilde{t}*$) = 0.24 days

4.2.2 Fuzzy Optimum Economic order quantity:

$$q\tilde{*} = \sqrt{\frac{(2R\tilde{s}+\alpha\beta\mu^2R^2+2aL^{-b}R)\,(\tilde{c}+\tilde{r})}{2\tilde{p}(\tilde{c}+\tilde{r})+\tilde{c}\tilde{r}+2\tilde{T}(\tilde{c}+\tilde{r})+\alpha\beta(\tilde{c}+\tilde{r})+2S(\tilde{c}+\tilde{r})+2\gamma\theta(\tilde{c}+\tilde{r})}}$$

= Rs. (136.26, 180.72, 272.44, 370.10)

Graded mean integration method:

p ($\tilde{q}*$) = Rs. 235.45

4.2.3 Fuzzy Optimum total annual cost:

$$\tilde{TC}* = \sqrt{(2R\tilde{s}+\alpha\beta\mu^2R^2+2aL^{-b}R)\left[2\tilde{p}+\frac{\tilde{c}\tilde{r}}{\tilde{c}+\tilde{r}}+2\tilde{T}+\alpha\beta+2S+2\gamma\theta\right]}-\alpha\beta\mu R+\tilde{c}k\sigma\sqrt{L}$$

= Rs. (291695.81, 316599.5, 361710.73, 383100.93)

Graded Mean Integration Method:

p ($\tilde{TC}*$) = Rs. 338569.53

5. SENSITIVITY ANALYSIS:

Table 1:

S.No	Demand (R)	For $\tilde{p}$ =Rs.(600, 700, 900, 1000) $\tilde{c}$ = Rs. (7, 9,11,13) $\tilde{r}$ = Rs.(2, 3, 5, 6) $\tilde{s}$ = Rs.(16, 19, 21, 24) $\tilde{T}$ = Rs. (16, 19, 21, 24)		
		$\tilde{t}^*$	$\tilde{q}^*$	$\tilde{TC}^*$
1.	800	0.23	200.79	256443.37
2.	900	0.23	220.87	297280.61
3.	1000	0.24	235.45	338569.53
4.	1100	0.24	254.38	378076.90
5.	1200	0.24	273.51	418690.08

6. CONCLUSION

In this paper, we construct a formula for an optimum time, optimal economic order quantity and optimum total annual inventory cost in the crisp sense as well as in the fuzzy sense. This model is solved rationally by optimizing the total inventory cost. Finally, the proposed model has been verified by the numerical example along with the sensitivity analysis and we conclude that if the demand is increasing then optimal economic order quantity and optimum total annual inventory cost will also increase simultaneously.

7. REFERENCES

[1] Aaditya Pevakar and Nagare M.R, Inventory model for timely deteriorating
[2] products considering penalty cost and shortage cost, International Journal of
[3] Science Technology & Engineering, Volume 2, Issue 2, August 2015,ISSN(O):
[4] 2349-784X .
[5] Dutta D and Pavan Kumar, Fuzzy inventory model without shortage using
[6] trapezoidal fuzzy number with sensitivity analysis, IOSR Journal of
[7] Mathematics, Vol 4, Issue 3, Nov-Dec 2012, PP 32-37, ISSN : 2278-5728.
[8] Fujiwara O and Perera U.L.J.S.R (1993), EOQ model for continuously

[9] deteriorating products using linear and exponential penalty cost, European
[10] journal of operation research, 70, 104-114.
[11] Jayanthi J and Yasotha Nandhini (2020), Fuzzy production inventory model
[12] for deterioration items with shortages and lead time using penalty cost, Juni
[13] Khyat, Impact factor: 6.625, Vol: 10, Issue 9, September 2020, ISSN: 2278 –
[14] 4632, pp: 143-151.
[15] Jayanthi J and Yasotha Nandhini (2020),Fuzzy production inventory model with allowed lead time and shortages using Yager ranking methods, Our Heritage,
[16] Vol 68, Issue 4, January 2020, ISSN: 0474-9030, pp: 415-428.
[17] Jayanthi J and Yasotha Nandhini (2020), Production inventory model with allowed shortages: A fuzzy approach, Vol 68, Issue 4, January 2020, ISSN:
[18] 0474-9030, pp: 451-462.
[19] Maragatham M and Lakshmidevi P.K (2014), A fuzzy inventory model for
[20] deteriorating items with price dependent demand, International journal of fuzzy
[21] mathematical studies, vol. 5, No. 1, 39-47.
[22] Mishra S.S, Gupta S, Yadav S.K and Rawat S (2015), Optimization of fuzzified
[23] economic order quantity model allowing shortage and deterioration with full
[24] backlogging, American journal of operational research, vol. 5(5), 103-110.
[25] Nalini Prava Behera, Pradip Kumar Tripathy, Fuzzy EOQ Model for Time-
[26] Deteriorating Items Using Penalty Cost, American Journal of Operational
[27] Research 2016, 6(1): 1-8 DOI: 10.5923/j.ajor.20160601.01.
[28] Park K.S. (1987) Fuzzy sets theoretic interpretation of economic order quantity, IIIE Transactions on systems, Man and Cybernetics, 17, 1082-1084.
[29] Pevekar A and Nagare M.R (2015) Inventory model for timely deteriorating
[30] products considering penalty cost and shortage cost, International journal of
[31] science technology & engineering, vol. 2, issue.2.
[32] Srivastava M and Gupta R (2009), EOQ model for time-deteriorating items
[33] using penalty cost, Journal of reliability and statistical studies, vol. 2, issue 2,
[34] 67-76.
[35] Yao J.S, Lee H.M, Fuzzy inventory with or without backorder for fuzzy order
[36] quantity with trapezoidal fuzzy number, Fuzzy sets and systems,1999,311- 337. [14] Zadeh L.A., Fuzzy sets, Information Control, 8, 338-353, 1965.
[37] Zimmerman, H.J., Using fuzzy sets in operational Research, European Journal
[38] of Operational Research 13, 1983, 201-206.