International Journal of Research in Engineering and Innovation (IJREI)
journal home page: http://www.ijrei.com
ISSN (Online): 2456-6934

**ORIGINAL ARTICLE**

# EOQ model for cubic deteriorating items carry forward with weibull demand and without shortages

**Chandan Kumar Sahoo[1], Kailash Chandra Paul[2]**

[1]*Department of Mathematics, GIET, Bhubaneswar, Odisha, India*
[2]*Research scholar, GIET University, Raygada, Odisha, India*

Article Information

Received: 6 June 2021
Revised: 01 July 2021
Accepted: 12 July 2021
Available online: 15 July 2021

Keywords:

Weibull demand;
Cubic deterioration;
Shortages, Deteriorating items

## Abstract

This paper develops an inventory model for deteriorating items with uniform replenishment rate with Weibull demand and without shortages. The deterioration rate is a cubic polynomial as a function of time. The objective of this study is to minimize the total cost in which the shortages are not allowed. A numerical example is presented to illustrate the model and the sensitivity analysis of the optimal solution with respect to various parameters is also studied. The total optimal average variable inventory cost as an important performance of the model. 

## 1. Introduction

In daily life, the deteriorating of goods is a common phenomenon. Most edible matters undergo straight exhaustion during simple storing. Extremely volatile liquids such as motor spirit, ethanol etc. undergoes substantial reduction in a time frame through the course of evaporation. Matters concern to the domain of electronic, nuclear, photoelectric, etc. weakens concern to potentiality and service with regard to time. As a matter of fact, deterioration is the degradation of value. The inventory models for deteriorating items have been thoroughly investigated by Covent and Philip [2] formulated an EOQ model in which the rate of deterioration of inventory models two-parameter Weibull distribution, demand rate is a constant and without shortage of inventory. While formulating inventory models, the factor such as demand and deterioration rate cannot be ignored. Kang & Kim [8] studied the price of the deteriorating inventory, since it is most important factor of demand as well as production level at the firm decided the basis price. Covert and Philip [2] moved over Ghare and Schrader's invariable declination rate to a two-attribute Weibull distribution. Afterward, Shah and Jaiswal [19] expressed and re-confirmed an order level inventory frame with a steady rate of deterioration respectively.

Lot of flourishing information currently derived by Sana and Chaudhuri [18] attempted the model analytically with power order deterioration but they made no attempt to solve the model numerically because of mathematical complexity of the model Lot of flourishing information currently derived by Chung and Ting [1], Covert and Philip [2]. Sahoo et. al. [17] have also established an EOQ model with two parameter constant deterioration and price dependent demand. Later, Sachan [13] elaborated the model on deficits. Hollier and Mak [12], Hariga and Benkherouf [10], Wee [5, 6] have also established their

*Corresponding author: C. K. Sahoo*
*Email Address: sahoock2012@gmail.com*
https://doi.org/10.36037/IJREI.2021.5510

pattern considering the exponential order. Earlier, Goyal and Giri [14], have put forwarded an exceptional study on the current drift in framing declination storage of the goods like vegetables, fruits, etc. whose declination rate gets augmented with time. Ghare and Schrader [11] have primarily exercised the model of deterioration chased by Covert and Philip [2] who devised a model with inconsistent rate of declination with two-factor Weibull distributions, which has further been comprehended by Philip [3] considering an inconsistent declination rate of three-factor Weibull distributions. Seldom in some storage units, the higher the waiting time is, the lesser the retreat rate would be and vice-versa. Consequently, all through the deficiency phase, the retreat rate is inconsistent and reliant on the waiting time for the subsequent refilling. Chang and Dye [4] has established an EOQ form accepting deficit. Newly, Ouyang, Wu and Cheng [9] have devised an EOQ stock account for declination matters in which order utility is exponentially declining and moderately retreat. Dye [4] proposed an EOQ model for perishable Items with Weibull distributed deterioration. He assumed that the demand rate is a power-form function of time. Sana and Chaudhuri [18] developed a stock-review inventory model for perishable items with uniform replenishment rate and stock-dependent demand. The deterioration function per unit time is a quadratic function of time. Mishra and Singh [7] developed an EOQ Model with Power-Form Stock-Dependent Demand and Cubic Deterioration. In the recent paper, Sahoo, Paul & kumar [15] have emphasized upon inventory model possessing two warehouses inventory model has been developed with exponentially diminishing order rate with limited suspension price including salvages. In another paper Sahoo, Paul & kalam[16] established An EOQ structure for declining matter with cubic order and inconsistent declining rate. Deficit has been accepted and moderately retreated. The Principal significance of the model is to establish an optimal frame.
In this model for cubic deteriorating items is developed in which demand rate is weibull function and without shortages. The total article has been organized in various important sections which include introduction fundamental assumption and notations, Mathematical model, Numerical analysis, sensitivity analysis and conclusion.

## 2. Assumptions and Notation

The following assumption and notations have been considered in this inventory model.

### *2.1 Assumptions*

The following hypotheses are prepared to initiate the representation.

- The demand function D(I) is taken to be a Weibull function of inventory level I(t) at any time t as $D(I) = \alpha\beta t^{\beta-1}, \alpha > 0, \beta > 1$.
- The replenishment occurs instantaneously at an infinite but replenishment size is finite.
- Lead time is zero.
- The deteriorating rate, $\theta(t)$ is a cubic function of time. Here $\theta(t) = a + bt + ct^2 + dt^3$ ,where $a$,$b$, $c$ and $d$ are real numbers, $d \neq 0$
  Where $a$ = initial deterioration
  $b$ = initial rate of change of deterioration.
  $c$= acceleration of deterioration
  $d$=rate of change of acceleration of deterioration.
  The items undergo decay at $\theta(t).I(t)$ at any time $t$.
- Shortages are not allowed.
- The time-horizon is infinite.
- Holding cost and set-up cost per inventory cycle both are constant.
- Procurement cost per unit item is constant.

### *2.2 Notations*

The subsequent data have been admitted in establishing the representation.

- $I(t)$ =The inventory level at time $t$ .
- $I_1$ =Intial and Terminal inventory level.
- $I_2$ =Pick of the inventory level.
- $R$ =Finite replenishment rate.
- $C_s$ =Set up cost per cycle.
- $C_h$ =Holding cost per unit per unit time.
- $C_p$ = Procurement cost per unit time.
- $t_1$ =Pick off time per inventory level.
- $T$ & $TAC$ =The length of a cycle and Total average cost respectively.

## 3. Mathematical Formulation

In this model the inventory cycle time consist of two segments i.e. [0, $t_1$] and [$t_1$, T]. Uniform replenishment rate starts with inventory $t_1$ and continue up to time t=$t_1$. The inventory piles up during [0, $t_1$], after meeting demands in the market.

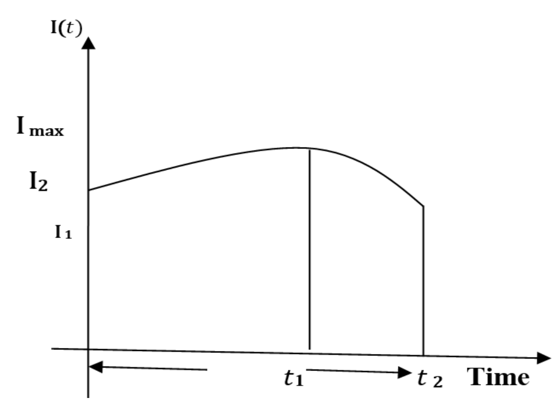

*Figure 1: Graphical presentation of inventory system*

The inventory level at t=$t_1$ is $I_2$. The storage space is limited. It can store maximum ($I_{max}$) units. Again the inventory level gradually reaches to $I_1$ at time t=T. The instantaneous states of the inventory level I (t) at any time 't' are governed by the following system of differential equations. The inventory level at different instants of time is shown in fig.1

$\theta(t) = a + bt + ct^2 + dt^3, where\ a, b, c, d \in R\ and\ d \neq 0$
$\theta'(t) = b + 2ct + 3dt^2$
$\theta''(t) = 2c + 6dt$
$\theta'''(t) = 6d$

Where,

a= initial deterioration
b = initial rate of change of deterioration
c = acceleration of deterioration
d = Rate of change of acceleration of the deterioration.

$$\frac{dI(t)}{dt} = R - \propto \beta t^{\beta-1} - \theta(t).I(t), 0 \le t \ll t_1 \quad (1)$$

$with\ I(0) = I_1\ and\ I(t_1) = I_2$

$$\frac{dI(t)}{dt} = -\propto \beta t^{\beta-1} - \theta(t).I(t), t_1 \le t \ll T \quad (2)$$

with $I(T) = I_1$

We prefer to work I (t) = I

$\theta(t) = \theta$
$\theta'(t) = \theta'$
$\theta''(t) = \theta''$
$\theta'''(t) = \theta'''$

Solving the above equations using Taylor's series expansion Now equation (1) reduces to the following equations.

$$\frac{dI}{dt} = R - \propto \beta t^{\beta-1} - \theta.I$$

$$\frac{d^2I}{dt^2} = -\alpha\beta(\beta-1)t^{\beta-2} + \propto \beta\theta t^{\beta-1} - (\theta' - \theta^2)I - \theta R$$

$$\frac{d^3I}{dt^3} = -\alpha\beta(\beta-1)(\beta-2)t^{\beta-3} + \propto \beta(\beta-1)\theta t^{\beta-2} + \propto \beta\theta^2 t^{\beta-1} - \left(\theta'' - \theta\theta' - \theta^3\right)I - \theta^2 R$$

$$\frac{d^4I}{dt^4} = -\alpha\beta(\beta-1)(\beta-2)(\beta-3)t^{\beta-4} + \alpha\beta(\beta-1)(\beta-2)\theta t^{\beta-3} + \alpha\beta(\beta-1)(\theta' + \theta^2)t^{\beta-2} + \alpha\beta(\theta\theta' + \theta'' - \theta^3)t^{\beta-1} + (\theta\theta' + 2\theta\theta'' + 2\theta^2\theta' - \theta''' - \theta^4)I - \left(\theta'' + \theta\theta' - \theta^3\right)R$$

Applying initial condition at t=0, I (0) $= I_1$, $\theta(0) = a, \theta'(0) = b, \theta''(0) = 2c, \theta'''(0) = 6d$

$$\frac{dI}{dt}\Big]_{t=0} = R - aI_1 = f_1(I_1)$$

$$\frac{d^2I}{dt^2}\Big]_{t=0} = -(b - a^2)I_1 - aR = f_2(I_1)$$

$$\frac{d^3I}{dt^3}\Big]_{t=0} = -(2c - ab - a^3)I_1 - a^2R = f_3(I_1)$$

$$\frac{d^4I}{dt^4}\Big]_{t=0} = (ab + 4ac + 2a^2b - 6d - a^4)I_1 - (2c + ab - a^3)R = f_4(I_1)$$

$$I(t) = I(0) + [\frac{dI}{dt}]_{t=0}.t + [\frac{d^2I}{dt^2}]_{t=0}.\frac{t^2}{2} + + [\frac{d^3I}{dt^3}]_{t=0}.\frac{t^3}{6} + + [\frac{d^4I}{dt^4}]_{t=0}.\frac{t^4}{24} = I_1 + tf_1(I_1) + \frac{t^2}{2}f_2(I_1) + \frac{t^3}{6}f_3(I_1) + \frac{t^4}{24}f_4(I_1), 0 \le t \le t_1 \quad (3)$$

Again from equation (2), we get

$$\frac{dI(t)}{dt} = -\propto \beta t^{\beta-1} - \theta(t).I(t)$$

This can be written as

$$\frac{dI}{dt} = -\propto \beta t^{\beta-1} - \theta.I$$

$$\frac{d^2I}{dt^2} = -\alpha\beta(\beta-1)t^{\beta-2} + \propto \beta\theta t^{\beta-1} - (\theta' - \theta^2)I$$

$$\frac{d^3I}{dt^3} = -\alpha\beta(\beta-1)(\beta-2)t^{\beta-3} + \propto \beta(\beta-1)\theta t^{\beta-2} + \propto \beta(2\theta' - \theta^2)t^{\beta-1} + \left(3\theta\theta' - \theta'' - \theta^3\right)I$$

$$\frac{d^4I}{dt^4} = -\alpha\beta(\beta-1)(\beta-2)(\beta-3)t^{\beta-4} + \propto \beta(\beta-1)(\beta-2)\theta t^{\beta-3} + \propto \beta(\beta-1)(3\theta' - \theta^2)t^{\beta-2} + \propto \beta(3\theta'' - 5\theta\theta' + \theta^3)t^{\beta-1} + (3\theta'^2 + 4\theta\theta'' - \theta''' - 6\theta^2\theta' + \theta^4)I$$

At $t = t_1$
$I(t_1) = I_2$
$\theta(t_1) = a + bt_1 + ct_1^2 + dt_1^3$
$\theta'(t_1) = b + 2ct_1 + 3dt_1^2$
$\theta''(t_1) = 2c + 6dt_1$
$\theta'''(t_1) = 6d$

$$\frac{dI}{dt}\Big]_{t=t_1} = -\propto \beta t_1^{\beta-1} - (a + bt_1 + ct_1^2 + dt_1^3)I_2 = f_1(I_2)$$

$$\frac{d^2I}{dt^2}\Big]_{t=t_1} = -\alpha\beta(\beta-1)t_1^{\beta-2} + \alpha\beta(a + bt_1 + ct_1^2 + dt_1^3)t_1^{\beta-1} - [(b - a^2) + (2c - 2ab)t_1 + (3d - 2ac - b^2)t_1^2 - (2bc + 2ad)t_1^3 - (2bd + c^2)t_1^4 - 2cdt_1^5 - d^2t_1^6]I_2 = f_2(I_2)$$

$$\frac{d^3I}{dt^3}\Big]_{t=t_1} = -\alpha\beta(\beta-1)(\beta-2){t_1}^{\beta-3} + \propto\beta(\beta-1)(a+bt_1+c{t_1}^2+d{t_1}^3){t_1}^{\beta-2} + \propto\beta\left\{\begin{array}{c}(2b-a^2)+(4c-2ab)t_1\\ +(6d-2ac-b^2){t_1}^2-(2bc+2ad){t_1}^3\\ -(2bd+c^2){t_1}^4-2cd{t_1}^5-d^2{t_1}^6\end{array}\right\}{t_1}^{\beta-1}$$
$$+\left[\begin{array}{c}(3ab-a^3-2c)+(6ac-3a^2b+3b^2-6d)t_1+(9ad-3a^2c-3ab^2+9bc){t_1}^2\\ +(-6abc-3a^2d+6bd+b^2c-b^3){t_1}^3+(-6abd-3ac^2-3b^2c+15cd){t_1}^4\\ +(-6acd-3b^2d-3bc^2+9d^2){t_1}^5+(-6bcd-3ad^2-c^3){t_1}^6\\ +(-3bd^2-3c^2d){t_1}^7-3cd^2{t_1}^8-d^3{t_1}^9\end{array}\right] I_2 = f_3(I_2)$$

$$\frac{d^4I}{dt^4}\Big]_{t=t_1} = -\alpha\beta(\beta-1)(\beta-2)(\beta-3){t_1}^{\beta-4} + \alpha\beta(\beta-1)(\beta-2)(a+bt_1+c{t_1}^2+d{t_1}^3){t_1}^{\beta-3}$$
$$+\propto\beta(\beta-1)\left[\begin{array}{c}(3b-a^2)+(6c-2ab)t_1+(9d-2ac-b^2){t_1}^2\\ +(-2bc-2ad){t_1}^3+(-2bd-c^2){t_1}^4-2cd{t_1}^5-d^2{t_1}^6\end{array}\right]{t_1}^{\beta-2}$$
$$+\alpha\beta\left[\begin{array}{c}(6c-5ab+a^3)+(18d-10ac-5b^2+3a^2b)t_1\\ +(-15ad-15bc+3a^2c+3ab^2){t_1}^2+(-20bd-10c^2+6abc+3a^2d+b^3){t_1}^3\\ +(-25cd+6abd+3ac^2+3b^2c){t_1}^4+(-15d^2+6acd+3b^2d+3bc^2){t_1}^5\\ +(6bcd+3ad^2+c^3){t_1}^6+(3bd^2+3c^2d){t_1}^7+3cd^2{t_1}^8+d^3{t_1}^9\end{array}\right]{t_1}^{\beta-1}$$
$$+\left[\begin{array}{c}(3b^2+8ac-6d-6a^2b+a^4)+(20bc+24ad-12ab^2-12a^2c+4a^3b)t_1\\ +(42bd+20c^2-36abc-18a^2d-6b^3+4a^3c+6a^2b^2){t_1}^2\\ +(68cd-48abd-24b^2c-24ac^2+12a^2bc+4a^3d+4ab^3){t_1}^3\\ +(51d^2-60acd-30b^2d-30bc^2+12a^2bd+12ab^2c+6a^2c^2+b^3){t_1}^4\\ +(-72bcd-36ad^2-12c^3+12a^2cd+12ab^2d+12abc^2+4b^3c){t_1}^5\\ +(-42bd^2-42c^2d+24abcd+6a^2d^2+4ac^3+6b^2c^2+4b^3d){t_1}^6\\ +(-48cd^2+12abd^2+12ac^2d+12b^2cd+4bc^3){t_1}^7\\ +(-18d^3+12acd^2+12bc^2d+6b^2d^2+c^4){t_1}^8\\ +(12bcd^2+4ad^3+4c^3d){t_1}^9+(4bd^3+6c^2d^2){t_1}^{10}+4cd^3{t_1}^{11}+d^4{t_1}^{12}\end{array}\right] I_2 = f_4(I_2)$$

The total Inventory in the cycle

$$\int_0^T I(t)dt = \int_0^{t_1} I(t)dt + \int_{t_1}^T I(t)dt = I_1t_1 + f_1(I_1)\frac{{t_1}^2}{2} + f_2(I_1)\frac{{t_1}^3}{6} f_3(I_1)\frac{{t_1}^4}{24} + f_4(I_1)\frac{{t_1}^5}{120} + I_2(\mathrm{T}-t_1) + f_1(I_2)\frac{(\mathrm{T}-t_1)^2}{2} + f_2(I_2)\frac{(\mathrm{T}-t_1)^3}{6} + f_3(I_2)\frac{(\mathrm{T}-t_1)^4}{24} + f_4(I_2)\frac{(\mathrm{T}-t_1)^5}{120}$$

Total invested during each inventory cycle is given by

$$\mathrm{TC}\ (\mathrm{T}) = C_h\{\int_0^{t_1} \mathrm{I(t)dt} + \int_{t_1}^{\mathrm{T}} \mathrm{I(t)dt}\} + \mathrm{C_s} + C_p\mathrm{R}t_1$$
$$= C_h\left\{\begin{array}{c} I_1t_1 + f_1(I_1)\frac{{t_1}^2}{2} + f_2(I_1)\frac{{t_1}^3}{6} f_3(I_1)\frac{{t_1}^4}{24} + f_4(I_1)\frac{{t_1}^5}{120}\\ +I_2(\mathrm{T}-t_1) + f_1(I_2)\frac{(\mathrm{T}-t_1)^2}{2} + f_2(I_2)\frac{(\mathrm{T}-t_1)^3}{6} + f_3(I_2)\frac{(\mathrm{T}-t_1)^4}{24} + f_4(I_2)\frac{(\mathrm{T}-t_1)^5}{120}\end{array}\right\}$$
$$+ \mathrm{C_s} + \mathrm{C_pR}\, t_1.$$

Therefore, the total average cost is

$$\mathrm{TAC}\ (\mathrm{T}) = \frac{1}{T}\left[C_h\left\{\int_0^{t_1} \mathrm{I(t)dt} + \int_{t_1}^{\mathrm{T}} \mathrm{I(t)dt}\right\} + \mathrm{C_s} + C_p \mathrm{R} t_1\right] = \frac{1}{T}\left[C_h\left\{\begin{array}{c} I_1 t_1 + f_1(I_1)\frac{{t_1}^2}{2} + f_2(I_1)\frac{{t_1}^3}{6} f_3(I_1)\frac{{t_1}^4}{24} + f_4(I_1)\frac{{t_1}^5}{120} \\ + I_2(\mathrm{T}-t_1) + f_1(I_2)\frac{(\mathrm{T}-t_1)^2}{2} + f_2(I_2)\frac{(\mathrm{T}-t_1)^3}{6} + f_3(I_2)\frac{(\mathrm{T}-t_1)^4}{24} + f_4(I_2)\frac{(\mathrm{T}-t_1)^5}{120} \end{array}\right\} + \mathrm{C_s} + \mathrm{C_p R}\, t_1\right]$$

Now we optimize TAC (T), for $I_1 \geq 0, R > \propto \beta t^{\beta-1} \mathrm{a} I_1$ , $I_2 > I_1$ and $I_2 \leq I_1$

The optimal value of T for the minimum total average cost is the solution of the nonlinear equation in T

i.e. $\frac{d}{dt}(TAC) = 0$ provided that this obtained value of T satisfies the condition

$$\left[\frac{d^2}{dt^2}(TAC)\right]_{t=T} > 0$$

When $T^*$ is the optimal value of T.

The above constrained optimization problem can be solved using any iterative method, when the values of the parameters are prescribed. Hence this objective is fulfilled using MATHEMATICA 12.0 which returns us optimal value of T and Total optimal average cost (TAC) of the system.

## 4. Numerical Illustration

*Example 1*

In this section, we provide a numerical example to illustrate the above theory. Considering an inventory system with following parameter value in proper units and the output of the Numerical example implemented by MATHEMATICA 12.0. $\alpha = 2, \beta = 2, a = 0.08, b = 0.06, c = 0.04, d = 0.02, I_1 = 1500, I_2 = 2000, C_s = 2500, C_h = 7, C_p = 2,, t_1 = 2, R = 300$.The total average cost *TAC**=15.2531 and the optimal value of *T**=0.9234.

Table 1: *Effect of change in various parameters of example 1*

| Changing parameter | % change in the parameter | *T** | *TAC** | % change in *TAC** |
|---|---|---|---|---|
| $C_h$ | 50 | 0.87532 | 15.5621 | 2.026 |
| | 25 | 0.97321 | 14.2395 | -6.645 |
| | 10 | 0.98342 | 12.5345 | -17.823 |
| | -10 | 0.99324 | 12.1543 | -20.316 |
| | -25 | 1.45462 | 11.9364 | -21.745 |
| | -50 | 2.32152 | 10.2135 | -33.040 |
| $C_s$ | 50 | 0.91783 | 21.7314 | 42.472 |
| | 25 | 0.93252 | 20.5075 | 34.448 |
| | 10 | 0.95276 | 17.4632 | 14.490 |
| | -10 | 0.97673 | 14.7645 | -3.203 |
| | -25 | 0.98351 | 12.4164 | -18.598 |
| | -50 | 1.28427 | 10.3172 | -32.360 |
| $C_p$ | 50 | 0.87306 | 15.2544 | 0.009 |
| | 25 | 0.95732 | 15.3615 | 0.711 |
| | 10 | 0.98453 | 15.5437 | 1.905 |
| | -10 | 0.99564 | 15.6528 | 2.620 |
| | -25 | 1.32164 | 15.8774 | 4.093 |
| | -50 | 2.52316 | 16.3543 | 7.220 |
| $I_1$ | 50 | 0.95995 | 23.8113 | 56.108 |
| | 25 | 0.97132 | 19.3272 | 26.710 |
| | 10 | 0.98342 | 14.2112 | -6.831 |
| | -10 | 0.99352 | 9.11545 | -40.239 |
| | -25 | 0.99602 | 7.35461 | -51.783 |
| | -50 | 1.56743 | 5.37869 | -64.737 |
| $I_2$ | 50 | 1.32529 | 11.7554 | -22.931 |
| | 25 | 0.99315 | 13.1624 | -13.707 |
| | 10 | 0.95347 | 15.4657 | 1.394 |
| | -10 | 0.91645 | 17.3659 | 13.852 |
| | -25 | 0.87216 | 20.9985 | 37.667 |
| | -50 | 0.83129 | 27.6683 | 81.395 |
| $R$ | 50 | 0.9775 | 18.3484 | 20.293 |
| | 25 | 0.9874 | 18.4125 | 20.713 |
| | 10 | 0.99435 | 18.8595 | 23.644 |
| | -10 | 1.00763 | 19.2883 | 26.455 |
| | -25 | 1.10721 | 21.4986 | 40.946 |
| | -50 | 1.24327 | 24.2534 | 59.007 |
| $t_1$ | 50 | 0.8573 | 15.5504 | 1.949 |
| | 25 | 0.83912 | 15.5636 | 2.036 |
| | 10 | 0.82146 | 15.5832 | 2.164 |
| | -10 | 0.81124 | 15.8313 | 3.791 |
| | -25 | 0.80243 | 15.8946 | 4.206 |
| | -50 | 0.78287 | 15.9647 | |

## 5. Sensitivity Analysis

We now study the effect of changes of values of the parameters $a, b, c, d, \alpha, \beta, , t_1, C_h, C_s, C_p, R, I_1, I_2$ on the optimal total cost. The Sensitivity analysis is performed by changing each of parameters by +50%, +25%, +10%, -10%, -25%, -50% taking one parameter at a time and keeping the remaining parameters unchanged.

The investigation has been based upon the previous numerical demonstration and the consequences have appeared in table 1. The comment underneath has to be experienced.

- *T** increases while *TAC** decreases with the decrease in the value of the parameter $C_h$**.** The obtained result shows that *T**is moderately sensitive to change in $C_h$ and *TAC** is highly sensitive to change in $C_h$.

- $T^*$ increases while $TAC^*$ decreases with the decrease in the value of the parameter $C_s$. The obtained result shows that $T^*$ is low sensitive to change in $C_h$ and $TAC^*$ is highly sensitive to change in $C_h$.
- $T^*$ increases while $TAC^*$ increases with the decrease in the value of the parameter $C_p$. The obtained result shows that $T^*$ is low sensitive to change in $C_p$ and $TAC^*$ is moderately sensitive to change in $C_p$.
- $T^*$ increases while $TAC^*$ decreases with the decrease in the value of the parameter $I_1$. The obtained result shows that $T^*$ is low sensitive to change in $I_1$ and $TAC^*$ is highly sensitive to change in $I_1$.
- $T^*$ decreases while $TAC^*$ increases with the decrease in the value of the parameter $I_2$. The obtained result shows that $T^*$ is low sensitive to change in $I_2$ and $TAC^*$ is highly sensitive to change in $I_2$.
- $T^*$ increases while $TAC^*$ increases with the decrease in the value of the parameter $R$. The obtained result shows that $T^*$ is low sensitive to change in $R$ and $TAC^*$ is highly sensitive to change in $R$.
- $T^*$ decreases while $TAC^*$ increases with the decrease in the value of the parameter $t_1$. The obtained result shows that $T^*$ & $TAC^*$ are moderately sensitivity to change in $t_1$.

## 6. Conclusions

In this study, we have developed an inventory model for the cubic deterioration rate for the items like fruits, vegetables, milk, sweets and radioactive substances. Retailer in super market faces this difficulty during trading products whose importance goes down with each passing moment. The demand rate is assumed Weibull function of time. The pattern in which the basic independent factors influencing the total average cost has also been projected through sensitivity analysis column within this model. This very model can be highly appreciable for the industries in which the demand rate depends upon the time. The objective of our study is to determine the total optimal average variable inventory cost at optimal inventory level which is total sum of the set-up cost, carrying cost and procurement costs of inventory items.

## References


[1] Chung K. and Ting P., (1993). "An heuristic for replenishment of deteriorating items with a linear trend in demand; Journal of the Operational Research Society, 44, 1235-1241.

[2] Covert R. P., and Philip G. C., (1973). "An EOQ model for items with Weibull distribution deterioration", AIIE Transactions, 5, 323-326.

[3] G. C. Philip, "A Generalized EOQ Model for Items with Weibull Distribution," AIIE.

[4] H. J. Chang and C. Y. Dye, (1973)., "An EOQ Model for Deteriorating Items with Time Varying Demand and Partial Back- logging," Journal of the Operational Research Society, Vol. 50, No. 11, pp. 1176-1182. doi:10.1057/palgrave.jors.2600801.

[5] H. M. Wee, (1995) "A Deterministic Lot Size Inventory Model for Deteriorating Items with Shortages and a Declining Market," Computers and Operations Research, Vol. 22, No. 3, , pp. 345-356. doi:10.1016/0305-0548(94)E0005-R.

[6] H. M. Wee, (1995) "JOINT pricing and Replenishment Policy for Deteriorating Inventory with Declining Market," International Journal of Production Economics, Vol. 40, No. 2-3, , pp. 163-171. doi:10.1016/0925-5273(95)00053-3.

[7] Mishra S. S.*( 2011), Singh P. K. A Computational Approach to EOQ Model with Power-Form Stock-Dependent Demand and Cubic Deterioration. American Journal of Operational Research; 1(1): 5-13.

[8] Kang, S. and Kim, I.T. (1983). A Study on Price And Pro-duction Level of the Deteriorating Inventory System. Internationl Journal of Production Research 21: 899-908.

[9] L. Y. Ouyang, K. S. Wu and M. C. Cheng,( 2005) "An Inventory Model for Deteriorating Items with Exponential Declining Demand and Partial Backlogging," Yugoslav Journal of Operations Research, Vol. 15, No. 2, , pp. 277- 288. doi:10.2298/YJOR0502277O.

[10] M. Hariga and L. Benkherouf,( 1994) "Optimal and Heuristic Replenishment Models for Deteriorating items with Exponential Time Varying Demand," European Journal of Operational Research, Vo. 79, No. 1, , pp. 123-137. doi:10.1016/0377-2217(94)90400-6.

[11] P. M. Ghare and G. H. Schrader(1963), "A Model for Exponentially Decaying Inventory Systems," International Journal of Production and Research, Vol. 21, , pp. 449- 460.

[12] R. H. Hollier and K. L. Mak,( 1983) "Inventory Replenishment Policies for Deteriorating Items in a Declining Market," International Journal of Production Research, Vol. 21, No. 6, , pp. 813-826. doi:10.1080/00207548308942414.

[13] R. S. Sachan,( 1984) "On (T, Si) Policy Inventory Model Deteriorating Items with Time Proportional Demand,"Journal of Operational Research Society, Vol. 35, No. 11, 1984, pp. 1013-1019, doi:10.1057/jors..197.

[14] S. K. Goyal and B. C. Giri(2001), "Recent Trends in Modeling of Deteriorating Inventory," European Journal of Operational Research, Vol. 134, No. 1, , pp. 1-16.doi:10.1016/S0377-2217(00)00248-4.

[15] Sahoo, C.K., Paul, K.C. & Kumar, (2020). S. Two Warehouses EOQ Inventory Model of Degrading Matter Having Exponential Decreasing Order, Limited Suspension in Price Including Salvage Value. SN COMPUT. SCI. **1,** 334.

[16] Sahoo, C.K., Paul, K.C. & Kalam,A(2020). An EOQ representation for declining matters with cubic order, inconsistent declination and inequitable backlogging .AIP Conference Proceedings **2253**, 020010

[17] Sahoo N. K., Sahoo C. K. and Sahoo S. K., (2009). "An EOQ model with two parameter constant deterioration and price dependent demand", International Journal of Ultra Scientist of Physical Sciences, 21(2) M 515-520.

[18] Sana, S. and Chaudhuri, K.S. (2004). A stock-review EOQ model with stock dependent demand, quadratic deterioration rate. Advanced Modelling and Optimization 6(2): 25-32.

[19] Shah, Y.K. and Jaiswal M.C. (1977). An Order-Level In-ventory Model for a System with Constant Rates of Deteri-oration. Opsearch 14: 174-184.


***Cite this article as:*** Chandan Kumar Sahoo, Kailash Chandra Paul, EOQ model for cubic deteriorating items carry forward with weibull demand and without shortages, International journal of research in engineering and innovation (IJREI), vol 5, issue 5 (2021), 285-290. https://doi.org/10.36037/IJREI.2021.5510.