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EPQ Model with Time Dependent IHC and Weibull Distributed Deterioration under Shortages

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ABSTRACT: In this paper, we have developed an inventory model to determine the economic production quantity for deteriorating items under time dependent demand. Inventory holding cost is taken as a linear function depending upon time. A combination of two parameter and three parameter Weibull distribution is considered for the deterioration of units over a period of time. For practical applicability, shortages are allowed to occur. Besides that we have assumed that demand is a linear and also quadratic function of time in different time intervals. A numerical example is given for the developed model with its sensitivity analysis.

KEYWORDS: EPQ model, Deterioration, Backlogging, Weibull distributions

I. INTRODUCTION

The classic Economic Production Quantity (EPQ) model is a mathematical model which determines the lot size in production process that minimizes the total inventory holding cost and set up cost. In classic EPQ model demand for an item is assumed to be continuous with constant rate. Further production of items is also assumed to be continuous with constant rate. Further production of items is also assumed to be continuous with constant rate. But production of items is also assumed to be continuous with constant rate. Further production of items is also assumed to be continuous with constant rate. But production of the assumptions of classic EPQ model by assuming the time varying production rate, deterioration rate, shortages and quantity discount.

An inventory model for deteriorating items with time-dependent demand and time-varying holding cost under partial backlogging developed by Mishra V.K., Singh L.S. & Kumar R. [18]. Ankit Bhojak and U. B. Gothi [1] prepared an EOQ model with time dependent demand and Weibull distributed deterioration. Wu J. W. and Lee W. C. [25] presented an EOQ inventory model for items with Weibull distributed deterioration, shortages and time varying demand. Ghosh S. K. and Chaudhari K. S. [11] have given an order-level inventory model for a deteriorating item with Weibull distribution deterioration, time-quadratic demand and shortages.

Baten Azizul and Kamil Anton Abdulbasah [2] analysed an inventory-production system with Weibull distributed deterioration. Chaman Singh and S.R. Singh [3] developed an EPQ model with power form stock dependent demand under inflationary environment using genetic algorithm. Chang, H. C. [4] has given note on the EPQ model with shortages and variable lead time. A note on the improved algebric method for the EPQ model with stochastic lead time is given by Chun-Hsiung Lan, Yen-Chieh Yu, Robert H. J. Lin, Cheng-Tan Tung, Chih-Pin Yen and Peter Shaohua Deng [6]. Chung-Ho Chen [5] has modified economic manufacturing quantity model for product with quality loss function.Hui- Ming Wee, Wan-Tsu Wang and Po-Chung Yang [12] presented a production quantity model for imperfect quality items with shortage and screening constraint. GedeAgus Widyadana and Hui Ming Wee [10] have developed an economic production quantity for deteriorating items with preventive maintenance policy and random machine breakdown. Mehdi Alimohamadi, Seyed Mojtaba Sajadi, Seyed Akbar and Nilipour Tabatabaie [17] have formed a new EPQ model by considering preventive maintenance, imperfect product, shortage and work in process inventory. Garima Garg, Bindu Vaish and Shalini Gupta [9] formulated an economic production lot size model with price discounting for non-instantaneous deteriorating items with ramp type production and demand rates. Leopoldo Eduardo Cahrdenas-Barron [15] derived the economic production quantity with shortage algebraically. Feng-Tsung



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Cheng, Huei-Hsin Chang and Singa Wang Chiu [8] presented economic production quantity model with backordering, rework and machine failure taking place in stock piling time. Jinn-Tsair Teng, Liang-Yuh Ouyang and Chun-Tao Chang [13] formed deterministic economic production quantity model with time-varying demand and cost. R. Shamsi, A. Haji, S. Shadrokh and F. Nourbakhsh [19] formulated an economic production quantity in reworkable production systems with inspection errors, scraps and backlogging. U. B. Gothi and Devyani A. Chatterji [24] have developed an EPQ model for imperfect quality items under constant demand rate and varying inventory holding cost.

Samanta G. P. and Roy Ajanta [20] presented a production inventory model with deteriorating items and shortages. Madhu Jain, G.C. Sharma and Shalini Rathore [16] developed an economic production quantity models with shortage, price and stock-dependent demand for deteriorating items. Sugapriya C. and Jeyaraman K. [22] have given an EPQ model for non-instantaneous deteriorating item in which holding cost varies with time. Sarkar S. and Chakrabarti T. [21] presented an EPQ model having Weibull distribution deterioration with exponential demand and production with shortages under permissible delay in payments. Kirtan Parmar and U. B. Gothi [14] formulated an EPQ model of deteriorating items using three parameter Weibull distribution with constant production rate and time varying holding cost.

Sunil V. Kawale and Pravin B. Bansode [23] developed an inventory model for time varying holding cost and Weibull distribution for deterioration with fully backlogged shortages Devyani Chatterji and U. B. Gothi [7] formulated an inventory model by considering combination of two parameters and three parameters Weibull distribution in different time intervals and partially backlogged shortages. In this paper we have developed an EPQ model having demand as a mixer of linear and quadratic function of time in different time intervals with fully backlogged shortages.

II. ASSUMPTIONS

The model is developed under the following assumptions

- 1. Replenishment rate is infinite.
- 2. Lead-time is zero.
- 3. A single item is considered over the prescribed period of time.
- 4. No repair or replacement of the deteriorated items takes place during a given cycle.
- 5. Finite time horizon period is considered.
- 6. Holding cost is a linear function of time given by $C_h = h + r t$ (h, r > 0).
- 7. The deterioration rate is a two parameter Weibull distribution during the time interval $[0, \mu]$ and during the time interval $[\mu, t_1]$ it is three parameter Weibull distributed deterioration rate.
- 8. Shortages are allowed and all unsatisfied demands are fully backlogged
- 9. Total inventory cost is a real and continuous function which is convex to the origin.

III. NOTATIONS

The following notations are used to develop the mathematical model

- 1. Q (t) : Inventory level of the product at time t (≥ 0).
- 2. R (t) : Demand rate varying over time.
- 3. $\theta(t)$: Deterioration rate.
- 4. A : Ordering cost per order during the cycle period.
- 5. C_h : Inventory holding cost per unit per unit time.
- 6. C_d : Deterioration cost per unit per unit time.
- 7. C_s : Shortage cost per unit per unit time.
- 8. C_p : Production cost per unit.
- 9. S_1 : Inventory level at $t = \mu$.
- 10. S_2 : The maximum inventory level during shortage period.
- 11. T : Duration of a cycle.
- 12. TC : Total cost per unit time.



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IV. MATHEMATICAL FORMULATION AND SOLUTION

In the beginning inventory is zero. At time t = 0, the production starts and supply also starts simultaneously. The production stops at $t = \mu$ where the maximum inventory level S_1 is reached. In the interval $[0, \mu]$ the inventory is built up at a rate p - (a + b t) along with the deterioration rate. The stock level falls to zero level at time $t = t_1$ due to demand with rate $-(a + b t + c t^2)$ along with the deterioration rate. Thereafter, shortages are allowed to occur during the time interval at a rate $-(a + b t + c t^2)$. At time $t = t_2$ shortage reaches to maximum level S_2 and the backlog is fulfilled at a rate of $p - (a + b t + c t^2)$ in the time interval $[t_2, T]$. The stock level becomes zero at time t = T. The same cycle is repeated for the further time period T. The graphical presentation of inventory model is shown in Figure 1.



Figure 1 Graphical representation of inventory model

Differential Equations pertaining to the above situation as explained are given by

$$\frac{\mathrm{d}\,Q(t)}{\mathrm{d}t} + \alpha\,\beta\,t^{\beta-1}\,Q(t) = p - (a+b\,t) \qquad \qquad 0 \le t \le \mu \qquad \dots (1)$$

$$\frac{\mathrm{d}\,Q(t)}{\mathrm{d}t} + \alpha\,\beta\,\left(t-\mu\right)^{\beta^{-1}}\,Q(t) = -\left(a+b\,t+c\,t^2\right) \qquad \mu \le t \le t_1 \qquad \dots (2)$$

$$\frac{d Q(t)}{dt} = -(a+bt+ct^2) \qquad \qquad t_1 \le t \le t_2 \qquad \dots (3)$$

$$\frac{\mathrm{d}\,Q(t)}{\mathrm{d}t} = p - \left(a + b\,t + c\,t^2\right) \qquad t_2 \leq t \leq T \qquad \dots (4)$$

Using the boundary conditions

 $Q(0) = Q(t_1) = Q(T) = 0, Q(\mu) = S_1, Q(t_2) = -S_2$



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the solutions of equations (1), (2), (3) and (4) are given by

$$Q(t) = (p - a) t - \frac{b t^{2}}{2} - \frac{(p - a)\alpha \beta t^{\beta + 1}}{\beta + 1} + \frac{\alpha \beta b t^{\beta + 2}}{2 (\beta + 2)} ...(5)$$

$$Q(t) = \left(S_{1}\left(1 - \alpha (t - \mu)^{\beta}\right) - z (t - \mu) - \frac{y (t - \mu)^{2}}{2} - \frac{c (t - \mu)^{3}}{3} - \frac{\alpha \beta z (t - \mu)^{\beta+1}}{3} - \alpha \beta x (t - \mu)^{\beta+2} - \alpha \beta c (t - \mu)^{\beta+3}\right) \qquad \dots (6)$$

$$+\frac{\alpha \beta z (t-\mu)^{p+1}}{\beta+1}+\frac{\alpha \beta y (t-\mu)^{p+2}}{2 (\beta+2)}+\frac{\alpha \beta c (t_1-\mu)^{p+3}}{3 (\beta+3)}\right)$$

$$Q(t) = a(t_1 - t) + \frac{b}{2}(t_1^2 - t^2) + \frac{c}{3}(t_1^3 - t^3) \qquad \dots (7)$$

$$Q(t) = (p - a) (t - T) - \frac{b}{2} (t^{2} - T^{2}) - \frac{c}{3} (t^{3} - T^{3}) \qquad ... (8)$$

where $y = 2 \mu c + b$ and $z = a + b \mu + c \mu^2$

Putting $Q(t_1) = 0$ in equation (6), we get

$$S_{1} = \frac{1}{1 - \alpha (t_{1} - \mu)^{\beta}} \begin{cases} z (t_{1} - \mu) + \frac{y (t_{1} - \mu)^{2}}{2} + \frac{c (t_{1} - \mu)^{3}}{3} - \frac{\alpha \beta z (t_{1} - \mu)^{\beta + 1}}{\beta + 1} \\ - \frac{\alpha \beta y (t_{1} - \mu)^{\beta + 2}}{2 (\beta + 2)} - \frac{\alpha \beta c (t_{1} - \mu)^{\beta + 3}}{3 (\beta + 3)} \end{cases} \qquad \dots (9)$$

Putting $Q(t_2) = -S_2$ in equation (7), we get

$$S_{2} = a \left(t_{2} - t_{1}\right) + \frac{b}{2} \left(t_{2}^{2} - t_{1}^{2}\right) + \frac{c}{3} \left(t_{2}^{3} - t_{1}^{3}\right) \qquad \dots (10)$$

Putting $Q(t_2) = -S_2$ in equation (8), we have

$$S_{2} = (p - a) (T - t_{2}) - \frac{b}{2} (T^{2} - t_{2}^{2}) - \frac{c}{3} (T^{3} - t_{2}^{3}) \qquad \dots (11)$$

From equation (10) and (11)

$$t_{2} = T - \frac{1}{p} \left[a \left(T - t_{1} \right) + \frac{b}{2} \left(T^{2} - t_{1}^{2} \right) + \frac{c}{3} \left(T^{3} - t_{1}^{3} \right) \right] ... (12)$$

The total cost consists of the following costs

(1) Operating Cost

(2) Production Cost

$$PC = p_{c} (\mu + T - t_{2}) p \qquad ... (14)$$



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(3) Inventory Holding Cost

$$\begin{aligned} \text{HC} &= \int_{0}^{\mu} (\mathbf{h} + \mathbf{r} \, \mathbf{t} \,) \, \mathbf{Q} \, (\mathbf{t}) \, d\mathbf{t} + \int_{\mu}^{\mathbf{t}} (\mathbf{h} + \mathbf{r} \, \mathbf{t} \,) \, \mathbf{Q} \, (\mathbf{t}) \, d\mathbf{t} \\ &= \mathbf{h} \left[\left(\mathbf{p} - \mathbf{a} \right) \, \frac{\mu^{2}}{2} \, - \, \frac{\mathbf{b} \, \mu^{3}}{6} \, - \, \frac{(\mathbf{p} - \mathbf{a})\alpha \, \beta \, \mu^{\beta + 2}}{(\beta + 1) \, (\beta + 2)} + \frac{\alpha \, \beta \, \mathbf{b} \, \mu^{\beta + 3}}{2 \, (\beta + 2) \, (\beta + 3)} \right] \\ &+ \mathbf{r} \left[\left(\mathbf{p} - \mathbf{a} \right) \, \frac{\mu^{3}}{3} \, - \, \frac{\mathbf{b} \, \mu^{4}}{8} \, - \, \frac{(\mathbf{p} - \mathbf{a})\alpha \, \beta \, \mu^{\beta + 3}}{(\beta + 1) \, (\beta + 3)} + \frac{\alpha \, \beta \, \mathbf{b} \, \mu^{\beta + 4}}{2 \, (\beta + 2) \, (\beta + 4)} \right] \\ &+ \left(\mathbf{h} + \mathbf{r} \, \mu \right) \left[\mathbf{S}_{1} \left(\left(\mathbf{t}_{1} - \mu \right) - \, \frac{\alpha \, \left(\mathbf{t}_{1} - \mu \right)^{\beta + 1}}{\beta + 1} \right) - \, \frac{\mathbf{z} \, \left(\mathbf{t}_{1} - \mu \right)^{2}}{2} \, - \, \frac{\mathbf{y} \, \left(\mathbf{t}_{1} - \mu \right)^{3}}{6} - \, \frac{\mathbf{c} \, \left(\mathbf{t}_{1} - \mu \right)^{4}}{12} \\ &+ \, \frac{\alpha \, \beta \, \mathbf{z} \, \left(\mathbf{t}_{1} - \mu \right)^{\beta + 2}}{(\beta + 1) \, (\beta + 2)} + \, \frac{\alpha \, \beta \, \mathbf{y} \, \left(\mathbf{t}_{1} - \mu \right)^{\beta + 3}}{2 \, (\beta + 2) \, (\beta + 3)} + \, \frac{\alpha \, \beta \, \mathbf{c} \, \left(\mathbf{t}_{1} - \mu \right)^{\beta + 4}}{3 \, (\beta + 3) \, (\beta + 4)} \right] \quad \cdots (15) \\ &+ \mathbf{r} \left[\mathbf{S}_{1} \left(\frac{\left(\mathbf{t}_{1} - \mu \right)^{2}}{2} \, - \, \frac{\alpha \, \left(\mathbf{t}_{1} - \mu \right)^{\beta + 2}}{\beta + 2} \right) \, - \, \frac{\mathbf{z} \, \left(\mathbf{t}_{1} - \mu \right)^{3}}{3} \, - \, \frac{\mathbf{y} \, \left(\mathbf{t}_{1} - \mu \right)^{4}}{8} \, - \, \frac{\mathbf{c} \, \left(\mathbf{t}_{1} - \mu \right)^{5}}{15} \\ &+ \, \frac{\alpha \, \beta \, \mathbf{z} \, \left(\mathbf{t}_{1} - \mu \right)^{\beta + 3}}{\left(\beta + 1 \, \right) \, \left(\beta + 3 \right)} + \, \frac{\alpha \, \beta \, \mathbf{y} \, \left(\mathbf{t}_{1} - \mu \right)^{\beta + 4}}{2 \, \left(\beta + 2 \, \right) \, \left(\beta + 4 \right)} \, + \, \frac{\alpha \, \beta \, \mathbf{c} \, \left(\mathbf{t}_{1} - \mu \right)^{\beta + 5}}{3 \, \left(\beta + 3 \, \right) \, \left(\beta + 5 \right)} \right] \end{array} \right] \end{aligned}$$

(4) Deterioration Cost

$$DC = C_{d} \left(\int_{0}^{\mu} \alpha \ \beta \ t^{\beta - 1} Q (t) \ dt + \int_{\mu}^{t_{1}} \alpha \ \beta \ (t - \mu)^{\beta - 1} Q (t) \ dt \right)$$
$$= C_{d} \left(\alpha \ \beta \left(\frac{(p - a) \ \mu^{\beta + 1}}{\beta + 1} - \frac{b \ \mu^{\beta + 2}}{2 \ (\beta + 2)} + \frac{S_{I}(t_{I} - \mu)^{\beta}}{\beta} - \frac{z \ (t_{I} - \mu)^{\beta + 1}}{(\beta + 1)} - \frac{y \ (t_{I} - \mu)^{\beta + 2}}{2 \ (\beta + 2)} - \frac{c \ (t_{I} - \mu)^{\beta + 3}}{3 \ (\beta + 3)} \right) \right) \qquad \dots (16)$$

(5) Shortage Cost

$$SC = -C_{s} \left(\int_{t_{1}}^{t_{2}} Q(t) dt + \int_{t_{2}}^{T} Q(t) dt \right)$$

$$= -C_{s} \left(\left(a t_{1} + \frac{b}{2} t_{1}^{2} + \frac{c}{3} t_{1}^{3} \right) (t_{2} - t_{1}) - \frac{a}{2} (t_{2}^{2} - t_{1}^{2}) - \frac{b}{6} (t_{2}^{3} - t_{1}^{3}) - \frac{c}{12} (t_{2}^{4} - t_{1}^{4}) - \left((p - a) T - \frac{b T^{2}}{2} - \frac{c T^{3}}{3} \right) (T - t_{2}) + \frac{(p - a)}{2} (T^{2} - t_{2}^{2}) \qquad \dots (17)$$

$$- \frac{b}{6} (T^{3} - t_{2}^{3}) - \frac{c}{12} (T^{4} - t_{2}^{4}) \right)$$

Hence, the average total cost per unit time is

$$TC = \frac{1}{T} \left[A + IHC + DC + SC + PC \right]$$



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$$= \frac{1}{T} \begin{cases} + C_{4} \left[\left(p - a \right) \frac{\mu^{2}}{2} - \frac{b \mu^{3}}{6} - \frac{(p - a) \alpha \beta \mu^{\beta + 2}}{(\beta + 1) (\beta + 2)} + \frac{\alpha \beta b \mu^{\beta + 3}}{2 (\beta + 2) (\beta + 3)} \right] \\ + r \left[(p - a) \frac{\mu^{3}}{3} - \frac{b \mu^{4}}{8} - \frac{(p - a) \alpha \beta \mu^{\beta + 3}}{(\beta + 1) (\beta + 3)} + \frac{\alpha \beta b \mu^{\beta + 4}}{2 (\beta + 2) (\beta + 4)} \right] \\ + (h + r \mu) \left[S_{1} \left((t_{1} - \mu) - \frac{\alpha (t_{1} - \mu)^{\beta + 1}}{\beta + 1} \right) - \frac{z (t_{1} - \mu)^{2}}{2} - \frac{y (t_{1} - \mu)^{3}}{6} \right] \\ - \frac{c (t_{1} - \mu)^{4}}{12} + \frac{\alpha \beta z (t_{1} - \mu)^{\beta + 2}}{(\beta + 1) (\beta + 2)} + \frac{\alpha \beta y (t_{1} - \mu)^{\beta + 3}}{2 (\beta + 2) (\beta + 3)} + \frac{\alpha \beta c (t_{1} - \mu)^{\beta + 4}}{3 (\beta + 3) (\beta + 4)} \right] \\ + r \left[S_{1} \left[\frac{(t_{1} - \mu)^{2}}{2} - \frac{\alpha (t_{1} - \mu)^{\beta + 2}}{(\beta + 1) (\beta + 3)} + \frac{\alpha \beta y (t_{1} - \mu)^{\beta + 3}}{2 (\beta + 2) (\beta + 4)} + \frac{\alpha \beta c (t_{1} - \mu)^{4}}{8} - \frac{c(t_{1} - \mu)^{5}}{15} \right] \\ + \frac{\alpha \beta z (t_{1} - \mu)^{\beta + 3}}{(\beta + 1) (\beta + 3)} + \frac{\alpha \beta y (t_{1} - \mu)^{\beta + 4}}{2 (\beta + 2) (\beta + 4)} + \frac{\alpha \beta c (t_{1} - \mu)^{\beta + 5}}{3 (\beta + 3) (\beta + 5)} \right] \\ + C_{4} \left\{ \left[\alpha \beta \left(\frac{(p - a) \mu^{\beta + 1}}{\beta + 1} - \frac{b \mu^{\beta + 2}}{2 (\beta + 2)} + \frac{S_{1}(t_{1} - \mu)^{\beta}}{\beta} - \frac{z (t_{1} - \mu)^{\beta + 1}}{(\beta + 1)} \right] \\ - \frac{y (t_{1} - \mu)^{\beta^{\beta + 2}}}{2 (\beta + 2)} - \frac{c (t_{1} - \mu)^{\beta + 3}}{3 (\beta + 3)} \right] \\ - C_{8} \left\{ \left[\left(a t_{1} + \frac{b}{2} t_{1}^{2} + \frac{c}{3} t_{1}^{3} \right] (t_{2} - t_{1}) - \frac{a}{2} (t_{2}^{2} - t_{1}^{2}) - \frac{b}{6} (t_{2}^{3} - t_{1}^{3}) - \frac{c}{12} (t_{1}^{4} - t_{1}^{4}) - \frac{c}{12} (T^{4} - t_{2}^{4}) \right] \right\} \\ + C_{9} (\mu + T - t_{2}) p$$
...(18)

Our objective is to determine optimum values t_1^* and T^* of t_1 and T respectively so that TC is minimum. Note that t_1^* and T * are the solutions of the equations

$$\frac{\partial (\mathrm{TC})}{\partial t_1} = 0 \& \frac{\partial (\mathrm{TC})}{\partial \mathrm{T}} = 0 \qquad \dots (19)$$

$$\left(\frac{\partial^{2} TC}{\partial t_{1}^{2}} \right) \left(\frac{\partial^{2} TC}{\partial T^{2}} \right) - \left(\frac{\partial^{2} TC}{\partial t_{1} \partial T} \right)^{2} \right]_{t_{1} = t_{1}^{*}, T = T^{*}} > 0$$

$$\frac{\partial^{2} TC}{\partial t_{1}^{2}} \right]_{t_{1} = t_{1}^{*}, T = T^{*}} > 0$$

$$\dots (20)$$

The optimal solution of the equations in (19) can be obtained by using Mathematica software. The above developed model is illustrated by the means of the following numerical example.



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V. NUMERICAL EXAMPLE

Let us consider the following example to illustrate the above developed model. We consider the following values of the parameters A = 200, α = 0.0001, β = 4, h = 6, r = 1.5, C_s = 3, C_d = 5, p =2500, C_p = 7, a = 2, b = 1.7, c = 0.1 & μ = 7 (with appropriate units of measurement). We obtain the optimal values t_1^* = 12.516462527627823 and T *= 54.750912148555784 units and optimal total cost TC = 22732.871686290677 units.

VI. SENSITIVITY ANALYSIS

Sensitivity analysis helps in identifying the effect of optimal solution of the model by the changes in its parameter values. In this section, we study the sensitivity of total cost per time unit TC with respect to the changes in the values of the parameters A, α , β , h, r, C_s, C_d, p, C_p, a, b, c and μ .

The sensitivity analysis is performed by considering 10% and 20% increase and decrease in each one of the above parameters keeping all other remaining parameter as fixed. The results are presented in **Table** – **1**. The last column of table shows the % change in TC as compared to the original solution corresponding to the change in parameters values.

Parameter	% change	Values	t ₁	Т	Min. TC	% change in Min. TC
A	- 20	160	12.51641	54.7502	22732.1	- 0.0035
	- 10	180	12.51644	54.7505	22732.5	- 0.0018
	10	220	12.51649	54.7513	22733.2	0.00132
	20	240	12.51651	54.7517	22733.6	0.00308
α	- 20	0.00008	12.59351	54.9154	22884.7	0.66775
	- 10	0.00009	12.55436	54.8332	22808.7	0.33344
	10	0.00011	12.47977	54.6685	22656.9	- 0.3343
	20	0.00012	12.44422	54.5859	22580.8	- 0.6691
β	- 20	3.2	12.84248	55.3743	23306.3	2.52234
	- 10	3.6	12.72472	55.1697	23118.5	1.69622
	10	4.4	12.20145	53.8862	21935.5	- 3.5077
	20	4.8	11.80196	52.049	20263.7	- 10.862
h	- 20	4.8	12.61831	53.4181	21452.7	- 5.6315
	- 10	5.4	12.56726	54.0933	22096.8	- 2.7981
	10	6.6	12.46599	55.3922	23361.3	2.76428
	20	7.2	12.41588	56.0184	23982.5	5.49688
r	- 20	1.2	12.89825	53.2347	21252.1	- 6.5139
	- 10	1.35	12.70074	54.0039	21998.3	- 3.2314
	10	1.65	12.34456	55.4774	23456.5	3.18305
	20	1.8	12.18412	56.185	24169.9	6.32123
Cs	- 20	2.4	12.04783	58.1247	21529.6	- 5.2932
	- 10	2.7	12.29687	56.3207	22155.2	- 2.5413
	10	3.3	12.51646	54.7509	23289.2	2.44711
	20	3.6	12.88452	52.1317	23772.3	4.57223
C _d	- 20	4	12.51514	54.6872	22671.5	- 0.2701
	- 10	4.5	12.5158	54.7191	22702.2	- 0.135
	10	5.5	12.51712	54.7827	22763.5	0.13461
	20	6	12.51777	54.8144	22794.1	0.26921



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р	- 20	2000	12.26263	51.8364	19292.8	- 15.133
	- 10	2250	12.39725	53.3492	21039.2	- 7.4504
	10	2750	12.62312	56.0588	24380.7	7.24853
	20	3000	12.71935	57.2862	25988	14.3189
C _p	- 20	5.6	12.47311	54.6441	22083.1	-2.8584
	- 10	6.3	12.4949	54.6981	22408	- 1.4292
	10	7.7	12.53781	54.8027	23057.6	1.42833
	20	8.4	12.55893	54.8534	23382.4	2.85709
a	- 20	1.6	12.51857	54.7748	22714.1	-0.0827
	- 10	1.8	12.51752	54.7629	22723.5	- 0.0413
	10	2.2	12.51541	54.739	22742.3	0.04135
	20	2.4	12.51436	54.727	22751.6	0.08226
b	- 20	1.36	12.58267	55.5429	22289.5	- 1.9505
	- 10	1.53	12.54932	55.1416	22513.2	- 0.9664
	10	1.87	12.4841	54.3705	22948.7	0.94928
	20	2.04	12.45222	54	23160.7	1.88185
c	- 20	0.08	12.68717	56.8871	21931.4	- 3.5257
	- 10	0.09	12.59842	55.7588	22345.1	- 1.7059
	10	0.11	12.44035	53.8423	23098.2	1.60692
	20	0.12	12.36931	53.0169	23443.8	3.12719
μ	- 20	5.6	11.05549	47.4194	16331.8	- 28.158
	- 10	6.3	11.79522	51.1599	19461.6	- 14.39
	10	7.7	13.21889	58.1414	26047.2	14.5793
	20	8.4	13.90073	61.2535	29266.9	28.7425

Table – 1 Sensitivity Analysis







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The effect of the percentage change in the values of parameters on the percentage change in minimum total cost is presented in the graphical presentation of sensitivity analysis of the model parameters.

VIII. CONCLUSION

From the above sensitivity analysis we may conclude that the average total cost per unit time TC is highly sensitive to changes in the values of the parameters μ and p moderately sensitive to changes in the value of the parameters β , h, r, C_s and less sensitive to changes in the values of the parameters C_p, c, b, α , C_d, a and A.

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