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ECONOMIC ORDER QUANTITY MODEL FOR DETERIORATING ITEMS WITH TRADE CREDIT FINANCING AND RAMP TYPE DEMAND UNDER SHORTAGES

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ABSTRACT

In this paper an inventory model is developed for ramp type dependent demand rate with the trade credit period. The shortages are allowed which is partially backlogged in the presented model. It is observed the effect of deterioration rate and different conditions of permissible delay period are discussed here. The mathematical models and cost functions for three different conditions based on permissible delay period and available money at the time of payment are derived. With the help of numerical example an optimal cost and ordering quantity are computed. A sensitivity analysis with respect to different associated system parameters have also been carried out to check the stability of the model. The numerical example shows that the model is applicable in real life situations.

KEYWORDS: Inventory, Deterioration, Ramp type demand, Permissible delay, Shortages, Partial backlogging.

1. INTRODUCTION

Economic order quantity in the inventory model is optimal ordering quantity in one batch which minimizes the total relevant cost. Inventory plays an important role in many different companies such as retail infrastructure, manufacturing distribution, industries etc. because a big amount of capital tied up in the inventory where the demand can play an important role to obtain the best inventory policy. Many research studies have been disclosed the different rates of demand such as constant rate, linearly increase or decrease demand rate, exponential increasing or decreasing demand rate etc. but assuming this rates are not prominent for the items which are fashionable, cosmetics ,electronic goods, fruits etc. However, demand of a commodity cannot increase/decrease continuously over time. It is observed that demand in the beginning of the season demand increases more rapidly, as the time passes, it becomes steady in the middle of the season and it decreases more rapidly towards the end of the pattern. In order to consider demand of such types, the concept of ramp-type demand is introduced. Ramp-type demand depicts a demand which increases up to a certain time after which it stabilizes and becomes constant. It is obvious that any ramp type demand function has at least one break point l between two time segments at which is not differentiable. This non-differentiable break point l makes the analysis of the problem more complicated. This has urged researchers to study inventory models with ramp type demand patterns.

After the EOQ model by **Wilson (1934)** under the assumption of constant demand rate, researchers extensively studied several aspects of inventory and supply chain modeling by assuming time dependent demand rate. **Hill (1995)** proposed an inventory model with variable branch being any power function of time. Research on this field continues with **Mandal and Pal (1998), Wu and Ouyang (2000) and Wu (2001). Wu and Ouyang (2000)** studied inventory models under two different replenishment policies: (i) those starting with no shortages and (b) those starting with shortages. **Chen et al. (2006)** derived optimal ordering quantity model with ramp type demand rate and time dependent deterioration rate. **Teng et al. (2011)** developed inventory model with ramp type demand rate assuming that shortages are partial backlogged for the items following Weibull deterioration rate. **Tripathy and Mishra (2011)** discussed an EOQ model with time dependent Weibull deterioration and ramp type demand. **Jalan, Giri & Chaudhuri (2001)** developed EOQ Ramp-type demand with Weibull rate of deterioration shortages allowed EOQ is given by Numerical Technique EOQ cannot be obtained analytically where Holding cost is constant. **Skouri & Konstantara (2009)** obtained an EOQ model with Ramp-type demand, Under Weibull rate of deterioration, with shortages and without shortages. An exact solution for EOQ is obtained with Holding cost is constant. **Jain & Kumar (2010)** considered a EOQ model with Ramp-type demand, three –parameter Weibull rate of deterioration, where shortages are allowed. **Dhagat *et al.* (2012)** studied an EOQ inventory model with ramp type demand for the items having generalized Weibull

International Journal of Engineering Researches and Management Studies

distribution deterioration to deal with shortages. **Garg *et al.* (2012)** developed an economic production lot size model with price discounting for non-instantaneous deteriorating items with ramp-type production and demand rates. **Singh and Singh (2010)** discussed a supply chain model with stochastic lead time under imprecise partially backlogging and fuzzy ramp type demand for expiring items.

Maintenance of inventories of deteriorating items is a problem of major concern in the supply chain of almost any business organizations. Many of the physical goods undergo decay or deterioration over time. The inventory lot-size problem for deteriorating items is prominent due to its important connection with commonly used items in daily life. Fruits, vegetables, meat, photographic films, etc are the examples of deteriorating products. Deteriorating items are often classified in terms of their life time or utility as a function of time while in stock. A model with exponentially decaying inventory was initially proposed by **Ghare and Schrader (1963). Covert and Phillip (1973)** developed an EOQ model with Weibull distributed deterioration rate. Thereafter, a great deal of research efforts have been devoted to inventory models of deteriorating items, and the details are discussed in the review article by **Raafat (1991)** and in the review article of inventory models considering deterioration with shortages by **Karmakar and Dutta Choudhury (2010). Gupta and Vrat (1986)** developed an inventory model where demand rate is replenishment size (initial stock) dependent. They analyzed the model through cost minimization. **Pal et al.(1993) Datta and Pal (1990)** have focused on the analysis of the inventory system which describes the demand rate as a power function, dependent on the level of the on hand inventory. **Samanta and Roy (2004)** developed a production control inventory model for deteriorating items with shortages when demand and production rates are constant, and they studied the inventory model for a number of structural properties of the inventory system with the exponential deterioration.

In today's competitive business transactions, it is common for the supplier to offer a certain fixed credit period to the retailer for stimulating demand. During this credit period the retailer can accumulate the revenue and earn interest on that revenue. However, beyond this period the supplier charges interest on the unpaid balance. Hence, a permissible delay indirectly reduces the cost of holding stock. On the other hand, trade credit offered by the supplier encourages the retailer to buy more. However this is important and relevant problem has not drawn much attention in literature so far.

Inventory policy with trade credit financing was formulated by **Haley and Higgins (1973)**. **Goyal (1985)** was the first to develop the economic order quantity under conditions of permissible delay in payments developed the optimal pricing and ordering policies for items under permissible delay. **Misra (1975, 1979)** also developed a discount model in which the effect of both inflation and time value of money was considered.

Teng, (1999) considered the EOQ under condition of permissible delay in payment which is further extended by **Chung et al. (2004)** for limited storage capacity. **Singh and Singh (2007)** developed an inventory model having linear demand rate under permissible delay in payments with constant rate of deterioration. Further **Singh and Singh (2009)** developed an inventory model having quadratic time dependent demand rate with variable rate of deterioration and trade credit. **Aggarwal and Jaggi (1995)** developed ordering policies of deteriorating items under permissible delay in payments. **Abad and Jaggi (2003)** considered the seller–buyer channel in which the end demand was price sensitive and the seller may offer trade credit to the buyer. **Singh et al (2009)** formulate an integrated supply chain model with multivariate demand under progressive credit period for deteriorating items. **Singh and Shruti (2012)** formulate the Integrated Inventory Model with the supplier's offer a trade credit. The main objective of the present paper is to investigate the optimal result such that total cost as minimized during finite planning horizon. **Singh et al (2013)** formulates an inventory model for deteriorating items, where demand depends on selling price and credit period offered by the retailer to the customers. **Shah et al (2015)** analyzed the retailer's decision for ordering and credit policies when a supplier offers its retailer either a cash discount or a fixed credit period if the order quantity is greater than or equal to regular order policy.

Assumptions:

1. The products assumed in this model are deteriorating in nature.
2. The deterioration rate is a linear function of time.
3. Demand rate D(t) is assumed to be a ramp type function and given by

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$$D(t) = a[t - (t-\mu)H(t-\mu)]$$

Where

$$H(t-\mu) = \begin{cases} 1 & if \quad t \geq \mu \\ 0 & if \quad t < \mu \end{cases}$$

4. The shortages are allowed and partially backlogged.
5. A permissible delay period 'M' is allowed by the vendor to the retailer.
6. If the retailer does not pay by 'M' then an interest at the rate of I_c will be charged to the retailer on unpaid amount.

Notations:

a	initial demand rate
µ	the time upto which demand rate increases
K	deterioration coefficient, 0<K<<1
T	cycle time
v	the time at which inventory level becomes zero
Q_1	initial inventory level
Q_2	the backordered quantity
η	rate of backlogging, $0 < \eta < 1$
c_1	purchasing cost per unit
p	selling price per unit
h	holding cost per unit
c_2	ordering cost per order
c_3	deterioration cost per unit
c_4	shortage cost per unit
c_5	lost sale cost per unit
I_e	rate of interest earned
I_c	rate of interest charged, $I_c > I_e$
M	permissible delay period up to which no interest will be charged

2. Mathematical Modeling

In this model the retailer receives the order quantity of Q_1 units. The inventory level depletes due to demand and deterioration during [0,v]. Since the demand rate follows a ramp type function, so it increases up to t=µ and after that it becomes constant. At t=v the inventory level becomes zero and shortages occurs. The differential equations governing the transition of the system are given as follow:

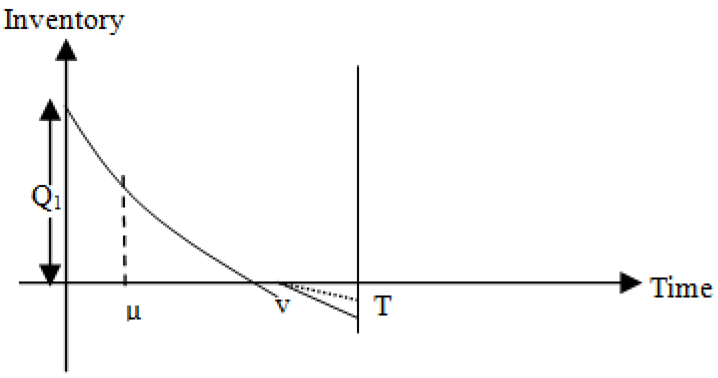

Fig. 1: Inventory time graph for the retailer

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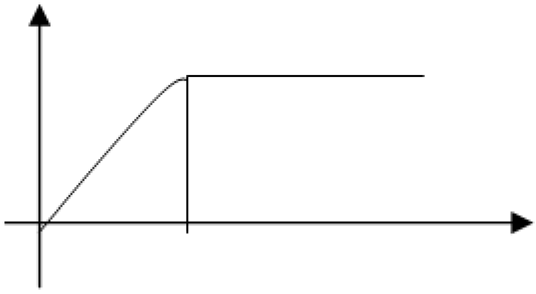

Fig. 2: ramp type demand pattern

$$\frac{dI_1(t)}{dt} = -KtI_1(t) - at \qquad 0 \le t \le \mu \qquad (1)$$

$$\frac{dI_2(t)}{dt} = -KtI_2(t) - a\mu \qquad \mu \le t \le v \qquad (2)$$

$$\frac{dI_3(t)}{dt} = -a\mu \qquad v \le t \le T \qquad (3)$$

with boundary conditions:

$$I_1(\mu) = I_2(\mu), \ \ I_2(v) = 0 \qquad (4)$$

Solving these equations with the help of boundary conditions we get:

$$I_1(t) = [a\mu\{(v-\mu) + \frac{K}{6}(v^3 - \mu^3)\} + a\{(\frac{\mu^2}{2} - \frac{t^2}{2}) + \frac{K}{8}(\mu^4 - t^4)\}]e^{-K\frac{t^2}{2}}$$

$$0 \le t \le \mu \qquad (5)$$

$$I_2(t) = [a\mu\{(v-t) + \frac{K}{6}(v^3 - t^3)\}]e^{-K\frac{t^2}{2}} \qquad \mu \le t \le v \qquad (6)$$

$$I_3(t) = a\mu(v-t) \qquad v \le t \le T \qquad (7)$$

Now from equation (5):

$$Q_1 = I_1(0) = [a\mu\{(v-\mu) + \frac{K}{6}(v^3 - \mu^3)\} + a\{\frac{\mu^2}{2} + \frac{K}{8}\mu^4\}] \qquad (8)$$

Different Associated Cost

Purchasing Cost $= (I_1(0) + Q_2)c_1$

Where $Q_2 = \int_v^T a\mu\eta \, dt$

$$Q_2 = a\mu\eta(T-v)$$

$$P.C. = [a\mu\{(v-\mu) + \frac{K}{6}(v^3 - \mu^3)\} + a(\frac{\mu^2}{2} + \frac{K}{8}\mu^4) + a\mu\eta(T-v)]c_1 \qquad (9)$$

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Holding Cost = $h[\int_0^{\mu} I_1(t)\,dt + \int_{\mu}^{v} I_2(t)\,dt]$

$$H.C. = h[a\mu\{(v-\mu)\mu + \frac{K}{6}(v^3-\mu^3)\mu\} + a(\frac{\mu^3}{3} + \frac{K}{10}\mu^5) - \frac{a\mu K}{2}(v-\mu)\frac{\mu^3}{3} - \frac{aK}{30}\mu^5$$
$$+a\mu(\frac{v^2}{2} + \frac{K}{8}v^4) - \frac{K}{24}a\mu v^4 - a\mu\{(v\mu - \frac{\mu^2}{2}) + \frac{K}{6}(v^3\mu - \frac{\mu^4}{4})\} + \frac{K}{2}a\mu(\frac{v\mu^3}{3} - \frac{\mu^4}{4})] \quad (10)$$

Ordering Cost = c_2 (11)

Deterioration Cost = $c_3[I_1(0) - \int_0^{\mu} at\,dt - \int_{\mu}^{v} a\mu\,dt]$

$$D.C. = c_3[a\mu\{(v-\mu) + \frac{K}{6}(v^3-\mu^3)\} + a(\frac{\mu^2}{2} + \frac{K}{8}\mu^4) - a\frac{\mu^2}{2} - a\mu(v-\mu)] \quad (12)$$

Shortage Cost = $c_4 \int_v^T a\mu\,dt$

$$S.C. = c_4 a\mu(T-v) \quad (13)$$

Lost Sale Cost = $c_5 \int_v^T (1-\eta)a\mu\,dt$

$$L.S.C. = c_5(1-\eta)a\mu(T-v) \quad (14)$$

Now based on permissible trade credit period two different cases arise:
Case 1: When trade credit period $M \geq v$
Case 2: When trade credit period $M < v$
Case 2.1: $p.D[0,M] + I.E[0,M] \geq c_1 Q_1$
Case 2.2: $p.D[0,M] + I.E[0,M] < c_1 Q_1$

Case 1: When trade credit period $M \geq v$

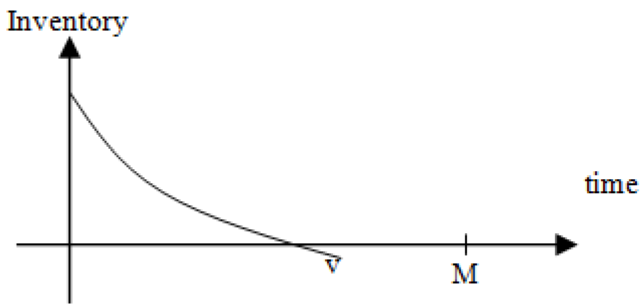

Fig. 3: When trade credit period $M \geq v$

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In this case the retailer has enough money to pay all the amount at t=M, so interest charged in this case will be zero.

$$I.C_1 = 0 \tag{15}$$

Interest Earned =

$$pI_e[\int_0^\mu t\,at\,dt + \int_\mu^v a\mu t\,dt + (M-v)\{\int_0^\mu at\,dt + \int_\mu^v a\mu\,dt\}]$$

$$I.E_1 = pI_e[\frac{a\mu^3}{3} + \frac{a\mu}{2}(v^2-\mu^2) + (M-v)(\frac{a\mu^2}{2} + a\mu(v-\mu))] \tag{16}$$

Case 2: When $M < v$

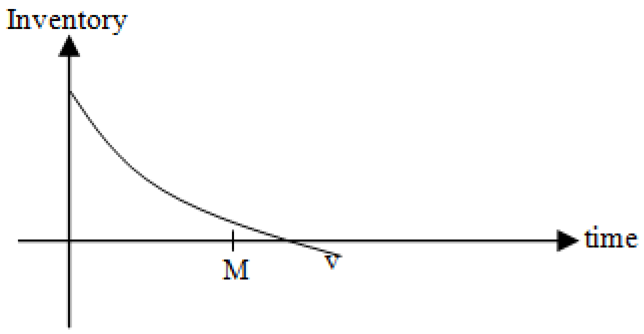

Fig. 4: When trade credit period $M < v$

Case 2.1: When $M < v$ **and** $p.D[0,M] + I.E[0,M] \geq c_1 Q_1$**:**

In this case the retailer has enough money at t=M, so interest charged in this case will also be zero.

$$I.C_{2.1} = 0 \tag{17}$$

Interest Earned $= pI_e[\int_0^\mu t\,at\,dt + \int_\mu^M t\,a\mu\,dt + \int_M^v t\,a\mu\,dt]$

$$I.E_2 = pI_e[\frac{a\mu^3}{3} + \frac{a\mu}{2}(M^2-\mu^2) + \frac{a\mu}{2}(v^2-M^2)] \tag{18}$$

Case 2.2: When $M < v$ **and** $p.D[0,M] + I.E[0,M] < c_1 Q_1$**:**

In this case the available money to the retailer is not enough to settle the account at t=M. So an interest will be charged on balanced unpaid amount.

If 'U' represents the unpaid amount then:

$$U = c_1Q_1 - pD[0,M] - I.E_2[0,M]$$

$$U = c_1Q_1 - pa\frac{\mu^2}{2} - pa\mu(M-\mu) - pI_e(\frac{a\mu^3}{3} + \frac{a\mu}{2}(M^2-\mu^2)) \tag{19}$$

Then interest charged in this case will be:

$$I.C_{2.2} = U(v-M)I_c \tag{20}$$

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Now the T.A.C. in different cases is given by:

$$T.A.C_1 = P.C. + H.C. + D.C. + O.C. + S.C. + L.S.C. - I.E_1$$

$$T.A.C_1 = \frac{1}{T}[\{a\mu\{(v-\mu)+\frac{K}{6}(v^3-\mu^3)\}+a(\frac{\mu^2}{2}+\frac{K}{8}\mu^4)+a\mu\eta(T-v)\}c_1+h\{a\mu\{(v-\mu)\mu+\frac{K}{6}(v^3-\mu^3)\mu\}+$$
$$a(\frac{\mu^3}{3}+\frac{K}{10}\mu^5)-\frac{a\mu K}{2}(v-\mu)\frac{\mu^3}{3}-\frac{aK}{30}\mu^5+a\mu(\frac{v^2}{2}+\frac{K}{8}v^4)-\frac{K}{24}a\mu v^4-a\mu\{(v\mu-\frac{\mu^2}{2})$$
$$+\frac{K}{6}(v^3\mu-\frac{\mu^4}{4})\}+\frac{K}{2}a\mu(\frac{v\mu^3}{3}-\frac{\mu^4}{4})\}+c_2+c_3\{a\mu\{(v-\mu)+\frac{K}{6}(v^3-\mu^3)\}+a(\frac{\mu^2}{2}+\frac{K}{8}\mu^4)$$
$$-a\frac{\mu^2}{2}-a\mu(v-\mu)\}+c_5(1-\eta)a\mu(T-v)+pI_e\{\frac{a\mu^3}{3}+\frac{a\mu}{2}(v^2-\mu^2)+(M-v)(\frac{a\mu^2}{2}+a\mu(v-\mu))\}] \tag{21}$$

$$T.A.C_{2.1} = \frac{1}{T}[\{a\mu\{(v-\mu)+\frac{K}{6}(v^3-\mu^3)\}+a(\frac{\mu^2}{2}+\frac{K}{8}\mu^4)+a\mu\eta(T-v)\}c_1+h\{a\mu\{(v-\mu)\mu+\frac{K}{6}(v^3-\mu^3)\mu\}+$$
$$a(\frac{\mu^3}{3}+\frac{K}{10}\mu^5)-\frac{a\mu K}{2}(v-\mu)\frac{\mu^3}{3}-\frac{aK}{30}\mu^5+a\mu(\frac{v^2}{2}+\frac{K}{8}v^4)-\frac{K}{24}a\mu v^4-a\mu\{(v\mu-\frac{\mu^2}{2})$$
$$+\frac{K}{6}(v^3\mu-\frac{\mu^4}{4})\}+\frac{K}{2}a\mu(\frac{v\mu^3}{3}-\frac{\mu^4}{4})\}+c_2+c_3\{a\mu\{(v-\mu)+\frac{K}{6}(v^3-\mu^3)\}+a(\frac{\mu^2}{2}+\frac{K}{8}\mu^4)$$
$$-a\frac{\mu^2}{2}-a\mu(v-\mu)\}+c_5(1-\eta)a\mu(T-v)+pI_e\{\frac{a\mu^3}{3}+\frac{a\mu}{2}(M^2-\mu^2)+\frac{a\mu}{2}(v^2-M^2)] \tag{22}$$

$$T.A.C_{2.2} = \frac{1}{T}[\{a\mu\{(v-\mu)+\frac{K}{6}(v^3-\mu^3)\}+a(\frac{\mu^2}{2}+\frac{K}{8}\mu^4)+a\mu\eta(T-v)\}c_1+h\{a\mu\{(v-\mu)\mu+\frac{K}{6}(v^3-\mu^3)\mu\}+$$
$$a(\frac{\mu^3}{3}+\frac{K}{10}\mu^5)-\frac{a\mu K}{2}(v-\mu)\frac{\mu^3}{3}-\frac{aK}{30}\mu^5+a\mu(\frac{v^2}{2}+\frac{K}{8}v^4)-\frac{K}{24}a\mu v^4-a\mu\{(v\mu-\frac{\mu^2}{2})$$
$$+\frac{K}{6}(v^3\mu-\frac{\mu^4}{4})\}+\frac{K}{2}a\mu(\frac{v\mu^3}{3}-\frac{\mu^4}{4})\}+c_2+c_3\{a\mu\{(v-\mu)+\frac{K}{6}(v^3-\mu^3)\}+a(\frac{\mu^2}{2}+\frac{K}{8}\mu^4)$$
$$-a\frac{\mu^2}{2}-a\mu(v-\mu)\}+c_5(1-\eta)a\mu(T-v)-pI_e\frac{a\mu}{2}(v^2-M^2)+I_c\{c_1Q_1-pa\frac{\mu^2}{2}-pa\mu(M-\mu)-$$
$$pI_e(\frac{a\mu^3}{3}+\frac{a\mu}{2}(M^2-\mu^2))\}(v-M)] \tag{23}$$

3. Numerical Example

Case 1: $M \geq v$

$T=30\,days,\ a=50\,units,\ \mu=10\,days,\ K=0.001,\ \eta=0.5,\ c_1=12\,rs/unit,\ h=0.2\,rs/unit,\ c_2=500\,rs/order$

$c_3=13\,rs/unit,\ c_4=6\,rs/unit,\ c_5=8\,rs/unit,\ p=18\,rs/unit,\ I_e=0.025,\ M=35\,days$

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Corresponding to these values the optimal values of v and T.A.C. comes out to be 22.7182 days and Rs 3734.57 respectively. The optimal value of ordered quantity in this case will be 11635.8 units.

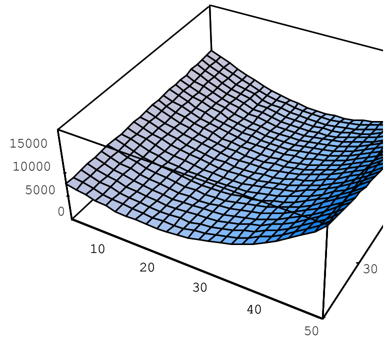

Fig. 5: Convexity of the T.A.C. function (case 1)

Case 2.1: When $M < v$ **and** $p.D[0,M]+I.E[0,M] \geq c_1 Q_1$ **:**

$$T = 30\,days,\ a = 50\,units,\ \mu = 10\,days,\ K = 0.001,\ \eta = 0.5,\ c_1 = 12\,rs/unit,\ h = 0.2\,rs/unit,\ c_2 = 500\,rs/order$$
$$c_3 = 13\,rs/unit,\ c_4 = 6\,rs/unit,\ c_5 = 8\,rs/unit,\ p = 18\,rs/unit,\ I_e = 0.025,\ M = 15\,days$$

Corresponding to these values the optimal values of v and T.A.C. comes out to be 27.56 days and Rs 5262.41 respectively. The optimal value of ordered quantity in this case will be 13613.6 units.

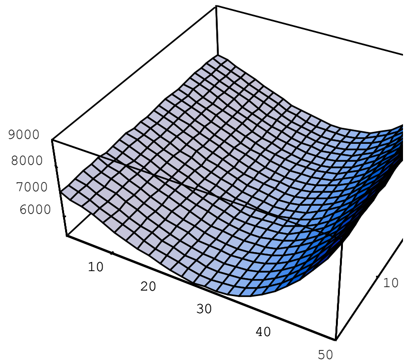

Fig. 6: Convexity of the T.A.C. function (case 2.1)

Case 2.2: When $M < v$ **and** $p.D[0,M]+I.E[0,M] < c_1 Q_1$ **:**

$$T = 30\,days,\ a = 50\,units,\ \mu = 10\,days,\ K = 0.001,\ \eta = 0.5,\ c_1 = 12\,rs/unit,\ h = 0.2\,rs/unit,\ c_2 = 500\,rs/order$$
$$c_3 = 13\,rs/unit,\ c_4 = 6\,rs/unit,\ c_5 = 8\,rs/unit,\ p = 18\,rs/unit,\ I_e = 0.025,\ I_c = 0.035, M = 12\,days$$

Corresponding to these values the optimal values of v and T.A.C. comes out to be 18.434 days and Rs 6097.23 respectively. The optimal value of ordered quantity in this case will be 10109.7 units.

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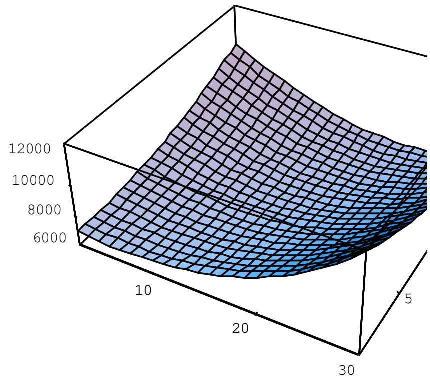

Fig. 7: Convexivity of the T.A.C. function (case 2.2)

Sensitivity Analysis:
Here we check the sensitivity of T.A.C. of the system with respect to different associated parameters taking one at a time.

Case 1: When $M \geq v$

Table 1: Variation in T.A.C. with the variation in 'a':

% variation in a	a	v	T.A.C.
-20%	40	22.7182	2990.99
-15%	42.5	22.7182	3176.88
-10%	45	22.7182	3362.78
-5%	47.5	22.7182	3548.67
0%	50	22.7182	3734.57
5%	52.5	22.7182	3920.46
10%	55	22.7182	4106.36
15%	57.5	22.7182	4292.25
20%	60	22.7182	4478.15

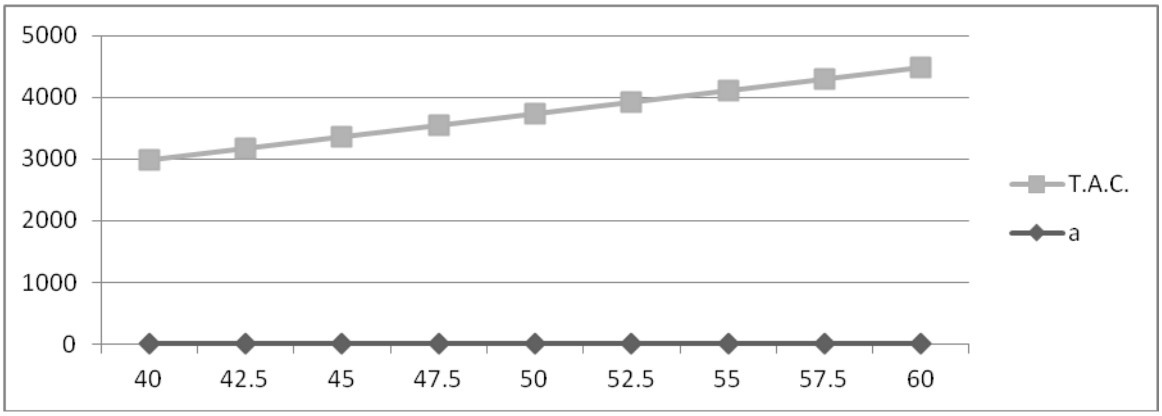

Fig. 8: T.A.C. v/s a

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Table 2: Variation in T.A.C. with the variation in 'K':

% variation in K	K	v	T.A.C.
-20%	0.0008	23.9203	3545.94
-15%	0.00085	23.598	3596.03
-10%	0.0009	23.291	3644.07
-5%	0.00095	22.9981	3690.2
0%	0.001	22.7182	3734.57
5%	0.00105	22.4503	3777.28
10%	0.0011	22.1935	3818.44
15%	0.00115	21.947	3858.17
20%	0.0012	21.71	3896.54

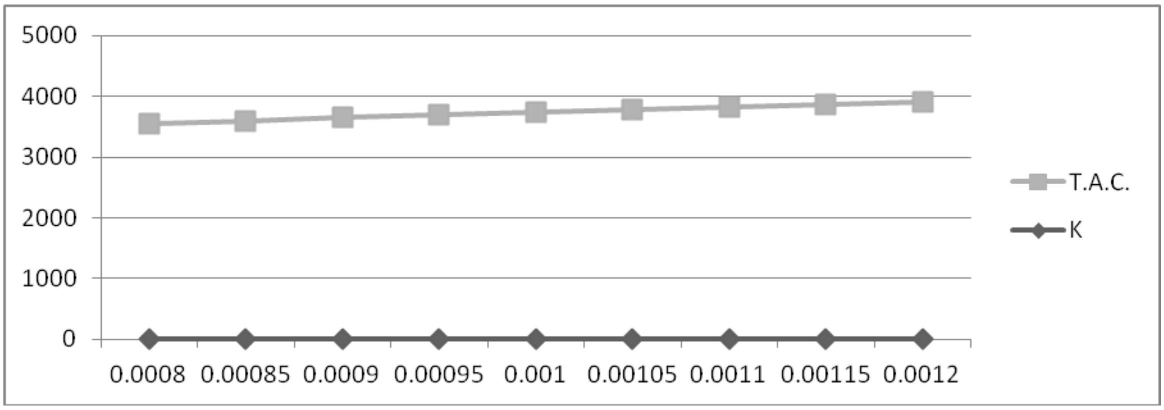

Fig. 9: T.A.C. v/s K

Table 3: Variation in T.A.C. with the variation in 'h':

% variation in h	h	v	T.A.C.
-20%	0.16	23.5542	3551.5
-15%	0.17	23.3394	3598.71
-10%	0.18	23.1286	3644.93
-5%	0.19	22.9216	3690.21
0%	0.2	22.7822	3734.61
5%	0.21	22.5185	3778.03
10%	0.22	22.3222	3820.62
15%	0.23	22.1292	3862.37
20%	0.24	21.9396	3903.29

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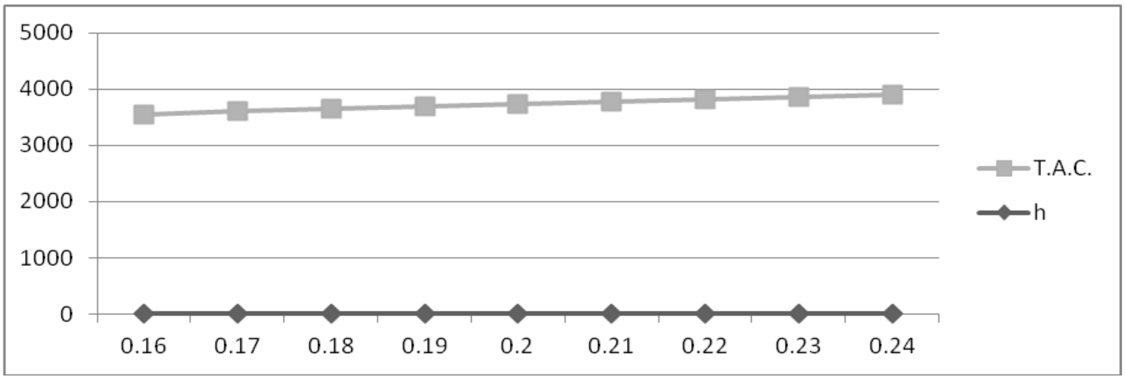

Fig. 10: T.A.C. v/s h

Table 4: Variation in T.A.C. with the variation in 'η':

% variation in η	η	v	T.A.C.
-20%	0.4	22.4143	3685.01
-15%	0.425	22.4905	3697.59
-10%	0.45	22.5665	3710.04
-5%	0.475	22.6425	3722.37
0%	0.5	22.7182	3734.57
5%	0.525	22.7938	3746.64
10%	0.55	22.8693	3758.59
15%	0.575	22.9446	3770.41
20%	0.6	23.0198	3782.1

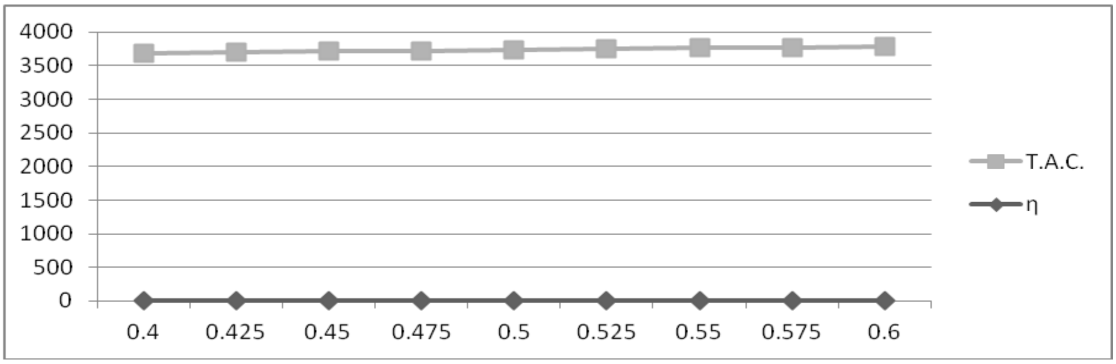

Fig. 11: T.A.C. v/s η

Table 5: Variation in T.A.C. with the variation in 'μ':

% variation in μ	μ	v	T.A.C.
-20%	8	22.3761	3063.31
-15%	8.5	22.4619	3234.59
-10%	9	22.5475	3403.57
-5%	9.5	22.633	3570.24
0%	10	22.7182	3734.57
5%	10.5	22.8033	3896.53
10%	11	22.8882	4056.1
15%	11.5	22.9728	4213.25
20%	12	23.0573	4367.94

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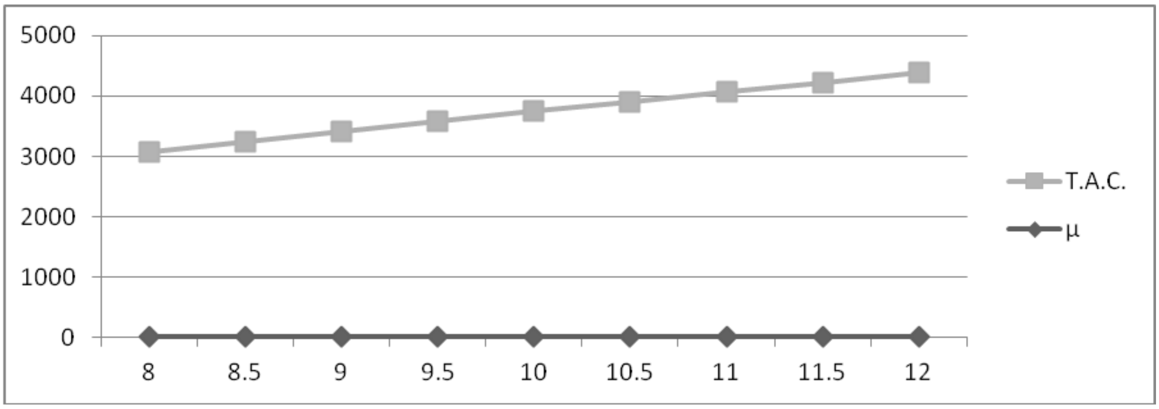

Fig. 12: T.A.C. v/s μ

Table 6: Variation in T.A.C. with the variation in 'p':

% variation in p	p	v	T.A.C.
-20%	14.4	21.4321	4406.5
-15%	15.3	21.7757	4241.82
-10%	16.2	22.1038	4074.85
-5%	17.1	22.4176	3905.72
0%	18	22.7182	3734.57
5%	18.9	23.0066	3561.5
10%	19.8	23.2835	3386.64
15%	20.7	23.5497	3210.08
20%	21.6	23.806	3031.9

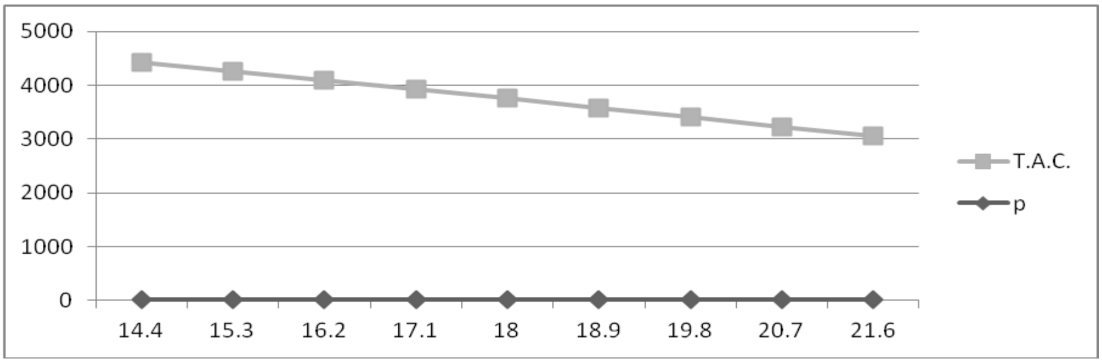

Fig. 13: T.A.C. v/s p

Table 7: Variation in T.A.C. with the variation in 'M':

M	v	T.A.C.
30	20.9763	4366.59
32	21.6826	4121.63
34	22.3761	3866.17
36	23.0573	3600.41
38	23.7269	3324.51
40	24.3862	3038.66
42	25.0327	2743.01
44	25.67	2437.73

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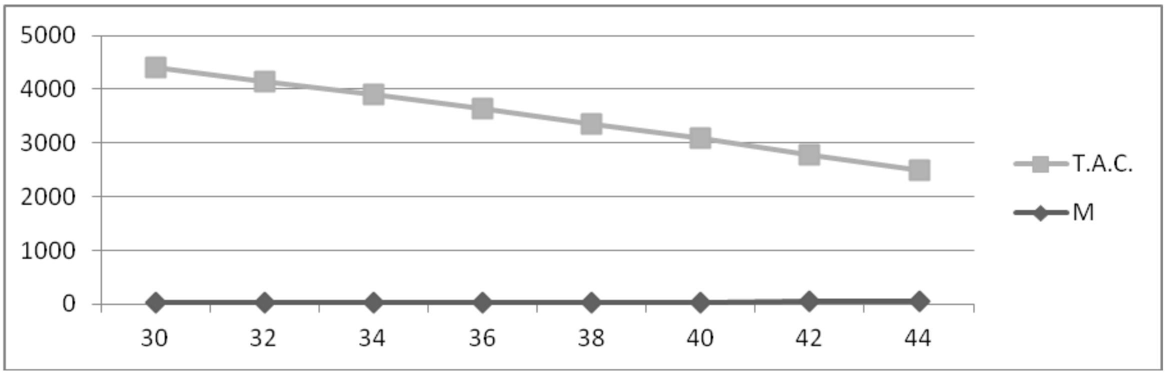

Fig. 14: T.A.C. v/s M

Case 2.1: When $M < v$ **and** $p.D[0,M] + I.E[0,M] \geq c_1 Q_1$ **:**

Table 8: Variation in T.A.C. with the variation in 'a':

% variation in a	a	v	T.A.C.
-20%	40	27.56	4213.27
-15%	42.5	27.56	4475.55
-10%	45	27.56	4737.84
-5%	47.5	27.56	5000.13
0%	50	27.56	5262.41
5%	52.5	27.56	5524.7
10%	55	27.56	5786.99
15%	57.5	27.56	6049.28
20%	60	27.56	6311.56

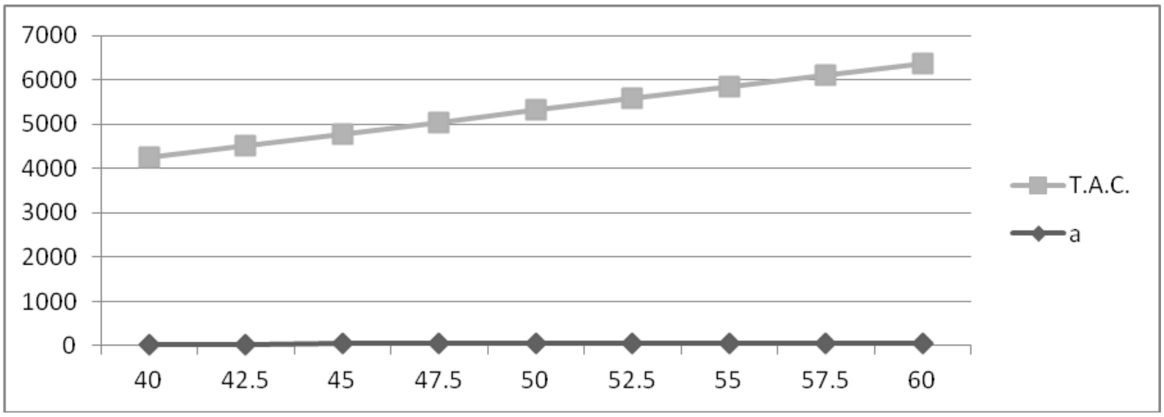

Fig. 15: T.A.C. v/s a

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Table 9: Variation in T.A.C. with the variation in 'K':

% variation in K	K	v	T.A.C.
-20%	0.0008	32.0223	4858.57
-15%	0.00085	30.738	4978.36
-10%	0.0009	29.5776	5084.13
-5%	0.00095	28.5231	5178.2
0%	0.001	27.56	5262.41
5%	0.00105	26.6766	5338.24
10%	0.0011	25.8627	5406.88
15%	0.00115	25.1101	5469.31
20%	0.0012	24.4119	5526.33

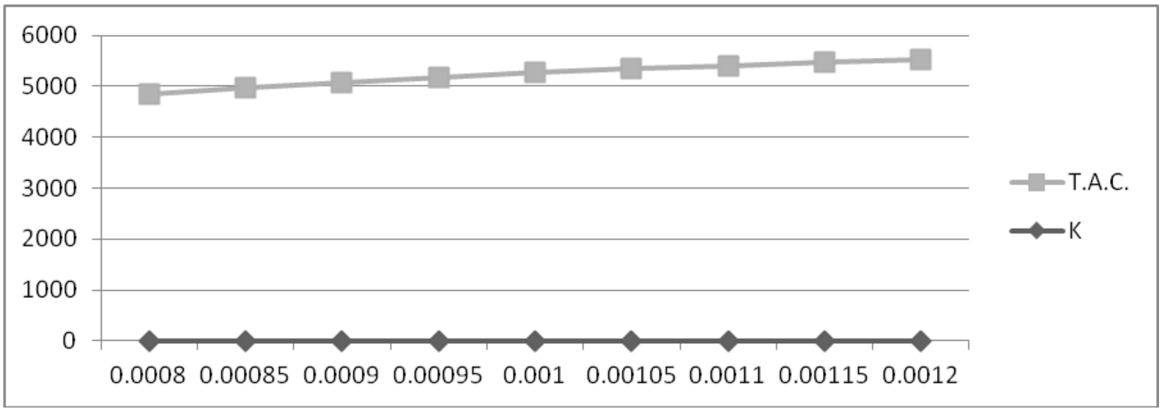

Fig. 16: T.A.C. v/s K

Table 10: Variation in T.A.C. with the variation in 'h':

% variation in h	h	v	T.A.C.
-20%	0.16	30.0165	4959.42
-15%	0.17	29.3792	5040.91
-10%	0.18	28.7578	5118.43
-5%	0.19	28.1516	5192.2
0%	0.2	27.56	5262.41
5%	0.21	26.9825	5329.27
10%	0.22	26.4183	5392.93
15%	0.23	25.8671	5453.56
20%	0.24	25.3283	5511.32

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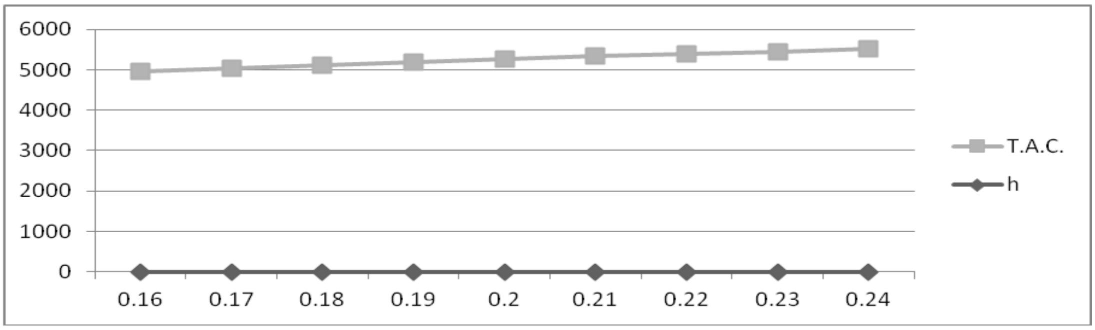

Fig. 17: T.A.C. v/s h

Table 11: Variation in T.A.C. with the variation in 'η':

% variation in η	η	v	T.A.C.
-20%	0.4	26.8686	5243.86
-15%	0.425	27.0443	5248.93
-10%	0.45	27.218	5253.71
-5%	0.475	27.3899	5258.21
0%	0.5	27.56	5262.41
5%	0.525	27.7284	5266.34
10%	0.55	27.8951	5269.99
15%	0.575	28.0601	5273.36
20%	0.6	28.2235	5276.46

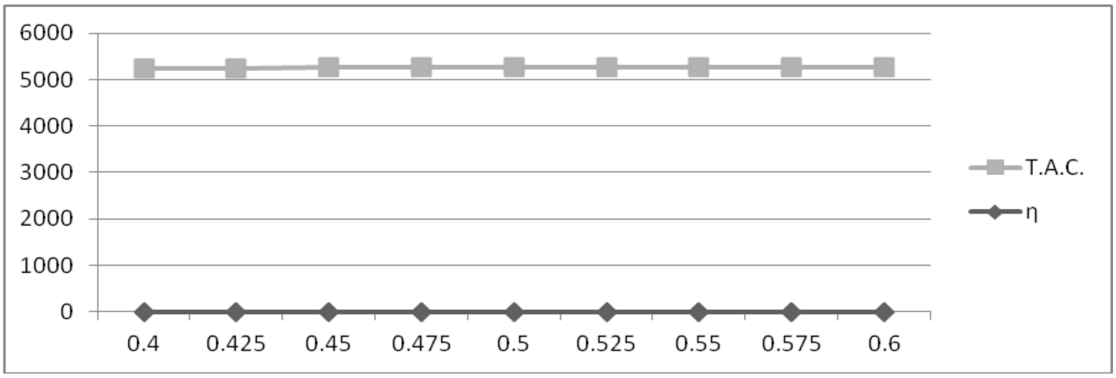

Fig. 18: T.A.C. v/s η

Table 12: Variation in T.A.C. with the variation in 'μ':

% variation in μ	μ	v	T.A.C.
-20%	8	27.56	4360.31
-15%	8.5	27.56	4592.59
-10%	9	27.56	4820.37
-5%	9.5	27.56	5043.65
0%	10	27.56	5262.41
5%	10.5	27.56	5476.68
10%	11	27.56	5686.43
15%	11.5	27.56	5891.65
20%	12	27.56	6092.35

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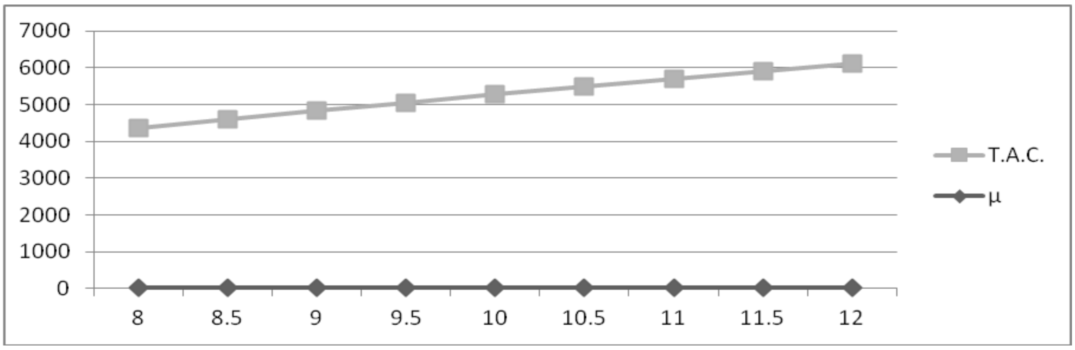

Fig. 19: T.A.C. v/s μ

Table 13: Variation in T.A.C. with the variation in 'p':

% variation in p	p	v	T.A.C.
-20%	14.4	23.4845	5726.15
-15%	15.3	24.4777	5624.57
-10%	16.2	25.4892	5513.79
-5%	17.1	26.5173	5393.44
0%	18	27.56	5262.41
5%	18.9	28.6155	5120.73
10%	19.8	29.6821	4967.67
15%	20.7	30.7581	4802.67
20%	21.6	31.8421	4625.22

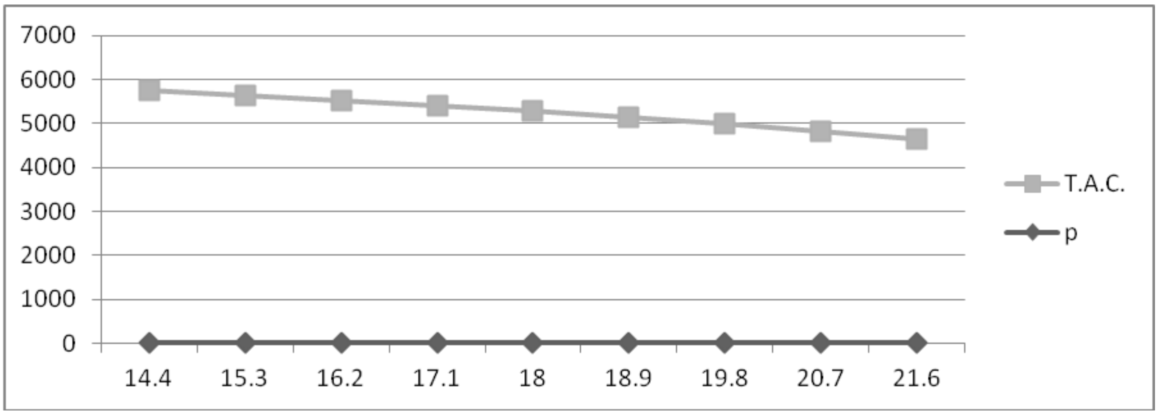

Fig. 20: T.A.C. v/s p

Observations

- Table (1) and table (8) list the variation in demand parameter 'a' and it is observed from these tables that with the increment in demand parameter 'a', the total average cost of the system increases.
- From table (2) and table (9) we observe the variation in deterioration parameter 'K' in different cases and it is observed that as the value of deterioration parameter 'K' increases, the T.A.C. of the system also increases.
- Table (3) and table (10) show the sensitivity in T.A.C. with the variation in holding cost in different cases of trade credit period and it is observed that an increment in holding cost 'h' also show the same effect of increment in T.A.C. of the system.
- Table (4) and table (11) list the variation in backlogging parameter (η), it is observed from these tables that an increment in backlogging parameter lists also an increment in T.A.C. of the system.
- From table (5) and table (12) we observe that as the value of demand parameter 'μ' increases, the T.A.C. of the system also increases due to the increment in purchasing cost.

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- Table (6) and table (13) shows the variation in selling price 'p' and other variables unchanged and it is observed that with the increment in 'p' the T.A.C. of the system shows the reverse effect.
- Table (7) shows the effect of trade credit period 'M' on T.A.C. of the system. It is shown in this table that as the value of trade credit period 'M' increases, the T.A.C. of the system decreases.

4. Conclusion

Most of the existing inventory models in trade credit period assumed the demand and deterioration as a constant function. But both of them cannot be treated as a constant. Generally the demand for a product increases up to a certain time and after that it becomes constant. In this paper we have presented an inventory model for deteriorating products with ramp type demand and permissible delay period. It has been shown in the model that a permissible delay period works as an incentive for the retailer. It is also shown that a higher value of trade credit period reduces the total average cost of the system. A numerical example and sensitivity analysis are also presented to illustrate the model. The research paper presented here can be extended in several ways such as time dependent rate of backlogging, inflation and stock dependent demand

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