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Different Deterioration Rates Two Warehouse Production Inventory Model with Time and Price Dependent Demand under Inflation and Permissible Delay in Payments

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ABSTRACT: *A two warehouse production inventory model with different deterioration rates under inflation and permissible delay in payments is developed. Demand is considered as function of price and time. Holding cost is considered as linear function of time. Shortages are not allowed. To represent the model, numerical case is given. Sensitivity analysis for parameters is likewise done.*

KEY WORDS: *Two warehouse, Different deterioration, Time dependent demand, Price dependent demand, Inflation, Permissible Delay in Payments.*

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I. Introduction

In past many production inventory models have been studied. A finite horizon production lot size model was developed by Balkhi [2]. Goyal and Giri [10] provide solution for production inventory of a product with time varying demand, production and deterioration rates. A production inventory model with price and stock dependent demand was developed by Teng and Chang [20]. Bansal [3] considered a production inventory model based on assumption of price dependent demand and deterioration. Ghasemi [7] developed EPQ models for non-instantaneous deteriorating items.

In order to take advantages of bulk purchasing many times retailer decides to buy goods exceeding their Own Warehouse (OW) capacity. So an additional stock is arranged as Rented Warehouse (RW) which has better storage facilities with low rate of deterioration and higher inventory holding cost. A two-warehouse inventory model was first developed by Hartley [11]. An inventory model with infinite rate of replenishment with two-warehouse was considered by Sarma [18]. Ghosh and Chakrabarty [8] developed an order level inventory model with two levels of storage facility for deteriorating items. A deterministic inventory model for a single item having two levels of storage was considered by Madhavilata et al. [14]. Tyagi and Singh [21] considered a two warehouse inventory model with time dependent demand, varying rate of deterioration and variable holding cost.

Goyal [9] first considered the economic order quantity model under the condition of permissible delay in payments. Aggarwal and Jaggi [1] extended Goyal's [9] model to consider the deteriorating items. The related work are found in (Chung and Dye [5], Salameh et al. [17], Chung et al. [6], Chang et al. [4]). Liao et al. [13] considered an inventory model for stock dependent consumption and permissible delay in payment under inflationary conditions. Singh [19] developed an EOQ model with linear demand and permissible delay in payments. The effect of inflation and time value of money were also taken into account. Parekh and Patel [15] developed a two warehouse inventory model under inflation and permissible delay in payments. A two warehouses production inventory model for deteriorating items with linear demand, time varying holding cost, inflation and permissible delay in payments was developed by Patel and Parekh [16]. Jaggi et al. [12] gave replenishment policy for non-instantaneous deteriorating items in two storage facilities under inflation.

Generally the products are such that there is no deterioration initially. After certain time deterioration starts and again after certain time the rate of deterioration increases with time. Here we have used such a concept and developed two warehouses deteriorating items inventory model.

In this paper we have developed a two warehouse production inventory model with different deterioration rates under inflation and permissible delay. Demand is a function of price and time. Holding cost is time varying. Shortages are not allowed. Numerical case is given to represent the model. Affectability investigation is likewise done for parameters.

II. Assumptions And Notations

NOTATIONS:

The following notations are used for the development of the model:

P(t) : Production rate is function of demand at time t, ($\eta D(t)$, $\eta>0$)
D(t) : Demand is a function of time and price ($a + bt - \rho p$, $a>0$, $0<b<1$, $\rho>0$)
HC(OW) : Holding cost is linear function of time t (x_1+y_1t, $x_1>0$, $0<y_1<1$) in OW.
HC(RW) : Holding cost is linear function of time t (x_2+y_2t, $x2>0$, $0<y_2<1$) in RW.
B : Set-up cost per order
c : Purchasing cost per unit
p : Selling price per unit
T : Length of inventory cycle
$I_0(t)$: Inventory level in OW at time t.
$I_r(t)$: Inventory level in RW at time t.
I_e : Interest earned per year
I_p : Interest paid in stocks per year
R : Inflation rate
Q_1 : Inventory level at t_1
Q : Order quantity
t_r : Time at which inventory level becomes zero in RW.
W : Capacity of own warehouse
θ : Deterioration rate in RW and OW during $\mu_1<t< t_1$, $0< \theta<1$
θt : Deterioration rate in RW and OW during $t_1 \le t \le T$, $0< \theta<1$
π : Total relevant profit per unit time.

ASSUMPTIONS:
The following assumptions are considered for the development of model.

- The demand of the product is declining as a function of time and price.
- Replenishment rate is infinite and instantaneous.
- Lead time is zero.
- Shortages are not allowed.
- OW has fixed capacity W units and RW has unlimited capacity.
- The goods of OW are consumed only after consuming the goods kept in RW.
- The unit inventory cost per unit in the RW is higher than those in the OW.
- Deteriorated units neither be repaired nor replaced during the cycle time.
- During the time, the account is not settled; generated sales revenue is deposited in an interest bearing account. At the end of the credit period, the account is settled as well as the buyer pays off all units sold and starts paying for the interest charges on the items in stocks.

III. The Mathematical Model And Analysis

At time t=0, production starts at rate η, the level of inventory increases to W up to time μ_1 in OW, due to combined effect of production and demand. Then inventory is continued to be stored in RW up to time t_1, production stops at time t_1. During interval $[\mu_1,t_1]$ inventory in RW gradually decreases due to demand and deterioration at rate θ, during $[\mu_1,t_1]$ inventory in OW depletes due to deterioration at rate θ. During interval $[t_1,t_r]$ inventory in OW depletes due to deterioration at rate θt, inventory in RW depletes due to demand and deterioration at rate θt and reaches to zero at time t_r. During the interval (t_r,T) inventory depletes in OW due to demand and deterioration (θt). By time T both the warehouses are empty.
Let I(t) be the inventory at time t ($0 \le t \le T$) as shown in figure.

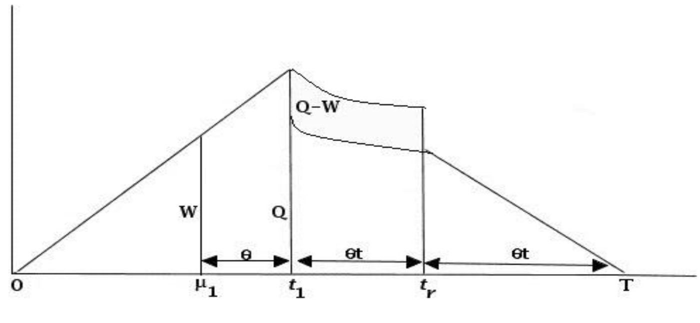


Figure 1

Hence, the inventory level at time t in RW and OW and governed by the following differential equations:

$$\frac{dI_0(t)}{dt} = (\eta\text{-}1)(a + bt - \rho p), \qquad 0 \le t \le \mu_1 \qquad (1)$$

$$\frac{dI_r(t)}{dt} + \theta I_r(t) = (\eta\text{-}1)(a+bt - \rho p), \qquad \mu_1 \le t \le t_1 \qquad (2)$$

$$\frac{dI_0(t)}{dt} + \theta I_0(t) = 0 \qquad \mu_1 \le t \le t_1 \qquad (3)$$

$$\frac{dI_r(t)}{dt} + \theta t I_r(t) = -(a+bt - \rho p), \qquad t_1 \le t \le t_r \qquad (4)$$

$$\frac{dI_0(t)}{dt} + \theta t I_0(t) = 0 \qquad t_1 \le t \le t_r \qquad (5)$$

$$\frac{dI_0(t)}{dt} + \theta t I_0(t) = -(a+bt - \rho p), \qquad t_r \le t \le T \qquad (6)$$

with initial conditions $I_0(0) = 0$, $I_0(\mu_1) = W$, $I_0(t_1) = W$, $I_0(t_r) = W$, $I_0(T) = 0$, $I_r(0) = 0$, $I_r(\mu_1)=0$, $I_r(t_1) = Q_1$-W, and $I_r(t_r) = 0$.
Solving equations (1) to (6) we have,

$$I_0(t) = (\eta\text{-}1)\left[(a - \rho p)t + \frac{1}{2}bt^2\right] \qquad (7)$$

$$I_r(t) = (\eta\text{-}1)\begin{bmatrix} (a - \rho p)(t - \mu_1) + \frac{1}{2}b\left(t^2\text{-}\mu_1^2\right) + \frac{1}{2}(a - \rho p)\theta\left(t^2\text{-}\mu_1^2\right) \\ +\frac{1}{3}b\theta\left(t^3\text{-}\mu_1^3\right) - (a - \rho p)\theta t(t - \mu_1) - \frac{1}{2}b\theta t\left(t^2\text{-}\mu_1^2\right) \end{bmatrix} \qquad (8)$$

$$I_0(t) = W\left[1+ \theta(\mu_1 - t)\right] \qquad (9)$$

$$I_r(t) = \begin{bmatrix} (a - \rho p)(t_r - t) + \frac{1}{2}b\left(t_r^2 - t^2\right) + \frac{1}{6}(a - \rho p)\theta\left(t_r^3 - t^3\right) \\ +\frac{1}{8}b\theta\left(t_r^4 - t^4\right) - \frac{1}{2}(a - \rho p)\theta t^2(t_r - t) - \frac{1}{4}b\theta t^2\left(t_r^2 - t^2\right) \end{bmatrix} \qquad (10)$$

$$I_0(t) = W\left[1+ \frac{1}{2}\theta(t_1^2 - t^2)\right] \qquad (11)$$

$$I_0(t) = \begin{bmatrix} (a - \rho p)(T - t) + \frac{1}{2}b\left(T^2 - t^2\right) + \frac{1}{6}(a - \rho p)\theta\left(T^3 - t^3\right) \\ +\frac{1}{8}b\theta\left(T^4 - t^4\right) - \frac{1}{2}(a - \rho p)\theta t^2(T - t) - \frac{1}{4}b\theta t^2\left(T^2 - t^2\right) \end{bmatrix} \qquad (12)$$

(by neglecting higher powers of θ)

Putting $t = t_1$ in equation (8), we get

$$Q_1 = (\eta\text{-}1)\begin{bmatrix} (a - \rho p)(t_1 - \mu_1) + \frac{1}{2}b\left(t_1^2\text{-}\mu_1^2\right) + \frac{1}{2}(a - \rho p)\theta\left(t_1^2\text{-}\mu_1^2\right) \\ +\frac{1}{3}b\theta\left(t_1^3\text{-}\mu_1^3\right) - (a - \rho p)\theta t_1(t_1 - \mu_1) - \frac{1}{2}b\theta t_1\left(t_1^2\text{-}\mu_1^2\right) \end{bmatrix} + W \qquad (13)$$

Putting $t = t_r$ in equation (11) and (12), we get

$$I_0(t_r) = W\left[1+ \frac{1}{2}\theta(t_1^2 - t_r^2)\right] \qquad (14)$$

$$I_0(t_r) = \begin{bmatrix} (a - \rho p)(T - t_r) + \frac{1}{2}b\left(T^2 - t_r^2\right) + \frac{1}{6}(a - \rho p)\theta\left(T^3 - t_r^3\right) \\ +\frac{1}{8}b\theta\left(T^4 - t_r^4\right) - \frac{1}{2}(a - \rho p)\theta t_r^2(T - t_r) - \frac{1}{4}b\theta t_r^2\left(T^2 - t_r^2\right) \end{bmatrix} \qquad (15)$$

So from equations (14) and (15), we have

$$T=\frac{1}{b\left(-2+\theta tr^2\right)}\left(2a-2\rho p-a\theta tr^2+\rho p\theta tr^2+\sqrt{\begin{pmatrix}4a^2-8a\rho p-4a^2\theta t_r^2+8a\theta t_r^2\rho p+4\rho^2p^2-4\rho^2p^2\theta t_r^2+\theta^2t_r^4a^2\\ -2\theta^2t_r^4a\rho p+\theta^2t_r^4\rho^2p^2-8b\rho pt_r+4b^2t_r^2+8bW\left(1+\frac{1}{2}\theta t_1^2-\frac{1}{2}\theta t_r^2\right)\\ +8abt_r+4b\theta t_r^3\rho p-2b^2\theta t_r^4-4ab\theta t_r^3-4b\theta t_r^2W\left(1+\frac{1}{2}\theta t_1^2-\frac{1}{2}\theta t_r^2\right)\end{pmatrix}}\right) \quad (16)$$

From equation (16), we see that T is a function of W, t_1 and t_r, so T is not a decision variable.

Based on the assumptions and descriptions of the model, the total annual relevant profit(π) include the following elements:

(i) Set-up cost (SeC) = B (17)

$$\text{(ii) } HC(OW)=\int_0^{\mu_1}(x_1+y_1t)e^{-Rt}I_0(t)dt+\int_{\mu_1}^{t_1}(x_1+y_1t)e^{-Rt}I_0(t)dt+\int_{t_1}^{t_r}(x_1+y_1t)e^{-Rt}I_0(t)dt+\int_{t_r}^{T}(x_1+y_1t)e^{-Rt}I_0(t)dt \quad (18)$$

$$\text{(iii) } HC(RW)=\int_{\mu_1}^{t_1}(x_2+y_2t)e^{-Rt}I_r(t)\,dt+\int_{t_1}^{t_r}(x_2+y_2t)e^{-Rt}I_r(t)\,dt \quad (19)$$

$$\text{(iv) } DC=c\left(\int_{\mu_1}^{t_1}\theta I_r(t)\,e^{-Rt}dt+\int_{\mu_1}^{t_1}\theta I_0(t)e^{-Rt}dt+\int_{t_1}^{t_r}\theta tI_r(t)e^{-Rt}dt+\int_{t_1}^{t_r}\theta tI_0(t)e^{-Rt}dt+\int_{t_r}^{T}\theta tI_0(t)e^{-Rt}dt\right) \quad (20)$$

$$\text{(v) } SR=p\left(\int_0^T(a+bt-\rho p)e^{-Rt}dt\right) \quad (21)$$

(by neglecting higher powers of θ)

To determine the interest earned, there will be two cases i.e.

Case I: ($0\le M\le T$) and Case II: ($M>T$).

Case I: ($0\le M\le T$): In this case the retailer can earn interest on revenue generated from the sales up to M. Although, he has to settle the accounts at M, for that he has to arrange money at some specified rate of interest in order to get his remaining stocks financed for the period M to T.

(vi) Interest earned per cycle:

$$IE_1=pI_e\int_0^M(a+bt-\rho p)te^{-Rt}dt \quad (22)$$

Case II: (M>T):

In this case, the retailer earns interest on the sales revenue up to the permissible delay period. So

(vii) Interest earned up to the permissible delay period is:

$$IE_2=pI_e\left[\int_0^T(a+bt-\rho p)te^{-Rt}dt+(a+bT-\rho p)T(M-T)\right] \quad (23)$$

To determine the interest payable, there will be five cases i.e.

(viii) Interest payable per cycle for the inventory not sold after the due period M is

Case I: ($0\le M\le \mu_1$):

$$\text{(ix) } IP_1=cI_p\left(\int_M^{\mu_1}I_0(t)e^{-Rt}dt+\int_{\mu_1}^{t_1}I_r(t)e^{-Rt}dt+\int_{\mu_1}^{t_1}I_0(t)e^{-Rt}dt+\int_{t_1}^{t_r}I_r(t)e^{-Rt}dt+\int_{t_1}^{t_r}I_0(t)e^{-Rt}dt+\int_{t_r}^{T}I_0(t)e^{-Rt}dt\right) \quad (24)$$

Case II: ($\mu_1\le M\le t_1$):

$$\text{(x) } IP_2=cI_p\left(\int_M^{t_1}I_r(t)e^{-Rt}dt+\int_M^{t_1}I_0(t)e^{-Rt}dt+\int_{t_1}^{t_r}I_r(t)e^{-Rt}dt+\int_{t_1}^{t_r}I_0(t)e^{-Rt}dt+\int_{t_r}^{T}I_0(t)e^{-Rt}dt\right) \quad (25)$$

Case III: ($t_1\le M\le t_r$):

$$\text{(xi) } IP_3=cI_p\left(\int_M^{t_r}I_r(t)e^{-Rt}dt+\int_M^{t_r}I_0(t)e^{-Rt}dt+\int_{t_r}^{T}I_0(t)e^{-Rt}dt\right) \quad (26)$$

Case IV: ($t_r\le M\le T$):

$$\text{(xii) } IP_4=cI_p\left(\int_M^{T}I_0(t)e^{-Rt}dt\right) \quad (27)$$

Case V: (M>T):

(xiii) $IP_5 = 0$ (28)

(by neglecting higher powers of b and R)

The total profit (π_i), i=1,2,3,4 and 5 during a cycle consisted of the following:

$$\pi_i = \frac{1}{T}\left[SR - SeC - HC(RW) - HC(OW) - DC - IP_i + IE_i\right] \tag{29}$$

Substituting values from equations (17) to (28) in equation (29), we get total profit per unit. Putting $\mu_1 = v_1 T$ and value of T from equation (16) in equation (29), we get profit in terms of t_1, tr, and p for the five cases as under:

$$\pi_1 = \frac{1}{T}\left[SR - SeC - HC(RW) - HC(OW) - DC - IP_1 + IE_1\right] \tag{30}$$

$$\pi_2 = \frac{1}{T}\left[SR - SeC - HC(RW) - HC(OW) - DC - IP_2 + IE_1\right] \tag{31}$$

$$\pi_3 = \frac{1}{T}\left[SR - SeC - HC(RW) - HC(OW) - DC - IP_3 + IE_1\right] \tag{32}$$

$$\pi_4 = \frac{1}{T}\left[SR - SeC - HC(RW) - HC(OW) - DC - IP_4 + IE_1\right] \tag{33}$$

$$\pi_5 = \frac{1}{T}\left[SR - SeC - HC(RW) - HC(OW) - DC - IP_5 + IE_2\right] \tag{34}$$

The optimal value of t_1*, tr* and p* (say), which maximizes π_i can be obtained by solving equation (30), (31), (32), (33) and (34) by differentiating it with respect to t_1, tr, and p and equate it to zero, we have

i.e. $\frac{\partial\pi_i(t_1,t_r,p)}{\partial t_1}=0,\ \frac{\partial\pi_i(t_1,t_r,p)}{\partial t_r}=0,\ \frac{\partial\pi_i(t_1,t_r,p)}{\partial p}=0,$ i=1,2,3,4,5. (35)

provided it satisfies the condition

$$\begin{vmatrix} \frac{\partial\pi_i^2(t_1,t_r,p)}{\partial t_1^2} & \frac{\partial\pi_i^2(t_1,t_r,p)}{\partial t_1\partial t_r} & \frac{\partial\pi_i^2(t_1,t_r,p)}{\partial t_1\partial p} \\ \frac{\partial\pi_i^2(t_1,t_r,p)}{\partial t_r\partial t_1} & \frac{\partial\pi_i^2(t_1,t_r,p)}{\partial t_r^2} & \frac{\partial\pi_i^2(t_1,t_r,p)}{\partial t_r\partial p} \\ \frac{\partial\pi_i^2(t_1,t_r,p)}{\partial p\partial t_1} & \frac{\partial\pi_i^2(t_1,t_r,p)}{\partial p\partial t_r} & \frac{\partial\pi_i^2(t_1,t_r,p)}{\partial p^2} \end{vmatrix} > 0,\ i=1,2,3,4,5. \tag{36}$$

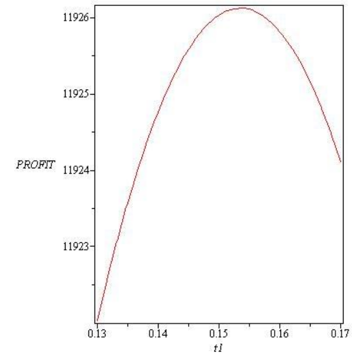
IV. Numerical Example

Considering B= Rs.100, W = 30, a = 500, b=0.05, c=Rs. 25, ρ= 5, η=2, θ=0.05, x_1 = Rs. 3, y_1=0.05, x_2=Rs. 6, y_2=0.06, v_1=0.30, R = 0.06, Ie = 0.12, Ip = 0.15, in appropriate units. The optimal values of t_1, t_r, p and Profit for the five cases are shown in table below.

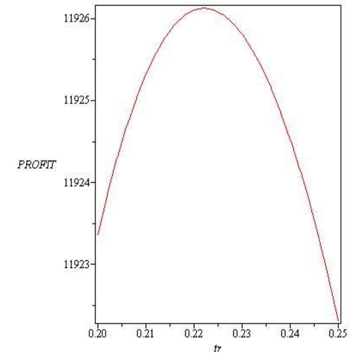
Case	M	t_1	t_r	p	Profit
I	0.06	0.1535	0.2221	50.2934	11926.1272
II	0.11	0.1354	0.1938	50.2553	11958.0763
III	0.14	0.1168	0.1725	50.2271	11991.0468
IV	0.21	0.1099	0.1615	50.1639	12079.6052
V	0.30	0.1001	0.1460	50.1387	12209.1021

The second order conditions given in equation (36) are also satisfied. The graphical representation of the concavity of the profit function is also given.

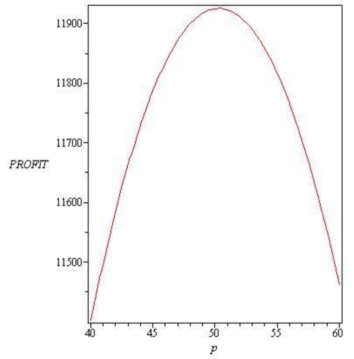
Case I		
t_1 and Profit	t_r and Profit	p and Profit



Graph 1



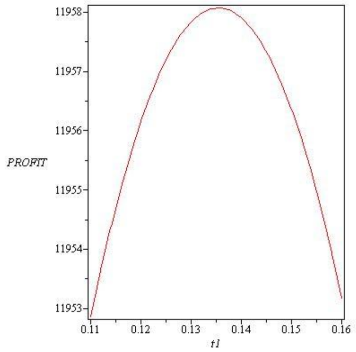
Graph 2



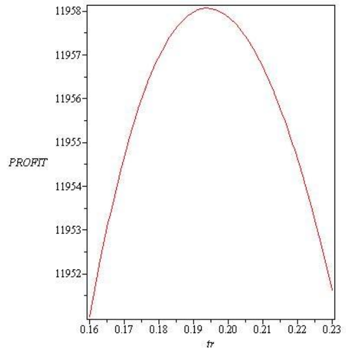
Graph 3

Case II

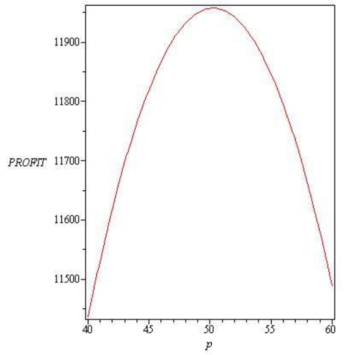
t_1 and Profit	t_r and Profit	p and Profit



Graph 4



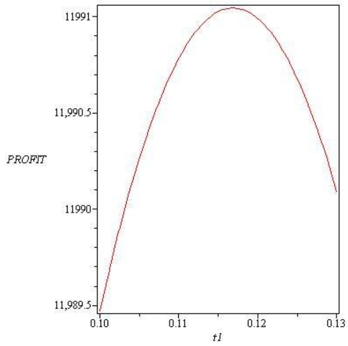
Graph 5



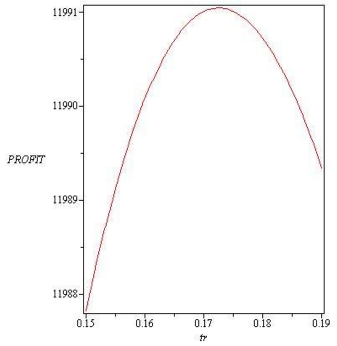
Graph 6

Case III

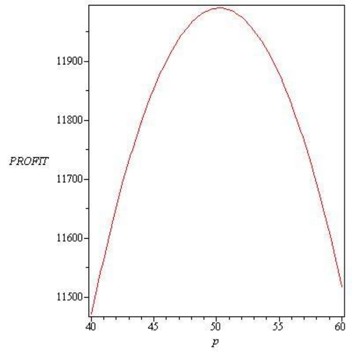
t_1 and Profit	t_r and Profit	p and Profit



Graph 7



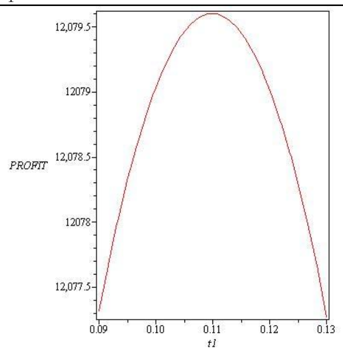
Graph 8



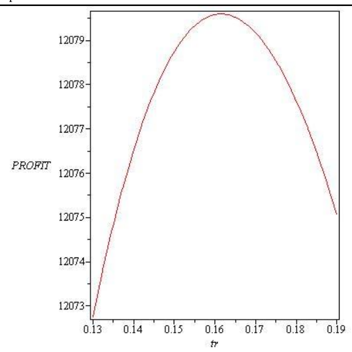
Graph 9

Case IV

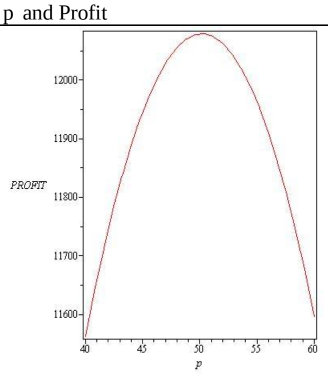
t_1 and Profit	t_r and Profit	p and Profit



Graph 10

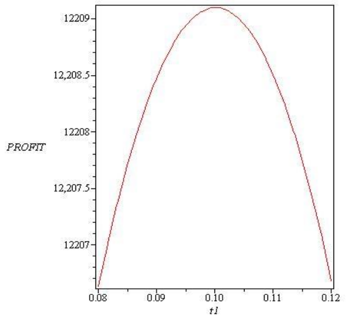
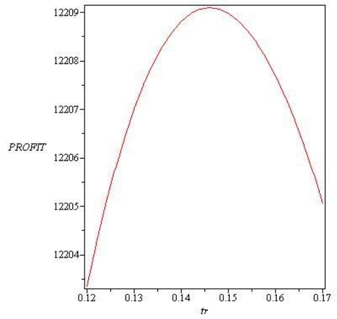
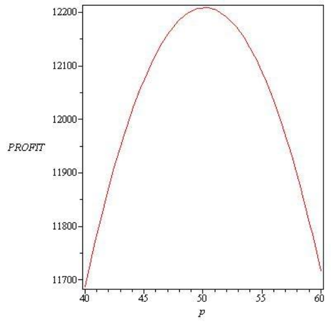


Graph 11



Graph 12

Case V

t_1 and Profit	t_r and Profit	p and Profit
		
Graph 13	Graph 14	Graph 15

V. Sensitivity Analysis

On the basis of the data given in example above we have studied the sensitivity analysis by changing the following parameters one at a time and keeping the rest fixed.

Table 1 Case I Sensitivity Analysis

Parameter	change	t_1	t_r	p	Profit
a	+20	0.1354	0.1972	60.2494	17350.6523
	+10	0.1439	0.2091	55.2698	14512.9736
	-10	0.1641	0.2364	45.3210	9590.1647
	-20	0.1761	0.2520	40.3540	7505.1720
θ	+20	0.1505	0.2200	50.2970	11924.1436
	+10	0.1520	0.2210	50.2952	11925.1276
	-10	0.1550	0.2231	50.2916	11927.1426
	-20	0.1566	0.2242	50.2898	11928.1738
x_1	+20	0.1513	0.2187	50.3019	11914.5455
	+10	0.1524	0.2204	50.2976	11920.3297
	-10	0.1546	0.2238	50.2892	11931.9382
	-20	0.1557	0.2255	50.2850	11937.7624
x_2	+20	0.1507	0.2163	50.3074	11923.0813
	+10	0.1521	0.2191	50.3005	11924.5831
	-10	0.1549	0.2251	50.2861	11927.7161
	-20	0.1563	0.2283	50.2786	11929.3520
B	+20	0.1766	0.2580	50.3206	11870.6980
	+10	0.1653	0.2405	50.3073	11897.7213
	-10	0.1410	0.2026	50.2789	11956.1525
	-20	0.1277	0.1819	50.2637	11988.1098
M	+20	0.1511	0.2184	50.2862	11931.7538
	+10	0.1524	0.2203	50.2900	11928.8056
	-10	0.1545	0.2236	50.2965	11923.7149
	-20	0.1554	0.2250	50.2992	11921.5650
R	+20	0.1438	0.2069	50.2820	11901.3192
	+10	0.1484	0.2142	50.2875	11913.5844
	-10	0.1589	0.2305	50.2998	11938.9671
	-20	0.1647	0.2395	50.3066	11952.1259
ρ	+20	0.1635	0.2377	41.9719	9863.4376
	+10	0.1588	0.2304	45.7540	10800.8898
	-10	0.1474	0.2127	55.8419	13301.8231
	-20	0.1405	0.2019	62.7784	15022.0200

Table 2 Case II Sensitivity analysis

Parameter	change	t_1	t_r	p	Profit
a	+20	0.1139	0.1636	60.2107	17401.5796
	+10	0.1241	0.1781	55.2318	14553.7101
	-10	0.1478	0.2109	45.2822	9614.5486
	-20	0.1616	0.2295	40.3136	7523.0397
θ	+20	0.1323	0.1916	50.2589	11956.3653
	+10	0.1339	0.1927	50.2571	11957.2126
	-10	0.1369	0.1950	50.2535	11958.9566
	-20	0.1385	0.1961	50.2518	11959.8536

Parameter	change	t_1	t_r	p	Profit
x_1	+20	0.1329	0.1899	50.2640	11946.9576
	+10	0.1341	0.1919	50.2597	11952.5084
	-10	0.1366	0.1958	50.2510	11963.6612
	-20	0.1379	0.1978	50.2468	11969.2629
x_2	+20	0.1327	0.1883	50.2674	11955.7548
	+10	0.1341	0.1910	50.2614	11956.8964
	-10	0.1367	0.1968	50.2490	11959.2972
	-20	0.1381	0.2000	50.2425	11960.5617
B	+20	0.1631	0.2371	50.2834	11898.5745
	+10	0.1497	0.2162	50.2698	11927.3677
	-10	0.1200	0.1698	50.2398	11991.1428
	-20	0.1033	0.1436	50.2228	12027.2116
M	+20	0.1218	0.1726	50.2367	11981.1978
	+10	0.1289	0.1837	50.2471	11968.9065
	-10	0.1412	0.2029	50.2618	11948.5717
	-20	0.1465	0.2112	50.2667	11940.2848
R	+20	0.1255	0.1783	50.2453	11935.3166
	+10	0.1302	0.1858	50.2501	11946.5551
	-10	0.1409	0.2025	50.2610	11969.9029
	-20	0.1470	0.2119	50.2672	11982.0605
ρ	+20	0.1475	0.2127	41.9342	9890.3271
	+10	0.1418	0.2038	45.7164	10830.0281
	-10	0.1281	0.1825	55.8036	13337.3671
	-20	0.1198	0.1695	62.7396	15062.2941

Table 3 Case III Sensitivity analysis

Parameter	change	t_1	t_r	p	Profit
a	+20	0.1025	0.1523	60.1772	17450.1090
	+10	0.1095	0.1622	55.2003	14594.1751
	-10	0.1247	0.1831	45.2586	9640.6186
	-20	0.1330	0.1940	40.2962	7542.8453
θ	+20	0.1135	0.1711	50.2304	11989.6894
	+10	0.1152	0.1718	50.2288	11990.3582
	-10	0.1185	0.1732	50.2255	11991.7556
	-20	0.1202	0.1739	50.2239	11992.4851
x_1	+20	0.1152	0.1699	50.2355	11980.2990
	+10	0.1160	0.1712	50.2313	11985.6668
	-10	0.1177	0.1738	50.2230	11986.4391
	-20	0.1185	0.1751	50.2188	12001.8435
x_2	+20	0.1172	0.1693	50.2373	11989.1230
	+10	0.1170	0.1709	50.2322	11990.0692
	-10	0.1165	0.1741	50.2219	11992.0602
	-20	0.1159	0.1758	50.2166	11993.1154
B	+20	0.1359	0.2025	50.2632	11926.1391
	+10	0.1266	0.1879	50.2454	11957.7997
	-10	0.1066	0.1562	50.2083	12026.1452
	-20	0.0957	0.1390	50.1890	12063.4423
M	+20	0.1144	0.1686	50.1978	12025.2545
	+10	0.1157	0.1707	50.2118	12007.9546
	-10	0.1179	0.1741	50.2437	11974.5250
	-20	0.1188	0.1756	50.2614	11958.3837
R	+20	0.1109	0.1630	50.2161	11969.5689
	+10	0.1138	0.1677	50.2215	11980.2217
	-10	0.1201	0.1776	50.2332	12002.0530
	-20	0.1234	0.1829	50.2395	12013.2495
ρ	+20	0.1249	0.1852	41.9089	9918.2848
	+10	0.1211	0.1793	45.6898	10860.3016
	-10	0.1118	0.1645	55.7734	13373.5299
	-20	0.1058	0.1550	62.7070	15102.3209

Table 4 Case IV Sensitivity analysis

Parameter	change	t_1	t_r	p	Profit
a	+20	0.0907	0.1336	60.1237	17579.5584
	+10	0.1002	0.1475	55.1415	14701.4744
	-10	0.1198	0.1754	45.1916	9713.2979
	-20	0.1300	0.1893	40.2257	7602.0567
θ	+20	0.1066	0.1601	50.1676	12078.3643
	+10	0.1082	0.1608	50.1658	12078.9748
	-10	0.1115	0.1622	50.1621	12080.2561
	-20	0.1132	0.1629	50.1602	12080.9279
x_1	+20	0.1082	0.1589	50.1731	12069.0657
	+10	0.1091	0.1602	50.1685	12074.3298
	-10	0.1107	0.1628	50.1594	12084.8936
	-20	0.1115	0.1641	50.1548	12090.1950
x_2	+20	0.1100	0.1586	50.1741	12077.9268
	+10	0.1101	0.1600	50.1691	12078.7514
	-10	0.1095	0.1630	50.1587	12080.4928
	-20	0.1089	0.1645	50.1533	12081.4202
B	+20	0.1296	0.1925	50.1924	12012.3713
	+10	0.1200	0.1774	50.1781	12045.1086
	-10	0.0992	0.1446	50.1500	12116.1787
	-20	0.0878	0.1265	50.1367	12155.2554
M	+20	0.1042	0.1525	50.1438	12137.8204
	+10	0.1072	0.1572	50.1520	12108.2091
	-10	0.1123	0.1653	50.1793	12051.9653
	-20	0.1144	0.1686	50.1979	12025.2542
R	+20	0.1041	0.1524	50.1563	12058.7373
	+10	0.1070	0.1568	50.1600	12069.0888
	-10	0.1130	0.1663	50.1682	12090.2948
	-20	0.1162	0.1715	50.1727	12101.1665
ρ	+20	0.1210	0.1790	41.8462	9995.5923
	+10	0.1159	0.1709	45.6267	10942.5907
	-10	0.1028	0.1503	55.7102	13470.2030
	-20	0.0943	0.1369	62.6442	15209.8724

Table 5 Case V Sensitivity analysis

Parameter	change	t_1	t_r	p	Profit
a	+20	0.0857	0.1257	60.1167	17772.5518
	+10	0.0924	0.1351	55.1268	14861.3095
	-10	0.1092	0.1588	45.1532	9815.9413
	-20	0.1201	0.1738	40.1712	7681.8444
θ	+20	0.0971	0.1449	50.1431	12208.0295
	+10	0.0986	0.1455	50.1409	12208.5560
	-10	0.1016	0.1465	50.1365	12209.6680
	-20	0.1032	0.1471	50.1343	12210.2543
x_1	+20	0.0988	0.1440	50.1494	12198.8780
	+10	0.0995	0.1450	50.1440	12203.9844
	-10	0.1008	0.1471	50.1335	12214.2311
	-20	0.1014	0.1481	50.1282	12219.3713
x_2	+20	0.1008	0.1440	50.1489	12207.7480
	+10	0.1006	0.1450	50.1439	12208.4132
	-10	0.0995	0.1470	50.1335	12209.8188
	-20	0.0985	0.1481	50.1282	12210.5692
B	+20	0.1163	0.1716	50.1501	12137.4725
	+10	0.1084	0.1591	50.1445	12172.4648
	-10	0.0914	0.1322	50.1327	12247.6431
	-20	0.0821	0.1176	50.1265	12288.4221
M	+20	0.1001	0.1460	50.1378	12299.1062
	+10	0.1001	0.1460	50.1383	12254.1041
	-10	0.1001	0.1460	50.1392	12164.1000
	-20	0.1001	0.1460	50.1397	12119.0980
R	+20	0.0956	0.1389	50.1357	12189.0751
	+10	0.0978	0.1424	50.1372	12199.0200
	-10	0.1025	0.1498	50.1404	12219.3272
	-20	0.1050	0.1537	50.1421	12229.7018
	+20	0.1129	0.1662	41.8143	10102.8880
	+10	0.1067	0.1565	45.5979	11059.7785

Parameter	change	t_1	t_r	p	Profit
ρ	-10	0.0930	0.1347	55.6894	13615.2189
	-20	0.0852	0.1225	62.6287	15374.7435

From the table we observe that as parameter a and M increases/ decreases average total profit increases/ decreases for all five cases.

From the table we observe that as parameter θ and x_2 increases/ decreases there is very minor decrease/increase in average total profit for all five cases.

From the table we observe that as parameters x_1, B, R and ρ increases/ decreases average total profit decreases/ increases for all five cases.

VI. Conclusion

We have developed a two warehouse production inventory model for deteriorating items with different deterioration rates under time and price dependent demand.and time varying holding cost in this paper. Sensitivity with respect to parameters has been carried out. The results show that with the increase/ decrease in the parameter values there is corresponding increase/ decrease in the value of profit.

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