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Two Level Optimal Ordering Policy For Variable Deterioration With Life Time Under Trended Demand And Time Discounting

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ABSTRACT:
In this paper, an inventory model of deteriorating product with life time has been discussed. The demand rate has been taken quadratic form which starts from zero in the beginning and ends to zero at completion of the cycle. The variable rate of deterioration rate has been taken. Model has been developed under trade credit and time discounting. Shortages are not considered .Cost minimization technique has been used in the development of model.

KEYWORDS: Deterioration, life time, trade credit and time discounting

INTRODUCTION:
In business translation, supplier may offer retailer a delay period, which is called trade credit period. During this period the retailer can sell the product and can earn the interest on the revenue generated. It is beneficial for the retailer to delay the settlement of the replenishment account up to the last moment of the permissible delay allowed by the supplier.
Several researchers discussed the inventory problems under the permissible delay in payment condition. Goyal S.K [6] discussed economic ordering quantities under the condition of permissible delay in payments. Agarwal & Jaggi [1] discussed the inventory model with the exponential deterioration rate under permissible delay in payment**.** Chang et.al**.** [3] Extended this work for variable deterioration rate**.** Liao ,et al.[17] discussed the topic with inflation**.** Jamal ,et.al [16] and Chang & Dye [4] extended this work with shortage**.** Haung & Shinn [13] studied an inventory system for the retailer's pricing and lot sizing policy for the exponentially deteriorating product under the condition of permissible delay in the payments. Teng [26] considered the selling price not equal to the purchasing price to modify the model under the permissible delay in payments. Shinn & Huang [25] obtained the optimal price and order size simultaneously under the condition of order –size dependent delay in payments. They assumed the length of the credit period as a function of retailer's order-size and the demand rate to the function of selling price .Huang [13] extended this work within the EPQ framework and obtained the retailer's optimal ordering policy. Huang [15] modify the Goyal's model [6] under the following assumptions
(i) The unit selling price and the unit purchasing price are not necessarily equal.
(ii) The supplier offers the retailer partial trade credit, i.e. the retailer has to make a partial payment to the supplier in the beginning and has to pay the remaining balance at he end of the permissible delay period.
He adopted the cost minimization technique to investigate the optimal retailer's inventory policy. Megha Rani , Hari Kishan and Shiv Raj Singh [20] discussed the inventory model of deteriorating products under the supplier's partial trade credit policy. Hari Krishan , Megha Rani and Deep Shikha [8] discussed the inventory model of deterioration products with the life time under declining demand and permissible delay in payment. Hari Krishan , Megha Rani and Deep Shikha [9] developed the inventory model with the variable demand , shortages and the deterioration**.** While determining the optimal ordering policy, the effect of the inflation and time value of the money cannot be ignored. Buzacott (1975) developed an EOQ model with inflation subject to different types of pricing policies.

Hou (2006) developed an inventory model with the deterioration, inflation, inflation, time value money and stock dependent consumption rate. Hou and Lin (2006) extended the work of Hou (2006) by considering the selling rate as a function of stock level and the selling price over the finite time horizon. Chandra and Bahner (1985**),** Ray and Chaudhary (1997), Chung and Lin (2001) , Wee and Law (2001) and Balkhi (2004) also worked in this direction. Hou and Lin (2008) developed an ordering policy for the deteriorating items under credit and time discounting Megha Rani , Vipin Kumar [10] developed the inventory model of ordering policy for the perishable products with life time under trade credit and time discounting. Hari Krishan , Megha Rani and Vipin Kumar [11] developed the inventory model in of deteriorating items with life time under trade credit and time.

In most of the inventory models it is assumed that the deterioration of item stars in vey beginning of the inventory. In real life problems the deterioration of items starts after some time which is known as life time. In this paper, an inventory model has been developed for the deterioration items with the life time under the assumption of life time, trade credit and time discounting. The work of Hari Krishan ,Megha Rani ,Vipin Kumar [10] has been extended with the life time with variable rate of deterioration and variable demand rate of quadratic form

ASSUMPTIONS AND NOTATIONS:

ASSUMPTION:

The following assumptions are considered in this paper

(i) The demand is quadratic function of time which is given by –at(T-t)

(ii) Time horizon is finite given by H.

(iii) The variable rate of deterioration has been taken. Deterioration starts after time μ which is the life time.

(iv) During the time the account is not settled, the generated sales revenue is deposited in an interest bearing account when $T \geq M$, the account is settled at T=M and we start paying for the interest charges on the item in stock. When $T \leq M$, the account is settled at T=m and we need not to pay any interest charge.

NOTATIONS:

The following notations have been used in the chapter**:**

(i) The demand rate - at (T- t), where a is constant.

(ii) A= the ordering cost per order.

(iii) C = the unit purchase price.

(iv) h = unit holding cost per unit time excluding interest charges.

(v) M = the trade credit period.

(vi) H = length of planning horizon.

(vii) T = the replenishment cycle time in year.

(viii) n = number of replenishment during planning horizon.

(ix) $\theta_0 t$ = the variable rate of deterioration of the on hand inventory.

(x) μ = the life time.

(xi) r = discount rate representing the time value of money.

(xii) f = inflation rate.

(xiii) R = the net discount rate of inflation.

(xiv) I_e = interest earned per Re per year

(xv) I_c = interest charged per Re per year.

(xvi) q(t) = stock level at any time t

(xvii) Q = maximum stock level

(xviii) s = selling price per unit.

(xix) TVC(T) = the annual total relevant cost, which is a function of T.

MATHEMATICAL MODELS

The total time horizon H has been divided in n equal parts of length T so that T= $\frac{H}{n}$. Therefore the reorder times over the planning horizon H are given by T =jT (j= 0, 1, 2, 3-------n-1). The model is given by fig 1.

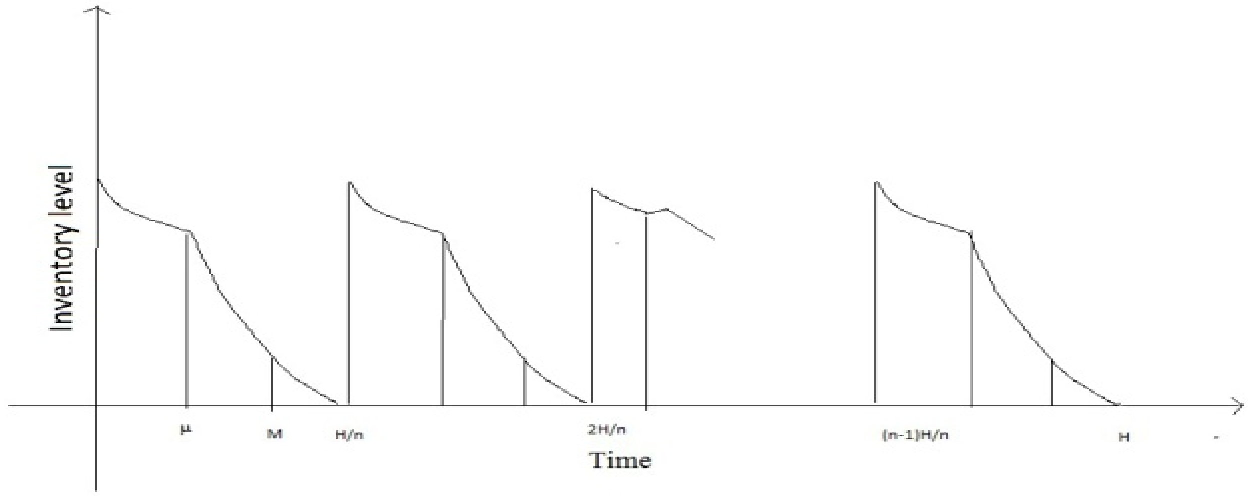

Figure-1

Let q(t) be the inventory level during the first replenishment cycle. This inventory level is depleted due to demand life time and due to demand and deterioration after life time. The governing differential equations of stock status during the period $0 \leq t \leq T$ Tare given by

$$\frac{dq}{dt} = -at(T-t) \qquad , 0 \leq t \leq \mu \qquad (1)$$

$$\frac{dq}{dt} = -at(T-t) - \theta_0 tq , \quad \text{where } 0 < \theta_0 < 1 , t > 0 \qquad , \mu \leq t \leq T \qquad (2)$$

θ_0 is constant

The boundary conditions are

$$q(0) = Q \qquad (3)$$

$$q(T) = 0 \qquad (4)$$

ANALYSIS:

Integrating (1) , we get

$$q = \frac{-aTt^2}{2} + \frac{at^3}{3} + Q \qquad (5)$$

Integrating (2), we get

$$\frac{dq}{dt} + \theta_0 tq = -at(T-t)$$

$$qe^{\theta_0 t^2/2} = \int -at(T-t)\, e^{\theta_0 t^2/2}\, dt$$

$$= -a\int t(T-t)\, [1+\frac{\theta_0 t^2}{2}]\, dt \text{ (neglecting higher order terms)}$$

$$= -a \int [tT - t^2 + (t^3 T - t^4)\frac{\theta_0}{2}]\, dt$$

$$= -a\, [T\frac{t^2}{2} - \frac{t^3}{3} + (T\frac{t^4}{4} - \frac{t^5}{5})\frac{\theta_0}{2}] + c_1 \qquad (6)$$

Now using boundary condition q(T) = 0 , we have

$$0 = [-a\, \{\frac{T^3}{2} - \frac{T^3}{3} + (\frac{T^5}{4} - \frac{T^3}{5})\frac{\theta_0}{2}\}]\, e^{\frac{-\theta_0 T^2}{2}} + c_1 e^{\frac{-\theta_0 T^2}{2}}$$

$0 = -a\left[\frac{T^3}{6}+\frac{T^5\theta_0}{20\,2}\right]+c_1$

$\therefore\ c_1 = a\left(\frac{T^3}{6}+\frac{T^6}{40}\theta_0\right)$ (7)

$qe^{\theta_0 t^2/2} = -a\left[T\frac{t^2}{2}-\frac{t^3}{3}+\left(T\frac{t^4}{4}-\frac{t^5}{5}\right)\frac{\theta_0}{2}\right]+a\left[\frac{T^3}{6}+\frac{T^6}{40}\theta_0\right]$ (8)

$\therefore\ Q = q + a\left[T\frac{t^2}{2}-\frac{t^3}{3}\right]$

$= a\left[T\frac{t^2}{2}-\frac{t^3}{3}\right] - a\left[\left\{T\frac{t^2}{2}-\frac{t^3}{3}+\left(T\frac{t^4}{4}-\frac{t^5}{5}\right)\frac{\theta_0}{2}\right\}+\left(\frac{T^3}{6}+\frac{T^6}{40}\theta_0\right)\right]e^{\frac{-\theta_0 t^2}{2}}$

$q(\mu) = Q - a\left[T\frac{\mu^2}{2}-\frac{\mu^3}{3}\right]$

$= -a\left[\left\{T\frac{\mu^2}{2}-\frac{\mu^3}{3}+\left(T\frac{\mu^4}{4}-\frac{\mu^5}{5}\right)\frac{\theta_0}{2}\right\}+\left(\frac{T^3}{6}+\frac{T^6}{40}\theta_0\right)\right]e^{\frac{-\theta_0 \mu^2}{2}}$

This provides

$q(0) = Q = a\left[T\frac{\mu^2}{2}-\frac{\mu^3}{3}\right] - a\left[\left\{T\frac{\mu^2}{2}-\frac{\mu^3}{3}+\left(T\frac{\mu^4}{4}-\frac{\mu^5}{5}\right)\frac{\theta_0}{2}\right\}+\left(\frac{T^3}{6}+\frac{T^6}{40}\theta_0\right)\right]e^{\frac{-\theta_0 \mu^2}{2}}$ (9)

The present value of the total replenishment cost is given by

$c_R = A\sum_{j=0}^{n-1} e^{-jRT} = \frac{A(1-e^{-RH})}{1-e^{\frac{RH}{n}}}$

The present value of the total purchasing cost is given by

$c_p = c\sum_{j=0}^{n-1} q(0)e^{-jRT}$

$= c\left[a\left[T\frac{\mu^2}{2}-\frac{\mu^3}{3}\right] - a\left[\left\{T\frac{\mu^2}{2}-\frac{\mu^3}{3}+\left(T\frac{\mu^4}{4}-\frac{\mu^5}{5}\right)\frac{\theta_0}{2}\right\}+\left(\frac{T^3}{6}+\frac{T^6}{40}\theta_0\right)\right]e^{\frac{-\theta_0 \mu^2}{2}}\right]\frac{(1-e^{-RH})}{1-e^{\frac{RH}{n}}}$ (10)

The present value of holding cost during first replenishment cycle is given by

$h_1 = h\left[\int_0^\mu q(t)e^{-Rt}\,dt + \int_\mu^T q(t)e^{-Rt}\,dt\right]$

$= h\left[\int_o^\mu \left[Q - a\left(T\frac{t^2}{2}-\frac{t^3}{3}\right)\right]e^{-Rt}\,dt + \int_\mu^T -a\left[\left(T\frac{t^2}{2}-\frac{t^3}{3}\right)+\left(T\frac{t^4}{4}-\frac{t^5}{5}\right)\frac{\theta_0}{2}-\left(\frac{T^3}{6}+\frac{T^6}{40}\theta_0\right)\right]e^{\frac{-\theta_0 t^2}{2}} e^{-Rt}\right]dt$ (11)

Let $h_1 = I_1 + I_2$ (12)

Where, $I_1 = h\left[\int_o^\mu Qe^{-Rt}\,dt - a\int_0^\mu\left(T\frac{t^2}{2}e^{-Rt}-\frac{t^3}{3}e^{-Rt}\right)\right]dt$

$= h\left[\left[\frac{Q}{R}\left(1-e^{-R\mu}\right)\right] + a\left[\left\{\frac{T}{2}\left(\frac{\mu^2}{R}+\frac{2\mu}{R^2}+\frac{2}{R^3}\right)-\left(\frac{1}{3}\frac{\mu^3}{R}+\frac{\mu^2}{R^2}+\frac{2\mu}{R^3}+\frac{2}{R^4}\right)\right\}e^{-R\mu}-\left(\frac{2}{R^3}+\frac{6}{R^4}\right)\right]\right]$

And $I_2 = h\left[\int_\mu^T -a\left[\left(T\frac{t^2}{2}-\frac{t^3}{3}\right)+\left(T\frac{t^4}{4}-\frac{t^5}{5}\right)\frac{\theta_0}{2}-\left(\frac{T^3}{6}+\frac{T^6}{40}\theta_0\right)\right]\left[1-\frac{\theta_0 t^2}{2}+\ .....\right](1-Rt)\right]dt$

$= h\left[\int_\mu^T -a\left[\left(T\frac{t^2}{2}-\frac{t^3}{3}\right)+\left(T\frac{t^4}{4}-\frac{t^5}{5}\right)\frac{\theta_0}{2}-\left(\frac{T^3}{6}+\frac{T^6}{40}\theta_0\right)-\frac{1}{2}\theta_0\left[\left(T\frac{t^4}{2}-\frac{t^5}{3}\right)+\left(T\frac{t^6}{4}-\frac{t^7}{5}\right)\frac{\theta_0}{2}-\left(\frac{T^3t^2}{6}-\frac{T^5t^2}{40}\theta_0\right)\right](1-Rt)\right]\right]dt$

$$= h[-a[\left[\frac{T^4}{12}+\frac{T^6\theta_0}{60\ 2}+\left(\frac{T^4}{6}-\frac{T^6}{40}\theta_0\right)+\frac{\theta_0}{2}\left[\frac{11}{360}T^6+\frac{3}{560}T^8\theta_0+\left(\frac{T^6}{18}-\frac{T^8}{120}\theta_0\right)\right]\right]$$

$$-\ [\left[\left(T\frac{\mu^3}{6}-\frac{\mu^4}{12}\right)+\left(T\frac{\mu^5}{20}-\frac{\mu^6}{30}\right)\frac{\theta_0}{2}-\left(\frac{T^3\mu}{6}-\frac{T^5\mu}{40}\theta_0\right)\right]$$

$$+\ \frac{\theta_0}{2}\left[\left(\frac{T\mu^5}{10}-\frac{\mu^6}{18}\right)+\left(\frac{T\mu^7}{28}-\frac{\mu^8}{40}\right)\frac{\theta_0}{2}-\left(\frac{T^3\mu^3}{18}-\frac{T^5\mu^3}{120}\theta_0\right)\right]]$$

$$-R[\left[\frac{T^5}{10}+\frac{11T^7}{1680}+\left(\frac{T^5}{6}-\frac{T^7}{40}\right)\frac{\theta_0}{2}-\frac{\theta_0}{2}\left\{\left(\frac{T^6}{12}-\frac{T^7}{21}\right)+\left(\frac{13T^9}{2880}\right)\theta_0+\left(\frac{T^7}{6}-\frac{T^9}{40}\right)\frac{\theta_0}{8}\right\}\right]$$

$$-\left(T\frac{\mu^4}{8}-\frac{\mu^5}{15}\right)-\left(\frac{T\mu^6}{24}-\frac{\mu^7}{35}\right)\frac{\theta_0}{2}-\left(\frac{T^3}{6}-\frac{T^5}{40}\right)\frac{\theta_0\mu^2}{2}+\frac{\theta_0}{2}\left\{\left(\frac{\mu^6}{12}-\frac{\mu^7}{21}\right)+\left(\frac{T\mu^8}{32}-\frac{\mu^9}{45}\right)\frac{\theta_0}{2}+\left(\frac{T^3}{6}-\frac{T^5}{40}\right)\frac{\theta_0\mu^4}{8}\right\}]]$$

(13)

Now putting the values of I_1 and I_2 in (12), we get

$$h_1 = h[\left[\frac{Q}{R}\left(1-e^{-R\mu}\right)\right]$$

$$+\ a\ [\{\frac{T}{2}\left(\frac{\mu^2}{R}+\frac{2\mu}{R^2}+\frac{2}{R^3}\right)-\left(\frac{1}{3}\frac{\mu^3}{R}+\frac{\mu^2}{R^2}+\frac{2\mu}{R^3}+\frac{2}{R^4}\right)\}\ e^{-R\mu}-\left(\frac{2}{R^3}+\frac{6}{R^4}\right)]]$$

$$+\ h[-a[\left[\frac{T^4}{12}+\frac{T^6\theta_0}{60\ 2}+\left(\frac{T^4}{6}-\frac{T^6}{40}\theta_0\right)+\frac{\theta_0}{2}\left[\frac{11}{360}T^6+\frac{3}{560}T^8\theta_0+\left(\frac{T^6}{18}-\frac{T^8}{120}\theta_0\right)\right]\right]$$

$$-\ [\left[\left(T\frac{\mu^3}{6}-\frac{\mu^4}{12}\right)+\left(T\frac{\mu^5}{20}-\frac{\mu^6}{30}\right)\frac{\theta_0}{2}-\left(\frac{T^3\mu}{6}-\frac{T^5\mu}{40}\theta_0\right)\right]$$

$$+\ \frac{\theta_0}{2}\left[\left(\frac{T\mu^5}{10}-\frac{\mu^6}{18}\right)+\left(\frac{T\mu^7}{28}-\frac{\mu^8}{40}\right)\frac{\theta_0}{2}-\left(\frac{T^3\mu^3}{18}-\frac{T^5\mu^3}{120}\theta_0\right)\right]]$$

$$-R\ [\left[\frac{T^5}{10}+\frac{11T^7}{1680}+\left(\frac{T^5}{6}-\frac{T^7}{40}\right)\frac{\theta_0}{2}-\frac{\theta_0}{2}\left\{\left(\frac{T^6}{12}-\frac{T^7}{21}\right)+\left(\frac{13T^9}{2880}\right)\theta_0+\left(\frac{T^7}{6}-\frac{T^9}{40}\right)\frac{\theta_0}{8}\right\}\right]$$

$$-\left(T\frac{\mu^4}{8}-\frac{\mu^5}{15}\right)-\left(\frac{T\mu^6}{24}-\frac{\mu^7}{35}\right)\frac{\theta_0}{2}-\left(\frac{T^3}{6}-\frac{T^5}{40}\right)\frac{\theta_0\mu^2}{2}+\frac{\theta_0}{2}\left\{\left(\frac{\mu^6}{12}-\frac{\mu^7}{21}\right)+\left(\frac{T\mu^8}{32}-\frac{\mu^9}{45}\right)\frac{\theta_0}{2}+\left(\frac{T^3}{6}-\frac{T^5}{40}\right)\frac{\theta_0\mu^4}{8}\right\}]]$$

(14)

The present value of the total holding cost is given by

$$c_h=\sum_{j=0}^{n-1} h_1 e^{-jRT}$$

$$= h[\left[\frac{Q}{R}\left(1-e^{-R\mu}\right)\right]$$

$$+\ a\ [\{\frac{T}{2}\left(\frac{\mu^2}{R}+\frac{2\mu}{R^2}+\frac{2}{R^3}\right)-\left(\frac{1}{3}\frac{\mu^3}{R}+\frac{\mu^2}{R^2}+\frac{2\mu}{R^3}+\frac{2}{R^4}\right)\}\ e^{-R\mu}-\left(\frac{2}{R^3}+\frac{6}{R^4}\right)]]$$

$$+\ h[-a[\left[\frac{T^4}{12}+\frac{T^6\theta_0}{60\ 2}+\left(\frac{T^4}{6}-\frac{T^6}{40}\theta_0\right)+\frac{\theta_0}{2}\left[\frac{11}{360}T^6+\frac{3}{560}T^8\theta_0+\left(\frac{T^6}{18}-\frac{T^8}{120}\theta_0\right)\right]\right]$$

$$-[\left[\left(T\frac{\mu^3}{6}-\frac{\mu^4}{12}\right)+\left(T\frac{\mu^5}{20}-\frac{\mu^6}{30}\right)\frac{\theta_0}{2}-\left(\frac{T^3\mu}{6}-\frac{T^5\mu}{40}\theta_0\right)\right]$$

$$+\ \frac{\theta_0}{2}\left[\left(\frac{T\mu^5}{10}-\frac{\mu^6}{18}\right)+\left(\frac{T\mu^7}{28}-\frac{\mu^8}{40}\right)\frac{\theta_0}{2}-\left(\frac{T^3\mu^3}{18}-\frac{T^5\mu^3}{120}\theta_0\right)\right]]$$

$$-R\ [\left[\frac{T^5}{10}+\frac{11T^7}{1680}+\left(\frac{T^5}{6}-\frac{T^7}{40}\right)\frac{\theta_0}{2}-\frac{\theta_0}{2}\left\{\left(\frac{T^6}{12}-\frac{T^7}{21}\right)+\left(\frac{13T^9}{2880}\right)\theta_0+\left(\frac{T^7}{6}-\frac{T^9}{40}\right)\frac{\theta_0}{8}\right\}\right]$$

$$-\left(T\frac{\mu^4}{8}-\frac{\mu^5}{15}\right)-\left(\frac{T\mu^6}{24}-\frac{\mu^7}{35}\right)\frac{\theta_0}{2}-\left(\frac{T^3}{6}-\frac{T^5}{40}\right)\frac{\theta_0\mu^2}{2}+\frac{\theta_0}{2}\left\{\left(\frac{\mu^6}{12}-\frac{\mu^7}{21}\right)+\left(\frac{T\mu^8}{32}-\frac{\mu^9}{45}\right)\frac{\theta_0}{2}+\left(\frac{T^3}{6}-\frac{T^5}{40}\right)\frac{\theta_0\mu^4}{8}\right\}\ ]\ ]]\left(\frac{1-e^{-RH}}{1-e^{\frac{RH}{n}}}\right)$$

(15)

Now we consider the two cases

M $\leq$ T = $\frac{H}{n}$

Sub case I $0 \leq M \leq \mu$

In this case, the interest payable is given by

$I_{p_1}^{1} = cI_c\left[\int_M^{\mu} q(t)e^{-Rt}\,dt + \int_{\mu}^{T} q(t)e^{-Rt}\,dt\right]$

$= cI_c[$

$\left[\frac{Q}{R}\left(e^{-RM} - e^{-R\mu}\right) + a\left[\left\{\frac{T}{2}\left(\frac{\mu^2}{R} + \frac{2\mu}{R^2} + \frac{2}{R^3}\right) - \left(\frac{1}{3}\frac{\mu^3}{R} + \frac{\mu^2}{R^2} + \frac{2\mu}{R^3} + \frac{2}{R^4}\right)\right\}e^{-R\mu}\right] - a\,[\{\frac{T}{2}\left(\frac{M^2}{R} + \frac{2M}{R^2} + \frac{2}{R^3}\right) - \left(\frac{1}{3}\frac{M^3}{R} + \frac{M^2}{R^2} + \frac{2M}{R^3} + \frac{2}{R^4}\right)\}\, e\right.$

$+ h[- a\left[\left[\frac{T^4}{12} + \frac{T^6\theta_0}{60\;2} + \left(\frac{T^4}{6} - \frac{T^6}{40}\theta_0\right) + \frac{\theta_0}{2}\left[\frac{11}{360}T^6 + \frac{3}{560}T^8\theta_0 + \left(\frac{T^6}{18} - \frac{T^8}{120}\theta_0\right)\right]\right]\right.$

$- \quad \left[\left[\left(T\frac{\mu^3}{6} - \frac{\mu^4}{12}\right) + \left(T\frac{\mu^5}{20} - \frac{\mu^6}{30}\right)\frac{\theta_0}{2} - \left(\frac{T^3\mu}{6} - \frac{T^5\mu}{40}\theta_0\right)\right]\right.$

$+ \quad \frac{\theta_0}{2}\left[\left(\frac{T\mu^5}{10} - \frac{\mu^6}{18}\right) + \left(\frac{T\mu^7}{28} - \frac{\mu^8}{40}\right)\frac{\theta_0}{2} - \left(\frac{T^3\mu^3}{18} - \frac{T^5\mu^3}{120}\theta_0\right)\right]]$

$- \; R\left[\left[\frac{T^5}{10} + \frac{11T^7}{1680} + \left(\frac{T^5}{6} - \frac{T^7}{40}\right)\frac{\theta_0}{2} - \frac{\theta_0}{2}\left\{\left(\frac{T^6}{12} - \frac{T^7}{21}\right) + \left(\frac{13T^9}{2880}\right)\theta_0 + \left(\frac{T^7}{6} - \frac{T^9}{40}\right)\frac{\theta_0}{8}\right\}\right]\right.$

$-\left(T\frac{\mu^4}{8} - \frac{\mu^5}{15}\right) - \left(\frac{T\mu^6}{24} - \frac{\mu^7}{35}\right)\frac{\theta_0}{2} - \left(\frac{T^3}{6} - \frac{T^5}{40}\right)\frac{\theta_0\mu^2}{2} + \frac{\theta_0}{2}\left\{\left(\frac{\mu^6}{12} - \frac{\mu^7}{21}\right) + \left(\frac{T\mu^8}{32} - \frac{\mu^9}{45}\right)\frac{\theta_0}{2} + \left(\frac{T^3}{6} - \frac{T^5}{40}\right)\frac{\theta_0\mu^4}{8}\right\}]]$

The present value of the total interest payable over the time horizon H is given by

$I_{p_1}^{H} = \sum_{j=0}^{n-1} I_{p_1}^{1} e^{-jRT}$

$= cI_c[$

$\left[\frac{Q}{R}\left(e^{-RM} - e^{-R\mu}\right) + a\left[\left\{\frac{T}{2}\left(\frac{\mu^2}{R} + \frac{2\mu}{R^2} + \frac{2}{R^3}\right) - \left(\frac{1}{3}\frac{\mu^3}{R} + \frac{\mu^2}{R^2} + \frac{2\mu}{R^3} + \frac{2}{R^4}\right)\right\}e^{-R\mu}\right] - a\,[\{\frac{T}{2}\left(\frac{M^2}{R} + \frac{2M}{R^2} + \frac{2}{R^3}\right) - \left(\frac{1}{3}\frac{M^3}{R} + \frac{M^2}{R^2} + \frac{2M}{R^3} + \frac{2}{R^4}\right)\}\right.$

$+ h[- a\left[\left[\frac{T^4}{12} + \frac{T^6\theta_0}{60\;2} + \left(\frac{T^4}{6} - \frac{T^6}{40}\theta_0\right) + \frac{\theta_0}{2}\left[\frac{11}{360}T^6 + \frac{3}{560}T^8\theta_0 + \left(\frac{T^6}{18} - \frac{T^8}{120}\theta_0\right)\right]\right]\right.$

$- \quad \left[\left[\left(T\frac{\mu^3}{6} - \frac{\mu^4}{12}\right) + \left(T\frac{\mu^5}{20} - \frac{\mu^6}{30}\right)\frac{\theta_0}{2} - \left(\frac{T^3\mu}{6} - \frac{T^5\mu}{40}\theta_0\right)\right]\right.$

$+ \quad \frac{\theta_0}{2}\left[\left(\frac{T\mu^5}{10} - \frac{\mu^6}{18}\right) + \left(\frac{T\mu^7}{28} - \frac{\mu^8}{40}\right)\frac{\theta_0}{2} - \left(\frac{T^3\mu^3}{18} - \frac{T^5\mu^3}{120}\theta_0\right)\right]]$

$- \; R\left[\left[\frac{T^5}{10} + \frac{11T^7}{1680} + \left(\frac{T^5}{6} - \frac{T^7}{40}\right)\frac{\theta_0}{2} - \frac{\theta_0}{2}\left\{\left(\frac{T^6}{12} - \frac{T^7}{21}\right) + \left(\frac{13T^9}{2880}\right)\theta_0 + \left(\frac{T^7}{6} - \frac{T^9}{40}\right)\frac{\theta_0}{8}\right\}\right]\right.$

$-\left(T\frac{\mu^4}{8} - \frac{\mu^5}{15}\right) - \left(\frac{T\mu^6}{24} - \frac{\mu^7}{35}\right)\frac{\theta_0}{2} - \left(\frac{T^3}{6} - \frac{T^5}{40}\right)\frac{\theta_0\mu^2}{2} + \frac{\theta_0}{2}\left\{\left(\frac{\mu^6}{12} - \frac{\mu^7}{21}\right) + \left(\frac{T\mu^8}{32} - \frac{\mu^9}{45}\right)\frac{\theta_0}{2} + \left(\frac{T^3}{6} - \frac{T^5}{40}\right)\frac{\theta_0\mu^4}{8}\right\}]]$

$$\left(\frac{1 - e^{-RH}}{1 - e^{\frac{RH}{n}}}\right) \tag{17}$$

The present value of the total interest earned during the first replenishment cycle is given

$I_{e_1}^{h} = s\, I_e \int_0^T at(T - t)t\, e^{-RT}\,dt$

$$= s\, I_e\left[\frac{T^2e^{-RT}}{R^2} + \frac{2Te^{-RT}}{R^3} + \frac{6}{R^4}\left(1 - e^{-RT}\right)\right] \tag{18}$$

Hence the present value of the total interest earned over the time horizon H is given by

$$I_{e_1}^{H} = \sum_{j=0}^{n-1} I_{e_1}^{1} e^{-jRT}$$

$$= s\, I_e\left[\frac{T^2e^{-RT}}{R^2} + \frac{2Te^{-RT}}{R^3} + \frac{6}{R^4}\left(1 - e^{-RT}\right)\right]\left(\frac{1-e^{-RH}}{1-e^{\frac{RH}{n}}}\right) \tag{19}$$

Sub case II $\mu \leq$ M

In this case, the interest payable is given by

$$I_{p_1}^{2} = c\, I_c\left[\int_M^T q(t)e^{-RT}\,dt\right]$$

$$= c\, I_c[\, h[-\, a[\left[\frac{T^4}{12} + \frac{T^6\theta_0}{60\,2} + \left(\frac{T^4}{6} - \frac{T^6}{40}\theta_0\right) + \frac{\theta_0}{2}\left[\frac{11}{360}T^6 + \frac{3}{560}T^8\theta_0 + \left(\frac{T^6}{18} - \frac{T^8}{120}\theta_0\right)\right]\right]$$

$$-\quad [\left[\left(T\frac{M^3}{6} - \frac{M^4}{12}\right) + \left(T\frac{M^5}{20} - \frac{M^6}{30}\right)\frac{\theta_0}{2} - \left(\frac{T^3M}{6} - \frac{T^5M}{40}\theta_0\right)\right]$$

$$+\quad \frac{\theta_0}{2}\left[\left(\frac{TM^5}{10} - \frac{\mu^6}{18}\right) + \left(\frac{T\,M^7}{28} - \frac{\mu^8}{40}\right)\frac{\theta_0}{2} - \left(\frac{T^3M^3}{18} - \frac{T^5M^3}{120}\theta_0\right)\right]]$$

$$-\, R\, [\left[\frac{T^5}{10} + \frac{11T^7}{1680} + \left(\frac{T^5}{6} - \frac{T^7}{40}\right)\frac{\theta_0}{2} - \frac{\theta_0}{2}\left\{\left(\frac{T^6}{12} - \frac{T^7}{21}\right) + \left(\frac{13T^9}{2880}\right)\theta_0 + \left(\frac{T^7}{6} - \frac{T^9}{40}\right)\frac{\theta_0}{8}\right\}\right]$$

$$-\left(T\frac{M^4}{8} - \frac{M^5}{15}\right) - \left(\frac{TM^6}{24} - \frac{M^7}{35}\right)\frac{\theta_0}{2} - \left(\frac{T^3}{6} - \frac{T^5}{40}\right)\frac{\theta_0 M^2}{2} + \frac{\theta_0}{2}\left\{\left(\frac{M^6}{12} - \frac{M^7}{21}\right) + \left(\frac{TM^8}{32} - \frac{M^9}{45}\right)\frac{\theta_0}{2} + \left(\frac{T^3}{6} - \frac{T^5}{40}\right)\frac{\theta_0 M^4}{8}\right\}]\,] \tag{20}$$

The present value of the total interest payable over the time horizon H is given by

$$I_{p_1}^{H} = \sum_{j=0}^{n-1} I_{p_1}^{2} e^{-jRT}$$

$$= c\, I_c[\, h[-\, a[\left[\frac{T^4}{12} + \frac{T^6\theta_0}{60\,2} + \left(\frac{T^4}{6} - \frac{T^6}{40}\theta_0\right) + \frac{\theta_0}{2}\left[\frac{11}{360}T^6 + \frac{3}{560}T^8\theta_0 + \left(\frac{T^6}{18} - \frac{T^8}{120}\theta_0\right)\right]\right]$$

$$-\quad [\left[\left(T\frac{M^3}{6} - \frac{M^4}{12}\right) + \left(T\frac{M^5}{20} - \frac{M^6}{30}\right)\frac{\theta_0}{2} - \left(\frac{T^3M}{6} - \frac{T^5M}{40}\theta_0\right)\right]$$

$$+\quad \frac{\theta_0}{2}\left[\left(\frac{TM^5}{10} - \frac{\mu^6}{18}\right) + \left(\frac{T\,M^7}{28} - \frac{\mu^8}{40}\right)\frac{\theta_0}{2} - \left(\frac{T^3M^3}{18} - \frac{T^5M^3}{120}\theta_0\right)\right]]$$

$$-\, R\, [\left[\frac{T^5}{10} + \frac{11T^7}{1680} + \left(\frac{T^5}{6} - \frac{T^7}{40}\right)\frac{\theta_0}{2} - \frac{\theta_0}{2}\left\{\left(\frac{T^6}{12} - \frac{T^7}{21}\right) + \left(\frac{13T^9}{2880}\right)\theta_0 + \left(\frac{T^7}{6} - \frac{T^9}{40}\right)\frac{\theta_0}{8}\right\}\right]$$

$$-\left(T\frac{M^4}{8} - \frac{M^5}{15}\right) - \left(\frac{TM^6}{24} - \frac{M^7}{35}\right)\frac{\theta_0}{2} - \left(\frac{T^3}{6} - \frac{T^5}{40}\right)\frac{\theta_0 M^2}{2} + \frac{\theta_0}{2}\left\{\left(\frac{M^6}{12} - \frac{M^7}{21}\right) + \left(\frac{TM^8}{32} - \frac{M^9}{45}\right)\frac{\theta_0}{2} + \left(\frac{T^3}{6} - \frac{T^5}{40}\right)\frac{\theta_0 M^4}{8}\right\}]\,]\;\left(\frac{1-e^{-RH}}{1-e^{\frac{RH}{n}}}\right)$$

(21)

Therefore the total present value of the cost over the time horizon H is given by

$$TVC_1(\mathrm{n}) = c_R + c_p + c_h + I_{p_1}^{H} - I_{e_1}^{H}$$

$$= A\left(\frac{1-e^{-RH}}{1-e^{\frac{RH}{n}}}\right) + c[a\,[\,T\frac{\mu^2}{2} - \frac{\mu^3}{2}] - a[\{T\frac{\mu^2}{2} - \frac{\mu^3}{3} + (\,T\,\frac{\mu^4}{4} - \frac{\mu^5}{5}\,)\,\frac{\theta_0}{2}\,\} + (\,\frac{T^3}{6} + \frac{T^6}{40}\theta_0)\;\;]\; e^{\frac{-\theta_0\mu^2}{2}}\;\;]\,\frac{(1-e^{-RH})}{1-e^{\frac{RH}{n}}}$$

$$+\; h[\left[\frac{Q}{R}\left(1 - e^{-R\mu}\right)\right]$$

$$+ \text{a} [\{\frac{T}{2}\left(\frac{\mu^2}{R}+\frac{2\mu}{R^2}+\frac{2}{R^3}\right)-\left(\frac{1}{3}\frac{\mu^3}{R}+\frac{\mu^2}{R^2}+\frac{2\mu}{R^3}+\frac{2}{R^4}\right)\} e^{-R\mu} - \left(\frac{2}{R^3}+\frac{6}{R^4}\right)]]$$

$$+ \text{h}[- \text{a}[\left[\frac{T^4}{12}+\frac{T^6\theta_0}{60\,2}+\left(\frac{T^4}{6}-\frac{T^6}{40}\theta_0\right)+ \frac{\theta_0}{2}\left[\frac{11}{360}T^6+\frac{3}{560}T^8\theta_0+\left(\frac{T^6}{18}-\frac{T^8}{120}\theta_0\right)\right]\right]$$

$$-[\left[\left(\text{T}\frac{\mu^3}{6}-\frac{\mu^4}{12}\right)+\left(\text{T}\frac{\mu^5}{20}-\frac{\mu^6}{30}\right)\frac{\theta_0}{2}-\left(\frac{T^3\mu}{6}-\frac{T^5\mu}{40}\theta_0\right)\right]$$

$$+ \frac{\theta_0}{2}\left[\left(\frac{T\mu^5}{10}-\frac{\mu^6}{18}\right)+\left(\frac{T\mu^7}{28}-\frac{\mu^8}{40}\right)\frac{\theta_0}{2}-\left(\frac{T^3\mu^3}{18}-\frac{T^5\mu^3}{120}\theta_0\right)\right]]$$

$$- R\left[\left[\frac{T^5}{10}+\frac{11T^7}{1680}+\left(\frac{T^5}{6}-\frac{T^7}{40}\right)\frac{\theta_0}{2}-\frac{\theta_0}{2}\left\{\left(\frac{T^6}{12}-\frac{T^7}{21}\right)+\left(\frac{13T^9}{2880}\right)\theta_0+\left(\frac{T^7}{6}-\frac{T^9}{40}\right)\frac{\theta_0}{8}\right\}\right]\right.$$

$$-\left(\text{T}\frac{\mu^4}{8}-\frac{\mu^5}{15}\right) - \left(\frac{T\mu^6}{24}-\frac{\mu^7}{35}\right)\frac{\theta_0}{2} - \left(\frac{T^3}{6}-\frac{T^5}{40}\right)\frac{\theta_0\mu^2}{2}+\frac{\theta_0}{2}\left\{\left(\frac{\mu^6}{12}-\frac{\mu^7}{21}\right)+\left(\frac{T\mu^8}{32}-\frac{\mu^9}{45}\right)\frac{\theta_0}{2}+\left(\frac{T^3}{6}-\frac{T^5}{40}\right)\frac{\theta_0\mu^4}{8}\right\}]]]\left(\frac{1-e^{-RH}}{1-e^{\frac{RH}{n}}}\right)+ c\, I_c[$$

$$\text{h}[- \text{a}[\left[\frac{T^4}{12}+\frac{T^6\theta_0}{60\,2}+\left(\frac{T^4}{6}-\frac{T^6}{40}\theta_0\right)+ \frac{\theta_0}{2}\left[\frac{11}{360}T^6+\frac{3}{560}T^8\theta_0+\left(\frac{T^6}{18}-\frac{T^8}{120}\theta_0\right)\right]\right]$$

$$- [\left[\left(\text{T}\frac{M^3}{6}-\frac{M^4}{12}\right)+\left(\text{T}\frac{M^5}{20}-\frac{M^6}{30}\right)\frac{\theta_0}{2}-\left(\frac{T^3M}{6}-\frac{T^5M}{40}\theta_0\right)\right]$$

$$+ \frac{\theta_0}{2}\left[\left(\frac{TM^5}{10}-\frac{\mu^6}{18}\right)+\left(\frac{TM^7}{28}-\frac{\mu^8}{40}\right)\frac{\theta_0}{2}-\left(\frac{T^3M^3}{18}-\frac{T^5M^3}{120}\theta_0\right)\right]]$$

$$- R\left[\left[\frac{T^5}{10}+\frac{11T^7}{1680}+\left(\frac{T^5}{6}-\frac{T^7}{40}\right)\frac{\theta_0}{2}-\frac{\theta_0}{2}\left\{\left(\frac{T^6}{12}-\frac{T^7}{21}\right)+\left(\frac{13T^9}{2880}\right)\theta_0+\left(\frac{T^7}{6}-\frac{T^9}{40}\right)\frac{\theta_0}{8}\right\}\right]\right.$$

$$-\left(\text{T}\frac{M^4}{8}-\frac{M^5}{15}\right) - \left(\frac{TM^6}{24}-\frac{M^7}{35}\right)\frac{\theta_0}{2} - \left(\frac{T^3}{6}-\frac{T^5}{40}\right)\frac{\theta_0M^2}{2}+\frac{\theta_0}{2}\left\{\left(\frac{M^6}{12}-\frac{M^7}{21}\right)+\left(\frac{TM^8}{32}-\frac{M^9}{45}\right)\frac{\theta_0}{2}+\left(\frac{T^3}{6}-\frac{T^5}{40}\right)\frac{\theta_0M^4}{8}\right\}]]\left(\frac{1-e^{-RH}}{1-e^{\frac{RH}{n}}}\right)$$

$$- s\, I_e\left[\frac{T^2e^{-RT}}{R^2}+\frac{2Te^{-RT}}{R^3}+\frac{6}{R^4}\left(1-e^{-RT}\right)\right]\left(\frac{1-e^{-RH}}{1-e^{\frac{RH}{n}}}\right)]] \qquad (22)$$

Case 2 : M >T $=\frac{H}{n}$

In this case, the interest charged by the supplier will be zero because the supplies can be paid at H which is greater than T.

The interest earned in the first cycle is the interest earned during the period (0,T) and the interest earned from cash invested during the period (T,M) . This is given by

$$I_{e_2}^{1} = s\, I_e\left[\int_0^T at(T-t)te^{-Rt}\,dt+(M-T)\,e^{-RT}\int_T^M at(T-t)t\,dt\right]$$

$$= a\,s\, I_e\left[\left(\frac{T^2}{R^2}+\frac{4T}{R^3}-\frac{T^4}{R^4}\right)e^{-RT}+\left(\frac{2T}{R^3}+\frac{6}{R^4}\right)+(M-T)e^{-RT}\left(\frac{TM^2}{3}-\frac{M^4}{4}-\frac{T^4}{12}\right)\right] \qquad (23)$$

Hence the present value of the total interest earned over time horizon H is given by

$$I_{e_2}^{H} = \sum_{j=0}^{n-1} I_{e_2}^{1} e^{-jRT}$$

$$= a\,s\, I_e\left[\left(\frac{T^2}{R^2}+\frac{4T}{R^3}-\frac{T^4}{R^4}\right)e^{-RT}+\left(\frac{2T}{R^3}+\frac{6}{R^4}\right)\ (M-T)e^{-RT}\left(\frac{TM^2}{3}-\frac{M^4}{4}-\frac{T^4}{12}\right)\right]\left(\frac{1-e^{-RH}}{1-e^{\frac{RH}{n}}}\right) \qquad (24)$$

As the replenishment cost, purchasing cost and holding cost over the time horizon H are same as in case I, the present value of the cost is given by

$TVC_2(n) = c_R + c_p + c_h - I_{e_2}^{H}$

$A\left(\frac{1-e^{-RH}}{1-e^{\frac{RH}{n}}}\right)$ + c[a [$T\frac{\mu^2}{2}-\frac{\mu^3}{2}$] $-$ a[{$T\frac{\mu^2}{2}-\frac{\mu^3}{3}$ + (T $\frac{\mu^4}{4}$ - $\frac{\mu^5}{5}$) $\frac{\theta_0}{2}$ } + ($\frac{T^3}{6}+\frac{T^6}{40}\theta_0$)] $e^{\frac{-\theta_0\mu^2}{2}}$] $\frac{(1-e^{-RH})}{1-e^{\frac{RH}{n}}}$ + h[$\left[\frac{Q}{R}\left(1-e^{-R\mu}\right)\right]$

$+ a\ [\{\frac{T}{2}\left(\frac{\mu^2}{R}+\frac{2\mu}{R^2}+\frac{2}{R^3}\right)-\left(\frac{1}{3}\frac{\mu^3}{R}+\frac{\mu^2}{R^2}+\frac{2\mu}{R^3}+\frac{2}{R^4}\right)\}\ e^{-R\mu}-\left(\frac{2}{R^3}+\frac{6}{R^4}\right)]]$

$+ h[-a[\left[\frac{T^4}{12}+\frac{T^6\theta_0}{60\ 2}+\left(\frac{T^4}{6}-\frac{T^6}{40}\theta_0\right)+\frac{\theta_0}{2}\left[\frac{11}{360}T^6+\frac{3}{560}T^8\theta_0+\left(\frac{T^6}{18}-\frac{T^8}{120}\theta_0\right)\right]\right]$

$-[\left[\left(T\frac{\mu^3}{6}-\frac{\mu^4}{12}\right)+\left(T\frac{\mu^5}{20}-\frac{\mu^6}{30}\right)\frac{\theta_0}{2}-\left(\frac{T^3\mu}{6}-\frac{T^5\mu}{40}\theta_0\right)\right]$

$+\frac{\theta_0}{2}\left[\left(\frac{T\mu^5}{10}-\frac{\mu^6}{18}\right)+\left(\frac{T\mu^7}{28}-\frac{\mu^8}{40}\right)\frac{\theta_0}{2}-\left(\frac{T^3\mu^3}{18}-\frac{T^5\mu^3}{120}\theta_0\right)\right]]$

$- R\ [\left[\frac{T^5}{10}+\frac{11T^7}{1680}+\left(\frac{T^5}{6}-\frac{T^7}{40}\right)\frac{\theta_0}{2}-\frac{\theta_0}{2}\left\{\left(\frac{T^6}{12}-\frac{T^7}{21}\right)+\left(\frac{13T^9}{2880}\right)\theta_0+\left(\frac{T^7}{6}-\frac{T^9}{40}\right)\frac{\theta_0}{8}\right\}\right]$

$-\left(T\frac{\mu^4}{8}-\frac{\mu^5}{15}\right)-\left(\frac{T\mu^6}{24}-\frac{\mu^7}{35}\right)\frac{\theta_0}{2}-\left(\frac{T^3}{6}-\frac{T^5}{40}\right)\frac{\theta_0\mu^2}{2}+\frac{\theta_0}{2}\left\{\left(\frac{\mu^6}{12}-\frac{\mu^7}{21}\right)+\left(\frac{T\mu^8}{32}-\frac{\mu^9}{45}\right)\frac{\theta_0}{2}+\left(\frac{T^3}{6}-\frac{T^5}{40}\right)\frac{\theta_0\mu^4}{8}\right\}\ ]\ ]]\left(\frac{1-e^{-RH}}{1-e^{\frac{RH}{n}}}\right)+c\ I_c[$

$h[-a[\left[\frac{T^4}{12}+\frac{T^6\theta_0}{60\ 2}+\left(\frac{T^4}{6}-\frac{T^6}{40}\theta_0\right)+\frac{\theta_0}{2}\left[\frac{11}{360}T^6+\frac{3}{560}T^8\theta_0+\left(\frac{T^6}{18}-\frac{T^8}{120}\theta_0\right)\right]\right]$

$-\ [\left[\left(T\frac{M^3}{6}-\frac{M^4}{12}\right)+\left(T\frac{M^5}{20}-\frac{M^6}{30}\right)\frac{\theta_0}{2}-\left(\frac{T^3M}{6}-\frac{T^5M}{40}\theta_0\right)\right]$

$+\frac{\theta_0}{2}\left[\left(\frac{TM^5}{10}-\frac{\mu^6}{18}\right)+\left(\frac{T\ M^7}{28}-\frac{\mu^8}{40}\right)\frac{\theta_0}{2}-\left(\frac{T^3M^3}{18}-\frac{T^5M^3}{120}\theta_0\right)\right]]$

$- R\ [\left[\frac{T^5}{10}+\frac{11T^7}{1680}+\left(\frac{T^5}{6}-\frac{T^7}{40}\right)\frac{\theta_0}{2}-\frac{\theta_0}{2}\left\{\left(\frac{T^6}{12}-\frac{T^7}{21}\right)+\left(\frac{13T^9}{2880}\right)\theta_0+\left(\frac{T^7}{6}-\frac{T^9}{40}\right)\frac{\theta_0}{8}\right\}\right]$

$-\left(T\frac{M^4}{8}-\frac{M^5}{15}\right)-\left(\frac{TM^6}{24}-\frac{M^7}{35}\right)\frac{\theta_0}{2}-\left(\frac{T^3}{6}-\frac{T^5}{40}\right)\frac{\theta_0M^2}{2}+\frac{\theta_0}{2}\left\{\left(\frac{M^6}{12}-\frac{M^7}{21}\right)+\left(\frac{TM^8}{32}-\frac{M^9}{45}\right)\frac{\theta_0}{2}+\left(\frac{T^3}{6}-\frac{T^5}{40}\right)\frac{\theta_0M^4}{8}\right\}]\ ]\ \left(\frac{1-e^{-RH}}{1-e^{\frac{RH}{n}}}\right)- a\ s$

$I_e\left[\left(\frac{T^2}{R^2}+\frac{4T}{R^3}-\frac{T^4}{R^4}\right)e^{-RT}+\left(\frac{2T}{R^3}+\frac{6}{R^4}\right)\ (M-T)e^{-RT}\ \left(\frac{TM^2}{3}-\frac{M^4}{4}-\frac{T^4}{12}\right)\right]\left(\frac{1-e^{-RH}}{1-e^{\frac{RH}{n}}}\right)$

At M = T = $\frac{H}{n}$,

We have , TVC_1(n) = TVC_2(n)

$$TVC(n) = \begin{cases} TVC_1(n), T = \frac{H}{n} \geq M \\ TVC_2(n), T = \frac{H}{n} \leq M \end{cases}$$

CONCLUSIONS:

In this paper, an inventory model has been developed for the deteriorating items with the life time under assumptions of trade credit and time discounting. Time horizon has been considered finite. The demand rate has been taken quadratic function of time starting from zero and ending with zero. The variable rate of deterioration has been taken. The time horizon has been divided into n equal subintervals. The work can be further being extended for the other form of demand rate and for multi items.

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