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Replenishment Policy for Deteriorating Items with Additive Exponential Life Time under Permissible Delay in Payment.

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ABSTRACT: A collaborative replenishment policy in an inventory management system of the venders and the customers is most important. There are many inventory policies where the purchaser is allowed a permissible trade period for paying back the cost of inventory bought without paying any interest. This permissible delay in payment is a win–win strategy for sharing profit in the collaborative system. However, the purchaser can get interest on the sales of the inventory during this payment period. The present paper deals with a replenishment policy for deteriorating items with linear trended demand assuming lifetime of the commodity as random and following additive exponential distribution under permissible payment delay in nature. Shortages are allowed and completely backlogged. Lastly the model is illustrated with the help of a numerical example and the sensitivity analysis on the optimal solution towards different facts of the permissible delays in payment is also discussed.

KEY WORDS: Replenishment, deterioration, linear tended demand, additive exponential, delay, payment and shortages.

I. INTRODUCTION

The effect of a permissible delay in payment on the replenishment policy plays an important role in an inventory management system. During development of a mathematical model in inventory control, the classical approach is that the payment would be made to the supplier for the goods soon after receiving the consignment. However, in day-to-day dealings, it is often found that a supplier allows certain fixed period of time for settling the amount owed to him for the items supplied. During this period there is no interest charged, but beyond this period of time, there is interest charged by the supplier under the terms and conditions agreed upon. This gives an opportunity to the customers in order to that they do not have to pay the supplier immediately after receiving the consignment, but otherwise, their payment can be made delay until the allowed time period is ended. Moreover, the customer can earn interest on the revenues accumulated from the sale of the product received. Inventory problems with such permissible credit period were first considered by Goyal [1]. Later, Jaggi and Aggarwa [4] have discussed a model on the optimum order quantity for deteriorating items under permissible delay in payment after rectification of certain flaws in the paper of Goyal. After that many researchers Davis and Gaither [2], Mandal and Phaujdar [3],Chung [5], Chang et al [6], Huang [7], Cheng et al [8], Li et al [9] and Behara et al [10] have developed economic order quantity modelon deteriorating items under conditions of trade credit policy.

The traditional inventory model of HarisF[11] considered an inventory model where the depletion is caused by a constant demand rate alone. In real-life, it was seen that this depletion may occur due to deterioration also. Many researchers like Shah [12],Datta and Pal [13]etc names only a few. Moreover several researchers like Rao[14], Biswaranjan Mandal[15, 16] have invented many inventory models on deteriorating items under additive exponential lifetime in nature. In this paper my development based on the assumption where the random lifetime of the commodity which is sum of two variables namely natural life and extended life. This extended life of commodity occurs mainly due to cold storage facilities, humidity, chemical treatment etc. So the lifetime of the commodity is to be approximated with an additive exponential distribution and its probability density function is of the form

$$f(t) = \frac{e^{-\frac{t}{\theta_1}} - e^{-\frac{t}{\theta_2}}}{\theta_1 - \theta_2}, \theta_1 > \theta_2 \text{ and } t \geq 0.$$

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The present paper deals with a replenishment policy for deteriorating items with linear trended demand assuming lifetime of the commodity as random and following additive exponential distribution under permissible delay in payment. Shortages are allowed and completely backlogged.
Finally, the model is illustrated with the help of a numerical example and the sensitivity analysis is made on the optimal solution towards different facts of the permissible delays in payment is also discussed.

II. THE NOTATIONS AND ASSUMPTIONS OF THE MODEL

The mathematical model is developed under the following notations and assumptions:

Notations:

C_3 : Ordering cost of inventory (dollars/order),
c: The unit cost per item(dollars/unit),
C_h : The inventory holding cost per unit per unit time,
I_e : The interest earned per dollar per unit time,
I_p : The interest paid per dollar per unit time,
C_2 : Shortage cost (dollars/unit),
t_c : The permissible delay period,
t_1 : Length of the period with positive stock of the item,
T : The fixed length of order cycle,
C_D : Total cost of the deterioration per cycle,
C_H : Total holding cost per cycle,
P_T : Total Interest payable per cycle,
I_T : Total Interest earned per cycle,
C_S : Total shortage cost per cycle,
Q : The total amount of Inventory,
S : The size of initial inventory,
.TC : The average total cost per unit time.

Assumptions:

(i) Replenishment size is constant and replenishment rate is infinite.
(ii) Lead time is zero.
(iii) There is no repair or replacement of the deteriorated items.
(iv) The instantaneous rate of deterioration of the on-hand inventory is

$$\theta(t)=\frac{e^{-\frac{t}{\theta_1}}-e^{-\frac{t}{\theta_2}}}{\theta_1 e^{-\frac{t}{\theta_1}}-\theta_2 e^{-\frac{t}{\theta_2}}},\theta_1>\theta_2;t\geq 0$$

(v) The demand rate R(t) is assumed as
R(t)= a +b t, where a and b are positive constants. (a is initial demand rate and b is the positive trend in demand).

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(vi) Shortages are allowed and completely backlogged.

III. THE MATHEMATICAL MODEL

Let I(t) be the inventory level at time t. Depletion in inventory occurs due to demand and deterioration simultaneously. For this, the inventory level gradually diminishes during the period (0, t_1) and ultimately falls to zero at t = t_1. Shortages occur during time period (t_1, T) which are fully backlogged. The differential equations representing the inventory status is given by the following:

$$\frac{dI(t)}{dt} + \theta(t)I(t) = -R(t), 0 \le t \le t_1 \quad (1)$$

And $$\frac{dI(t)}{dt} = -R(t), t_1 \le t \le T \quad (2)$$

The initial condition is $I(0) = S$ and $I(t_1) = 0$ (3)

Putting the values of $\theta(t) = \dfrac{e^{-\frac{t}{\theta_1}} - e^{-\frac{t}{\theta_2}}}{\theta_1 e^{-\frac{t}{\theta_1}} - \theta_2 e^{-\frac{t}{\theta_2}}}$ and R(t) = a + bt, and then solving the equations (1) and (2) using the initial condition (3) and neglecting the higher powers of $\frac{1}{\theta_1} and \frac{1}{\theta_2}$, we get the following

$$\text{I(t)} = S(1-\frac{t^2}{2\theta_1\theta_2}) - (at + \frac{b}{2}t^2 - \frac{a}{3\theta_1\theta_2}t^3 - \frac{b}{8\theta_1\theta_2}t^4),\ 0 \le t \le t_1 \quad (4)$$

And $$\text{I(t)} = a(t_1 - t) + \frac{b}{2}(t_1^2 - t^2),\ t_1 \le t \le T \quad (5)$$

Since I(t1) = 0, from equation (4) we get the following neglecting higher order terms of $\frac{1}{\theta_1} and \frac{1}{\theta_2}$

$$\text{S} = at_1 + \frac{b}{2}t_1^{\,2} + \frac{a}{6\theta_1\theta_2}t_1^{\,3} + \frac{b}{8\theta_1\theta_2}t_1^{\,4} \quad (6)$$

The number of items backlogged at the beginning of the period is

$$\text{Q} - \text{S} = \int_{t_1}^{T} (a + bt)dt$$

Or, $$\text{Q} = aT + \frac{b}{2}T^2 + \frac{a}{6\theta_1\theta_2}t_1^{\,3} + \frac{b}{8\theta_1\theta_2}t_1^{\,4} \text{ (using (6))} \quad (7)$$

Inventory scenarios:

Since the total depletion of the on-hand inventory occurs at time $t_1 (< T)$, the following two distinct cases are observed.

(i). $t_c \le t_1 < T$ (payment at or before the total depletion of inventory)

(ii). $t_1 < t_c$ (payment after depletion of inventory)

Case 1: $t_c \le t_1 < T$ (payment at or before the total depletion of inventory):

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In this case, the individual cost components are evaluated as follows:

(a). The ordering cost of inventory per cycle is fixed at C_3 (dollars/order).

(b). The deterioration cost of items C_D over entire cycle (0,T) is given by

$$C_D = cQ = c[aT + \frac{b}{2}T^2 + \frac{a}{6\theta_1\theta_2}t_1^3 + \frac{b}{8\theta_1\theta_2}t_1^4] \quad \text{[using (7)]} \tag{8}$$

(c). The total inventory holding cost over entire cycle (0,T) is

$$C_H = cC_h \int_0^{t_1} I(t)dt$$

Using the expression of I(t) given in (4) and then eliminating S given in the equation (6), and integrating we get

$$C_H = cC_h [\frac{a}{2}t_1^2 + \frac{b}{3}t_1^3 + \frac{a}{12\theta_1\theta_2}t_1^4 + \frac{b}{15\theta_1\theta_2}t_1^5] \tag{9}$$

(d). The total interest payable over the entire cycle (0,T) is

$$P_T = cI_p \int_{t_c}^{t_1} I(t)dt$$

Using the expression of I(t) given in (4) and then eliminating S given in the equation (6), and integrating we get

$$\begin{aligned} P_T = cI_p [&(\frac{a}{2}t_1^2 + \frac{b}{3}t_1^3 + \frac{a}{12\theta_1\theta_2}t_1^4 + \frac{b}{15\theta_1\theta_2}t_1^5) \\ &-(at_ct_1 + \frac{b}{2}t_ct_1^2 + \frac{a}{6\theta_1\theta_2}t_ct_1^3 + \frac{b}{8\theta_1\theta_2}t_ct_1^4 - \frac{a}{6\theta_1\theta_2}t_c^3t_1 - \frac{b}{12\theta_1\theta_2}t_c^3t_1^2) \\ &+(\frac{a}{2}t_c^2 + \frac{b}{6}t_c^3 - \frac{a}{12\theta_1\theta_2}t_1^4 - \frac{b}{40\theta_1\theta_2}t_1^5)] \end{aligned} \tag{10}$$

(e). The total interest earned over the entire cycle (0,T) is

$$I_T = cI_e \int_0^{t_1} (a+bt)tdt = cI_e [\frac{a}{2}t_1^2 + \frac{b}{3}t_1^3] \tag{11}$$

(f). The total shortage cost over the entire cycle (0,T) is

$$C_S = C_2 \int_{t_1}^{T} (a+bt)(T-t)dt = \frac{C_2}{6}(T-t_1)^2\{3a + b(T+2t_1)\} \tag{12}$$

The variable cost function:

The total variable cost per unit time (TC) for the case $t_c \le t_1 < T$ can be therefore obtained by subtracting the total interest I_T earned over the entire cycle from the sum of the ordering cost, deterioration cost, holding cost, shortage cost and the total interest payable over the entire cycle.

Hence $$TC(t_1) = \frac{1}{T}[C_3 + C_D + C_H + P_T - I_T + C_S]$$

Now putting the expressions for the different costs from the equations (8) – (12) we get,

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$$TC(t_1) = \frac{1}{T}[C_3 + c\{aT + \frac{b}{2}T^2 + \frac{a}{6\theta_1\theta_2}t_1^3 + \frac{b}{8\theta_1\theta_2}t_1^4\}$$
$$+ cC_h\{\frac{a}{2}t_1^2 + \frac{b}{3}t_1^3 + \frac{a}{12\theta_1\theta_2}t_1^4 + \frac{b}{15\theta_1\theta_2}t_1^5\} + cI_p\{(\frac{a}{2}t_1^2 + \frac{b}{3}t_1^3 + \frac{a}{12\theta_1\theta_2}t_1^4 + \frac{b}{15\theta_1\theta_2}t_1^5)$$
$$-(at_ct_1 + \frac{b}{2}t_ct_1^2 + \frac{a}{6\theta_1\theta_2}t_ct_1^3 + \frac{b}{8\theta_1\theta_2}t_ct_1^4 - \frac{a}{6\theta_1\theta_2}t_c^3t_1 - \frac{b}{12\theta_1\theta_2}t_c^3t_1^2)$$
$$+(\frac{a}{2}t_c^2 + \frac{b}{6}t_c^3 - \frac{a}{12\theta_1\theta_2}t_1^4 - \frac{b}{40\theta_1\theta_2}t_1^5)\} - cI_e\{\frac{a}{2}t_1^2 + \frac{b}{3}t_1^3\} + \frac{C_2}{6}(T-t_1)^2\{3a + b(T+2t_1)\}] \tag{13}$$

For minimization of the average system cost, the necessary condition is $\frac{dTC(t_1)}{dt_1} = 0$

This gives

$$\alpha_1 t_1^4 + \beta_1 t_1^3 + \gamma_1 t_1^2 + \delta_1 t_1 + \nu_1 = 0 \tag{14}$$

where $\alpha_1 = \frac{bc(C_h + I_p)}{3\theta_1\theta_2}$, $\beta_1 = \frac{c}{\theta_1\theta_2}\{\frac{b(1-t_cI_p)}{2} + \frac{a(C_h+I_p)}{3}\}$, $\gamma_1 = \frac{ac(1-t_cI_p)}{2\theta_1\theta_2} + bc(C_h + I_p - I_e) - \frac{bC_2}{3}$,

$\delta_1 = ac(C_h + I_p - I_e) - bct_cI_p(1 - \frac{t_c^2}{6\theta_1\theta_2}) + \frac{C_2}{3}(bT + 3a)$, $\nu_1 = -act_cI_p(1 - \frac{t_c^2}{6\theta_1\theta_2}) - C_2aT$.

Solving the above equation (14), the optimum value t_1^* of t_1 can be obtained.

For minimum $TC(t_1)$, the sufficient condition would be satisfied.

Putting the optimum value t_1^* in the expressions (6), (7) and (13), we get the optimum values of S(= S^*), Q(= Q^*)and TC(= TC^*) respectively.

A special case: $t_1 = t_c$

In this case, the ordering cost, deterioration cost, holding cost, interest earned and shortage cost remain same as in the previous section. Since the payment is done at the time $t_1 = t_c$, the interest payable P_T is zero. So replacing $t_c = t_1$ and P_T = 0, the expression (13) becomes

$$TC(t_1) = \frac{1}{T}[C_3 + c\{aT + \frac{b}{2}T^2 + \frac{a}{6\theta_1\theta_2}t_1^3 + \frac{b}{8\theta_1\theta_2}t_1^4\}$$
$$+ cC_h\{\frac{a}{2}t_1^2 + \frac{b}{3}t_1^3 + \frac{a}{12\theta_1\theta_2}t_1^4 + \frac{b}{15\theta_1\theta_2}t_1^5\} - cI_e\{\frac{a}{2}t_1^2 + \frac{b}{3}t_1^3\} + \frac{C_2}{6}(T-t_1)^2\{3a + b(T+2t_1)\}] \tag{15}$$

Now using optimality condition $\frac{dTC(t_1)}{dt_1} = 0$, we find the following

$$\alpha_2 t_1^4 + \beta_2 t_1^3 + \gamma_2 t_1^2 + \delta_2 t_1 + \nu_2 = 0 \tag{16}$$

where $\alpha_2 = \frac{bcC_h}{3\theta_1\theta_2}$, $\beta_2 = \frac{c}{\theta_1\theta_2}(\frac{b}{2} + \frac{aC_h}{3})$, $\gamma_2 = \frac{a}{2\theta_1\theta_2} + bc(C_h - I_e) - \frac{bC_2}{3}$,

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$\delta_2 = ac(C_h - I_e) + \frac{C_2}{3}(bT + 3a)$, $\nu_2 = -C_2 aT$.

Solving the equation (16), we get the optimal value of t_1 as in the case 1.

Case 2: $t_1 < t_c$ **(payment after depletion of inventory)**

In this case, the customer earn interest on sales revenue up to the permissible trade credit period and pays no interest (P_T = 0) for the items kept in stock. The interest earned per cycle is found as the sum of the interest earned during the positive inventory period and the interest earned from the cash invested during the time period (t_1, t_c) after the inventory exhausted at time t_1, and it is given by following

$$I_T = \text{c}\, I_e \int_0^{t_1} (a + bt)t\,dt + \text{c}\, I_e\, (t_c - t_1) \int_0^{t_1} (a + bt)\,dt$$

$$= \text{c}\, I_e\, t_1 \{ a t_c + \frac{bt_c - a}{2} t_1 - \frac{b}{6} t_1^{\,2} \} \tag{17}$$

Hence the total variable cost per unit time is given by the following

$$TC(t_1) = \frac{1}{T}[C_3 + \text{c}\{ aT + \frac{b}{2}T^2 + \frac{a}{6\theta_1\theta_2} t_1^{\,3} + \frac{b}{8\theta_1\theta_2} t_1^{\,4} \} + \text{c}\, C_h\ \{ \frac{a}{2} t_1^{\,2} + \frac{b}{3} t_1^{\,3} + \frac{a}{12\theta_1\theta_2} t_1^{\,4} + \frac{b}{15\theta_1\theta_2} t_1^{\,5} \}$$

$$- \text{c}\, I_e\, t_1 \{ a t_c + \frac{bt_c - a}{2} t_1 - \frac{b}{6} t_1^{\,2} \} + \frac{C_2}{6}(T - t_1)^2 \{ 3a + b(T + 2t_1) \}] \tag{18}$$

By the similar procedure as in case 1, the optimality condition $\frac{dTC(t_1)}{dt_1} = 0$ yields

$$\alpha_3 t_1^4 + \beta_3 t_1^3 + \gamma_3 t_1^2 + \delta_3 t_1 + \nu_3 = 0 \tag{19}$$

where $\alpha_3 = \frac{bcC_h}{3\theta_1\theta_2}$, $\beta_3 = \frac{c}{\theta_1\theta_2}(\frac{b}{2} + \frac{aC_h}{3})$, $\gamma_3 = \frac{ac}{2\theta_1\theta_2} + bc(C_h + \frac{I_e}{2}) - \frac{bC_2}{3}$,

$$\delta_3 = caC_h - cI_e(bt_c - a) + \frac{C_2}{3}(bT + 3a),\ \nu_3 = -acI_e t_c - C_2 aT.$$

The above equation can be solved to find the optimal values of $t_1 = t_1^*$, and then the optimal values of S, Q and TC as S^*, Q^* and TC^* can be obtained from the expressions (6), (7) and (18) respectively.

IV. NUMERICAL EXAMPLE

To illustrate the preceding theory, we consider the following example for the two scenarios namely, (case 1) : payment at or before the total depletion of inventory and (case 2) :]payment after depletion of inventory. Let the values of parameters be as follows:

C_3 = \$200/order; C_h = \$0.12/year; I_p = \$0.15/year ; I_e = \$0.13/year ; C_s = \$10 /unit/year; θ_1 =5; θ_2 = 3; a = 5; b = 2; T = 1 year and the set of values of t_c and c are assumed as t_c = {0, 0.1, 0.5, 0.7, 0.9} years and c = { 20, 40, 80, 100, 120, 150, 180, 200} dollars/unit.

With these values of the above parameters, the several optimal solutions towards different facts of the permissible delays in payment have been presented in the following two tables:

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Table A : Optimal solution for payment at or before the total depletion of inventory (Case-1)

$c \downarrow$	$t_c \downarrow$	t_1	S	Q	TC
	0.0	0.683	3.904	6.021	327.63
20	0.1	0.710	4.079	6.024	326.36
	0.5	0.821	4.820	6.038	322.47
	0.0	0.544	3.024	6.010	451.84
40	0.1	0.582	3.263	6.013	449.86
	0.5	0.741	4.284	6.028	443.83
	0.0	0.398	2.154	6.004	696.46
80	0.1	0.449	2.458	6.006	693.67
	0.5	0.661	3.762	6.019	685.30
	0.0	0.354	1.896	6.003	817.90
100	0.1	0.410	2.221	6.004	814.84
	0.5	0.638	3.613	6.017	805.75

Table B : Optimal solution for payment after depletion of inventory (Case 2)

$c \downarrow$	$t_c \downarrow$	t_1	S	Q	TC
	0.5	0.411	2.229	6.004	930.84
120	0.7	0.486	2.674	6.007	928.57
	0.9	0.561	3.133	6.011	926.68
	0.5	0.387	2.089	6.003	1111.75
150	0.7	0.466	2.552	6.006	1109.34
	0.9	0.545	3.030	6.010	1107.38
	0.5	0.399	2.046	6.003	1291.45
180	0.7	0.451	2.464	6.005	1289.93
	0.9	0.532	2.955	6.009	1287.94
	0.5	0.360	1.935	6.002	1412.80
200	0.7	0.443	2.418	6.005	1410.26
	0.9	0.526	2.917	6.009	1408.26

V. CONCLUDING REMARKS

Analysing the results of table A, we have studied the following observations:

(i). As the permissible credit period (t_c) increases, there is a moderate decrease of the total cost(TC), also moderate increase in the size of initial inventory(S)and the total amount of Inventory(Q).

(ii). With the increase in the values of the system parameter c, there are significant increase of the total cost (TC), and moderately decrease in the values of S and Q. The results obtained show that TC is very highly sensitive towards changes in the value of c.

Analysing the results of table B, we have studied the following observations:

(i). As the permissible credit period (t_c) increases, there is a moderate decrease of the total cost (TC), very insignificant changes in the size of initial inventory(S) and the total amount of Inventory (Q).

(ii). With the increase in the values of the system parameters c, there are significant increase of the total cost (TC), and insignificantly decrease in the values of S and Q. Here also the results obtained show that TC is very highly sensitive towards changes in the value of c.

From the above observation from table A and table B, it is seen that the unit cost parameter (c) is a critical parameter effecting in the optimal solution. Hence, adequate attention is needed to estimate the parameter c.

REFERENCES

(1) S.K. Goyal, "Economic order quantity under conditions of permissible delay in payment", J.Opl Res. Soc., 36, 1985,pp. 335-338.

(2) R.A. Davis , N. Gaither, "Optimal ordering policies under conditions of extended Payment privileges", Management Sciences, 31, 1985, pp. 499–509.

(3) B.N. Mandal, S. Phaujdar, "Some EOQ models under permissible delay in payments", International Journal of Managements Science, 5(2), 1989, pp. 99–108.

(4) S.P. Aggarwal and C.K. Jaggi, "Ordering policies of deteriorating items under permissible delay in payment", J.Opl Res. Soc., 46, 1995, pp. 658-662.

(5) K.J. Chung, "A theorem on the determination of economic order quantity under conditions of permissible delay in payments", Computer andOperations Research, 25, 1998, pp. 49–52.

(6)H.J. Chang, D. Chung-Yuan, "An inventory model for deteriorating items under the condition of permissible delay in payments, Production Planning and Control, 12(3), January 2002, pp. 73-83.

(7) Y.F. Huang, "Economic order quantity under conditionallypermissible delay in payments," European Journal ofOperationalResearch, 176(2), 2007, pp. 911–924.

(8) M.C.Cheng, K.R. Lou, L.Y.Ouyang, and Y.H. Chiang, "Theoptimal ordering policy with trade credit under two differentpayment methods," *TOP*, 18(2),2011, pp. 413–428.

(9) G. Li, Y. Kang, M. Liu and Z. Wang, "Optimal Inventory Policy under Permissible Payment Delay in Fashion Supply Chains", Mathematical Problems in Engineering, http://dx.doi.org/10.1155/2014/327131, 2014, pp. 1-9.

(10) N. P. Behera, P. K.Tripathy, "An Optimal Replenishment Policy for Deteriorating Items with Power Pattern under Permissible delay in payments", International Journal of Statistics and Systems, ISSN 0973-2675, 12(3), 2017, pp. 457-474.

(11) F. Harris, "Operations and Cost(Factory Management Science)", A. W. Shaw Co., Chicago, 1915, pp.48-52.

(12) Y. K. Shah, "An order level lot-size inventory model for deteriorating items", AIIE Trans., 9, 1977, pp. 108-112.

(13) T. K. Dutta andA.K.Pal, "A note on a replenishment policy for an inventory model with linear trend in demand and shortages", J. Operational Research Society, 43, 1992, pp. 993-1001.

(14) K. S. Rao, "Pricing and Ordering policies of an Inventory model for deteriorating items having additive exponential life time", International Journal of Mathematics and Mathematical Sciences, 5(1), 2009, pp. 9-16.

(15) Dr. Biswaranjan Mandal, "An Inventory Management for Deteriorating Items with Additive Exponential Life Time under Power Law form of Ramp Type Demand and Shortages", International Journal of Advanced Research in Science, Engineering and Technology, 7(10), 2020, pp. 15118-15123.

(16) Dr. Biswaranjan Mandal, "An Optimal Inventory Policy for Deteriorating Items with Additive Exponential Life Time having Linear Trended Demand and Shortages", International Journal of Engineering and Technical Research (IJETR), 10(9), 2020, pp.12-15.

(17) NADOOR E. (1975). Inventory Systems, John Wiley and Sons New York.