A Deterministic Inventory Model with Demand as a Biquadratic Polynomial Function of Time with Static Rates of Deterioration

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Abstract: ***In this paper, a Deterministic Model is evolving for the items decline by Demand as well as by Deterioration, where we take Demand as a Biquadratic Polynomial function of Time with the static rate of Deterioration. Here, Shortage is allowing and fully backlogging. An Organization can use this model where demand increases with time biquadratically with a static rate of Deterioration.***

Keywords: EOQ Model, Demand, Deterioration, shortage

1. Introduction

Inventory is the priority to run a business. But it may be a blessing or crush for a Business Owner. It is a blessing because when an owner buys a large no of goods then he gets benefit due to the lower wholesale price, which increases the quality of customer service. But it becomes a curse for an owner due to its large cost of maintenance: like its Deteriorating cost (because many of the physical goods undergo damage or chemically change with time for example product like milk, fruits, bread, butter, etc gets spoil with time), cost arises due to out of fashion of the product, storage and handling cost of goods, ordering cost, etc. So, an owner has to decide two main things; How much to order called EOQ and When to order to control Inventory. So, Inventory Management is very important to use working Capital Effectively. Because an owner's main aim is to Maximize Profit and Minimize Cost. So, in previous years various mathematical models have been created by researchers to minimize cost. Some of them are discussed here. Datta & Pal (1998) [4], Lee & Wu (2002) [9], Sharma, Sharrma & Ramani (2012) [15] and Sharma and Preeti (2013) [14] considered Power Demand pattern for Deteriorating Items with time varying deterioration in their respective models. Wu (1999) [17], Wu (2002) [18] considered Weibull distributed Deterioration in their respective models. Giri & Chaudhuri (1998) [5] considered demand rate as a function of on hand inventory in their model. Bhowmic & Samanta (2007) [2] considered stock dependent time-varying demand rate, Mishra and singh (2011) [11], Singh & Srivastava (2017) [16] considered Linear Demand ,Mishra and Singh (2013) [10] considered time dependent demand and deterioration, Bhowmi Samanta (2011) [3] considered constant demand rate and variable production cycle, Roy(2008) [13] considered time dependent deterioration rate and assumed Demand rate as a function of the selling price, Karmakar & Choudhury (2014) [6] assumed general ramp type demand rate, Kumar & Kumar (2015)[8] assumed time-dependent demand, Rasel (2017) [12] considered power distribution deterioration, Priya & Senbagam (2018) [7] assumed two parameter Weibull deterioration with quadratic time-dependent demand, Bansal, Kumar et al.(2021)[1] took stock-dependent demand rates, in their respective model. In this paper, I have developed a model by assuming demand as a biquadratic polynomial function of time with constant rate of deterioration.

2. Assumptions and Notations

Notations

- C_1 Inventory Carrying Charge per object per unit time.
- C_2 Cost due to deficiency of one object per unit time
- C_3 Cost of one Decayed Unit.
- T Length of every Production cycle.
- $C(t)$ Average entire cost
- S Inventory at $t = 0$, where t is used for time.
- $I(t)$ Inventory at any time t.
- $D(t)$ Demand rate.
- $\theta(t)$ Deterioration rate function.

Assumptions

1) The Demand rate D(t) is considered as $D(t) = \alpha + \beta t + \gamma t^2 + \delta t^3 + \mathcal{E} t^4$,where $\alpha, \beta, \gamma, \delta, \mathcal{E}$ are> 0.
2) Deterioration rate function, $\theta(t) = \theta_0$, where $0 < \theta_0 << 1$.
3) Lead time has been taken as 0.
4) Shortages are allowed and completely reserved.
5) Refill magnitude is static and refill rate is unbounded.
6) During the time period T, there is neither replacement nor repair of deteriorated units.

3. Analysis of Model

Let the no of objects in stock at any time t be I(t). In time period $0 < t < t_1$, I(t) lessens gradually due to requirement and decaying of items and falls to zero at $t = t_1$. In the time period (t_1, T), deficiency of items occurs which are wholly backlogged, where $t_1 < T$. The equations of this process are given by:

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

$$\frac{dI(t)}{dt} = -\{D(t)\} \quad t_1 \le t \le T \qquad (2)$$

Put $\theta = \theta_0$ and $D(t) = = \alpha + \beta t + \gamma t^2 + \delta t^3 + \varepsilon t^4$ in (1) and (2), we get

$$\frac{dI(t)}{dt} + \theta_0 I(t) = -\{ \alpha + \beta t + \gamma t^2 + \delta t^3 + \varepsilon t^4 \} \qquad (3)$$

$$\frac{dI(t)}{dt} = -\{ \alpha + \beta t + \gamma t^2 + \delta t^3 + \varepsilon t^4 \} \qquad (4)$$

Solution of (3) is

$$I(t)\, e^{\theta_0 t} = -\int (\alpha + \beta t + \gamma t^2 + \delta t^3 + \varepsilon t^4) e^{\theta_0 t} dt + C$$

$$= -\int (\alpha + \beta t + \gamma t^2 + \delta t^3 + \varepsilon t^4)(1 + \theta_0 t)\, dt + C$$

$$= -\left[\left(\alpha t + \frac{\beta t^2}{2} + \frac{\gamma t^3}{3} + \frac{\delta t^4}{4} + \frac{\varepsilon t^5}{5}\right) + \theta_0\left(\frac{\alpha t^2}{2} + \frac{\beta t^3}{3} + \frac{\gamma t^4}{4} + \frac{\delta t^5}{5} + \frac{\varepsilon t^6}{6}\right)\right] + C \qquad (5)$$

Place $t = 0$ in (5), we obtain $I(0) = C$, but $I(0) = S$, So $C = S$. Hence (5) implies

$$I(t)\, e^{\theta_0 t} = S - \left[\left(\alpha t + \frac{\beta t^2}{2} + \frac{\gamma t^3}{3} + \frac{\delta t^4}{4} + \frac{\varepsilon t^5}{5}\right) + \theta_0\left(\frac{\alpha t^2}{2} + \frac{\beta t^3}{3} + \frac{\gamma t^4}{4} + \frac{\delta t^5}{5} + \frac{\varepsilon t^6}{6}\right)\right] ; \quad 0 \le t \le t_1 (6)$$

Since $I(t_1) = 0$, So (6) implies

$$S = \left[\left(\alpha t_1 + \frac{\beta t_1^2}{2} + \frac{\gamma t_1^3}{3} + \frac{\delta t_1^4}{4} + \frac{\varepsilon t_1^5}{5}\right) + \theta_0\left(\frac{\alpha t_1^2}{2} + \frac{\beta t_1^3}{3} + \frac{\gamma t_1^4}{4} + \frac{\delta t_1^5}{5} + \frac{\varepsilon t_1^6}{6}\right)\right] \qquad (7)$$

Putting the value of S from (7) into (6), we get

$$I(t) = (1 - \theta_0 t)\left[\left\{ \alpha(t_1 - t) + \frac{\beta(t_1^2 - t^2)}{2} + \frac{\gamma(t_1^3 - t^3)}{3} + \frac{\delta(t_1^4 - t^4)}{4} + \frac{\varepsilon(t_1^5 - t^5)}{5} \right\} + \theta_0 \left\{ \frac{\alpha(t_1^2 - t^2)}{2} + \frac{\beta(t_1^3 - t^3)}{3} + \frac{\gamma(t_1^4 - t^4)}{4} + \frac{\delta(t_1^5 - t^5)}{5} + \frac{\varepsilon(t_1^6 - t^6)}{6} \right\}\right]$$

$$I(t) = \left\{ \alpha(t_1 - t) + \frac{\beta(t_1^2 - t^2)}{2} + \frac{\gamma(t_1^3 - t^3)}{3} + \frac{\delta(t_1^4 - t^4)}{4} + \frac{\varepsilon(t_1^5 - t^5)}{5} \right\} + \theta_0\left\{ \frac{\alpha(t_1^2 - t^2)}{2} + \frac{\beta(t_1^3 - t^3)}{3} + \frac{\gamma(t_1^4 - t^4)}{4} + \frac{\delta(t_1^5 - t^5)}{5} + \frac{\varepsilon(t_1^6 - t^6)}{6} \right\} - \theta_0 \left\{ \alpha(t_1 t - t^2) + \frac{\beta(t_1^2 t - t^3)}{2} + \frac{\gamma(t_1^3 t - t^4)}{3} + \frac{\delta(t_1^4 t - t^5)}{4} + \frac{\varepsilon(t_1^5 t - t^6)}{5} \right\} \qquad (8)$$

(neglecting terms containing θ^2, which is very small)

Also, solution of (4) is

$$I(t) = -\left(\alpha t + \frac{\beta t^2}{2} + \frac{\gamma t^3}{3} + \frac{\delta t^4}{4} + \frac{\varepsilon t^5}{5}\right) + A \qquad (9)$$

Applying $I(t_1) = 0$ in (9), we get

$$I(t) = \alpha(t_1 - t) + \frac{\beta(t_1^2 - t^2)}{2} + \frac{\gamma(t_1^3 - t^3)}{3} + \frac{\delta(t_1^4 - t^4)}{4} + \frac{\varepsilon(t_1^5 - t^5)}{5} ; \quad t_1 \le t \le T \qquad (10)$$

Therefore amount of Deteriorated Items = I(0) - Stock loss due to Demand

$$= S - \int_0^{t_1} (\alpha + \beta t + \gamma t^2 + \delta t^3 + \varepsilon t^4)\, dt (11)$$

(Using (7))

$$= \theta_0 \left(\frac{\alpha t_1^2}{2} + \frac{\beta t_1^3}{3} + \frac{\gamma t_1^4}{4} + \frac{\delta t_1^5}{5} + \frac{\varepsilon t_1^6}{6} \right) \qquad (12)$$

Total amount of Inventory held during $[0, t_1]$ is

$I_1 = \int_0^{t_1} I(t)\, dt =$

$$\int_0^{t_1} \left\{ \alpha(t_1 - t) + \frac{\beta(t_1^2 - t^2)}{2} + \frac{\gamma(t_1^3 - t^3)}{3} + \frac{\delta(t_1^4 - t^4)}{4} + \frac{\varepsilon(t_1^5 - t^5)}{5} \right\} dt + \theta_0 \int_0^{t_1} \left\{ \frac{\alpha(t_1^2 - t^2)}{2} + \frac{\beta(t_1^3 - t^3)}{3} + \frac{\gamma(t_1^4 - t^4)}{4} + \frac{\delta(t_1^5 - t^5)}{5} + \frac{\varepsilon(t_1^6 - t^6)}{6} \right\} dt - \theta_0 \int_0^{t_1} \left\{ \alpha(t_1 t - t^2) + \frac{\beta(t_1^2 t - t^3)}{2} + \frac{\gamma(t_1^3 t - t^4)}{3} + \frac{\delta(t_1^4 t - t^5)}{4} + \frac{\varepsilon(t_1^5 t - t^6)}{5} \right\} dt (13)$$

$$= \left[\left(\frac{\alpha t_1^2}{2} + \frac{\beta t_1^3}{3} + \frac{\gamma t_1^4}{4} + \frac{\delta t_1^5}{5} + \frac{\varepsilon t_1^6}{6}\right) + \theta_0\left(\frac{\alpha t_1^3}{6} + \frac{\beta t_1^4}{8} + \frac{\gamma t_1^5}{10} + \frac{\delta t_1^6}{12} + \frac{\varepsilon t_1^7}{14}\right)\right] \quad (14)$$

No. of shortage units $= \int_{t_1}^{T} -I(t)dt = \int_T^{t_1} \{ \alpha(t_1 - t) + \beta(t12 - t2)2 + \gamma(t13 - t3)3 + \delta(t14 - t4)4 + \varepsilon(t15 - t5)5 \}dt$ (using (10))

$$= T\left\{ \alpha\left(\frac{T}{2} - t_1\right) + \frac{\beta}{2}\left(\frac{T^2}{3} - t_1^2\right) + \frac{\gamma}{3}\left(\frac{T^3}{4} - t_1^3\right) + \frac{\delta}{4}\left(\frac{T^4}{5} - t_1^4\right) + \frac{\varepsilon}{5}\left(\frac{T^5}{6} - t_1^5\right) \right\} + \left\{ \frac{\alpha t_1^2}{2} + \frac{\beta t_1^3}{3} + \frac{\gamma t_1^4}{4} + \frac{\delta t_1^5}{5} + \frac{\varepsilon t_1^6}{6} \right\} (15)$$

Inventory carrying cost = C_1 * Amount of Inventory carried

$$= C_1\left(\frac{\alpha t_1^2}{2} + \frac{\beta t_1^3}{3} + \frac{\gamma t_1^4}{4} + \frac{\delta t_1^5}{5} + \frac{\varepsilon t_1^6}{6}\right) + C_1\theta_0\left(\frac{\alpha t_1^3}{6} + \frac{\beta t_1^4}{8} + \frac{\gamma t_1^5}{10} + \frac{\delta t_1^6}{12} + \frac{\varepsilon t_1^7}{14}\right) \quad (16)$$

Shortage cost = C_2* quantity of shortage units

$$= C_2 T\left\{ \alpha\left(\frac{T}{2} - t_1\right) + \frac{\beta}{2}\left(\frac{T^2}{3} - t_1^2\right) + \frac{\gamma}{3}\left(\frac{T^3}{4} - t_1^3\right) + \frac{\delta}{4}\left(\frac{T^4}{5} - t_1^4\right) + \frac{\varepsilon}{5}\left(\frac{T^5}{6} - t_1^5\right) \right\} + C_2\left\{ \frac{\alpha t_1^2}{2} + \frac{\beta t_1^3}{3} + \frac{\gamma t_1^4}{4} + \frac{\delta t_1^5}{5} + \frac{\varepsilon t_1^6}{6} \right\} \qquad (17)$$

Cost due to Deterioration = C_3 * quantity of Decayed units

$$= C_3\theta_0\left(\frac{\alpha t_1^2}{2} + \frac{\beta t_1^3}{3} + \frac{\gamma t_1^4}{4} + \frac{\delta t_1^5}{5} + \frac{\varepsilon t_1^6}{6}\right) \qquad (18)$$

Entire cost per unit time = Inventory carrying cost + shortage cost + cost due to Decaying objects

$$C(t) = C_1\left(\frac{\alpha t_1^2}{2} + \frac{\beta t_1^3}{3} + \frac{\gamma t_1^4}{4} + \frac{\delta t_1^5}{5} + \frac{\varepsilon t_1^6}{6}\right) + C_1\theta_0\left(\frac{\alpha t_1^3}{6} + \frac{\beta t_1^4}{8} + \frac{\gamma t_1^5}{10} + \frac{\delta t_1^6}{12} + \frac{\varepsilon t_1^7}{14}\right)] + C_2 T\left\{ \alpha\left(\frac{T}{2} - t_1\right) + \frac{\beta}{2}\left(\frac{T^2}{3} - t_1^2\right) + \frac{\gamma}{3}\left(\frac{T^3}{4} - t_1^3\right) + \frac{\delta}{4}\left(\frac{T^4}{5} - t_1^4\right) + \frac{\varepsilon}{5}\left(\frac{T^5}{6} - t_1^5\right) \right\} + C_2\left\{ \frac{\alpha t_1^2}{2} + \frac{\beta t_1^3}{3} + \frac{\gamma t_1^4}{4} + \frac{\delta t_1^5}{5} + \frac{\varepsilon t_1^6}{6} \right\} + C_3\theta_0\left(\frac{\alpha t_1^2}{2} + \frac{\beta t_1^3}{3} + \frac{\gamma t_1^4}{4} + \frac{\delta t_1^5}{5} + \frac{\varepsilon t_1^6}{6}\right) \qquad (19)$$

Average entire cost per unit time

$C(t_1) = \frac{1}{T}$ [Complete cost per unit time]

$$= \frac{C_1}{T}\left(\frac{\alpha t_1^2}{2} + \frac{\beta t_1^3}{3} + \frac{\gamma t_1^4}{4} + \frac{\delta t_1^5}{5} + \frac{\varepsilon t_1^6}{6}\right) + \frac{C_1\theta_0}{T}\left(\frac{\alpha t_1^3}{6} + \frac{\beta t_1^4}{8} + \frac{\gamma t_1^5}{10} + \frac{\delta t_1^6}{12} + \frac{\varepsilon t_1^7}{14}\right) + C_2\left\{ \alpha\left(\frac{T}{2} - t_1\right) + \frac{\beta}{2}\left(\frac{T^2}{3} - t_1^2\right) + \frac{\gamma}{3}\left(\frac{T^3}{4} - t_1^3\right) + \frac{\delta}{4}\left(\frac{T^4}{5} - t_1^4\right) + \frac{\varepsilon}{5}\left(\frac{T^5}{6} - t_1^5\right) \right\} + \frac{C_2}{T}\left\{ \frac{\alpha t_1^2}{2} + \frac{\beta t_1^3}{3} + \frac{\gamma t_1^4}{4} + \frac{\delta t_1^5}{5} + \frac{\varepsilon t_1^6}{6} \right\} + \frac{C_3\theta_0}{T}\left\{ \frac{\alpha t_1^2}{2} + \frac{\beta t_1^3}{3} + \frac{\gamma t_1^4}{4} + \frac{\delta t_1^5}{5} + \frac{\varepsilon t_1^6}{6} \right\}$$

For least average cost put $\frac{dC(t_1)}{dt_1} = 0$

$$D(t)\left[\frac{C_1\theta_0}{2T} t_1^2 + \left(\frac{C_1}{T} + \frac{C_3\theta_0}{T} + \frac{C_2}{T}\right)t_1 - C_2 \right] = 0$$

$$\left[\frac{C_1\theta_0}{2T} t_1^2 + \left(\frac{C_1}{T} + \frac{C_3\theta_0}{T} + \frac{C_2}{T}\right)t_1 - C_2 \right] = 0$$

Which is quadratic in t_1 with last term negative so, it has atleast one positive root say t_1^* and $\frac{d^2C(t_1^*)}{dt_1^{*2}} > 0$. So optimum value of t_1 is t_1^*. Hence the optimum value of S is

$$S^* = \left(\alpha t_1^* + \frac{\beta t_1^{*2}}{2} + \frac{\gamma t_1^{*3}}{3} + \frac{\delta t_1^{*4}}{4} + \frac{\varepsilon t_1^{*5}}{5}\right) + \theta_0\left(\frac{\alpha t_1^{*2}}{2} + \frac{\beta t_1^{*3}}{3} + \frac{\gamma t_1^{*4}}{4} + \frac{\delta t_1^{*5}}{5} + \frac{\varepsilon t_1^{*6}}{6}\right) \qquad (20)$$

Minimum value of $C(t_1)$ is

$$C(t_1^*) = \frac{C_1}{T}\left(\frac{\alpha t_1^{*2}}{2} + \frac{\beta t_1^{*3}}{3} + \frac{t_1^{*4}}{4} + \frac{\delta t_1^{*5}}{5} + \frac{\varepsilon t_1^{*6}}{6}\right) + \frac{C_1\theta_0}{T}\left(\frac{\alpha t_1^{*3}}{6} + \frac{\beta t_1^{*4}}{8} + \frac{\gamma t_1^{*5}}{10} + \frac{\delta t_1^{*6}}{12} + \frac{\varepsilon t_1^{*7}}{14}\right) + C_2 \left\{ \alpha\left(\frac{T}{2} - t^*_1\right) + \frac{\beta}{2}\left(\frac{T^2}{3} - t_1^{*2}\right) + \frac{\gamma}{3}\left(\frac{T^3}{4} - t_1^{*3}\right) + \frac{\delta}{4}\left(\frac{T^4}{5} - t_1^{*4}\right) + \frac{\varepsilon}{5}\left(\frac{T^5}{6} - t_1^{*5}\right) \right\} + \frac{C_2}{T}\left\{ \frac{\alpha t_1^{*2}}{2} + \frac{\beta t_1^{*3}}{3} + \frac{\gamma t_1^{*4}}{4} + \frac{\delta t_1^{*5}}{5} + \frac{\varepsilon t_1^{*6}}{6} \right\} + \frac{C_3\theta_0}{T}\left\{ \frac{\alpha t_1^{*2}}{2} + \frac{\beta t_1^{*3}}{3} + \frac{\gamma t_1^{*4}}{4} + \frac{\delta t_1^{*5}}{5} + \frac{\varepsilon t_1^{*6}}{6}\right\} \qquad (21)$$

Thus (20) gives optimal value of total average cost per unit time.

4. Conclusion

Here, an Inventory model has been created for items depleted due to demand as well as Deterioration by taking demand as a biquadratic polynomial function of time and constant deterioration rate and I have obtained minimum total average cost. This model can be extended further for other values of demand.

References

[1] Bansal, K. K; Kumar, Vijesh et al., *"Study of Deterministic Inventory Model for Deteriorating Items With Stock-Dependent Demand Rate under Inflation"*, European Journal of Molecular and Clinical Medicine, Vol.08, Issue 03,2021.

[2] Bhowmick Jhuma and Samanta,G.P.,*"A Continuous Deterministic Inventory System for Deteriorating Items with Inventory-Level-Dependent Time Varying Demand Rate"*,Tamsui Oxford Journal of Mathematical Sciences 23(2)(2007) 173-184.

[3] Bhowmick Jhuma and Samanta,G.P.,*"A Deterministic Inventory Model of Deteriorating Items with two Rate of Production, Shortages and Variable Production Cycle"*,International Scholarly Research Network,Vol.2011,Article ID 657464,16 pages.

[4] Datta,T.K. and Pal,A.K.,*"Order level Inventory system with power demand pattern for items with variable rate of deterioration"*,Indian J.Pure Appl.Math.,Vol.19,No 11,pp.1043-1053,November 1988.

[5] Giri, B.C. and Chaudhuri,K.S.,*"Deterministic Models of Perishable Inventory with Stock-Dependent Demand Rate and nonlinear Holding Cost"*,European Journal of Operational Research 105(1998)467-474.

[6] KARMAKAR Biplab and CHOUDHURY,K.D.,*"Inventory Models with Ramp-Type Demand for Deterioration Items with Partial Backlogging and Time-Varying Holding Cost"*, Yugoslav Journal of Operations Research, 24 (2014) No.2, 249- 266.

[7] Kavitha Priya, R. and Senbagam, K.,*"An EOQ Inventory Model for Two Parameter Weibull Deterioration with Quadratic Time Dependent Demand and Shortages"*,International Journal of Pure and Applied Mathematics, vol.119,No.7,467-478,2018.

[8] Kumar Sushil and Kumar Ravendra,*"A Deterministic Inventory Model for Perishable Items with Time Dependent Demand and Shortages"*,International Journal of Mathematics and its Applications,Vol.3,Issue 4-F(2015),105-111.

[9] Lee,W.C. and Wu,J.W.,*"An EOQ Model for items with Weibull distributed deterioration,shortages and power demand pattern"*,Information and Management Sciences,Vol.13,No.2,19-34,2002.

[10] Mishra,V.K.;Singh, L.S. et al.*"An Inventory Model for Deteriorating Items with Time Dependent Demand and Time Varying Holding cost under Partial Backlogging"*.Journal of Industrial Engineering International 2013,9:4.

[11] Mishra,V.K.;Singh, L.S.,*"Deteriorating Inventory Model for Time Dependent Demand and holding cost with partial backlogging"*,International Journal of Management Science and Engineering Management,6(4):267-271,2011.

[12] RASEL,S.K.,*"A Deterministic Inventory System with power Distribution Deterioration and fully backlogged shortage"*,Asian Journal of Current Research,2(3):81-88,2017.

[13] Roy Ajanta,*"An Inventory Model for Deteriorating Items with price Dependent Demand and Time-varying holding cost"*,AMO-Advanced Modeling and Optimization, Vol.10,No.1,2008.

[14] Sharma,A.K. and Preeti, *"An Inventory model for deteriorating items with power pattern demand and partial backlogging with time-dependent holding cost"*,IJLTEMAS,Vol.2(3),pp.92-104,2013.

[15] Sharma,A.K.,Sharma,M.K. and Ramani,N.,*"An Inventory model with Weibull distribution deteriorating item with power pattern demand with shortages and time dependent holding cost"*,American Journal of Applied Mathematical Sciences,Vol.1,No.1-2,pp.17-22,2012.

[16] Srivastava Saurabh and Singh Harendra.*"Deterministic Inventory Model for Items with Linear Demand,variable Deterioration and partial backlogging"*.Int.J.Inventory Research,Vol.4,No.4, 2017.

[17] Wu Jong-Wuu ,Lin Chinho et al.,*"An EOQ Inventory Model with Ramp Type Demand Rate for Items with Weibull Deterioration"*,Information and Management Sciences , vol.10,No.3,pp.41-51,1999.

[18] WU ,Kun-Shan,*"Deterministic Inventory Model for Items with Time Varying Demand,Weibull Distribution Deterioration and Shortages"*,Yugoslav Journal of Operations Research,12(2002), No.1,61-71.