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Design and Analysis of Inventory Model for Quadratic Trapezoidal Type Demand under Partial Backlogging

Pravat Kumar Sukla
P. S. College , Koksara,
Kalahandi, odisha
India

Anjan Kumar Rana[2]
Pragati College, Bhabanipatana,
Kalahandi, Odisha,
India

Rajani Ballav Dash[3]
Ex Reader in mathematics Revenshaw
University, at present Visiting Faculty Revenshaw
University, Cuttack. India

Abstract:- **In this paper, we consider the inventory model for perishable items with quadratic trapezoidal type demand rate, that is, the demand rate is a piecewise quadratic function. The model consider allows for shortages and the demand is partially backlogged. The model is solved analytically by minimizing the total inventory cost. The result is illustrated with numerical example for the model.**

Keywords: Quadratic ttrapezoidal demand. Deterioration. Shortages. Partial backlogging

1. INTRODUCTION

Deteriorating items are very common thing in our daily life situation. In recent years, many researchers have studied inventory models for deteriorating items, however, academia has not reached a consensus on the definition of the deteriorating items. According to the study of Wee (1993), deteriorating items refers to the items that become decayed, damaged, evaporative, expired, invalid, devaluation and so on through time. According to the definition, deteriorating items can be classified in to two categories. The first category refers to the items that become decayed, damaged, evaporative, or expired through time, like meat, vegetables, fruit, medicine, flowers and so on; the other category refers to the items that lose part or total value through time because of new technology or the introduction of alternatives, like computer chips, mobile phones, fashion and seasonal goods and so on. The inventory problem of deteriorating items was first studied by Whitin (1957), he studied fashion items deteriorating at the end of the storage period. Then Ghare and Schrader (1963) concluded in their study that the consumption of the deteriorating items was closely relative to a negative exponential function of time. Various authors (Deng et al. (2007), Cheng and Wang (2009), Cheng et al. (2011), Hung (2011)) studied inventory models for deteriorating items in various aspects.

In world business market, demand has been always one of the most key factors in the decisions relating to the inventory and production activities. There are mainly two categories demands in the present studies, one is deterministic demand and the other is stochastic demand. Various formations of consumption tendency have been studied, such as constant demand (Padmanabhan and Vrat (1990), Sukla (2012), , Sukla and sahu (2008) Chung and Lin (2001), Benkherouf et al. (2003), Chu et al (2004)), level-dependent demand (Giri and Choudhuri (1998), Chung et al. (2000), Bhattacharya (2005), Wu et al. (2006)), price dependent demand (Wee and Law (1999), Abad (1996, 2001)), time dependent demand (Resh et al. (1976), Henery (1979), Sachan (1984), Dave (1989), Teng (1996), Teng et al. (2002), Skouri and Papachristos (2002), Panda, Sahoo, and Sukla (2012)), Panda, Sahoo, and Sukla (2013) , Sett et al. (2013), Shah, , Chaudhari and Jani (2015), Shah, , Chaudhari and Jani (2016), Mishra et al. (2013)) and time and price dependent demand (Wee (1995)). Among them, ramp type demand is a special type of time dependent demand. Hill (1995), one of the pioneers, developed an inventory model with ramp type demand that begins with a linear increasing demand until to the turning point, denoted as μ, proposed by previous researchers, then it becomes a constant demand. There has been a movement towards developing this type of inventory system for minimum cost and maximum profit problems. Several authors: Mandal and Pal (1998) focused on deteriorating items. Wu et al. (1999) were concerned with backlog rates relative to the waiting time. Wu and Ouyang (2000) tried to build an inventory system under two replenishment policies: starting with shortage or without shortage. Panda, Sahoo and sukla (2013), Wu (2001) considered the deteriorated items satisfying Weibull distribution. Giri et al (2003) dealt with more generalized three parameter Weibull deterioration distribution. Deng (2005) extended the inventory model of Wu et al. (1999) for the situation where the in-stock period is shorter than μ. Manna and Chaudhuri (2006) set up a model where the deterioration is dependent on time. Panda et al. (2007) constructed an inventory model with a comprehensive ramp type demand. Deng et al. (2007)

contributed to the revision of Mandal and Pal (1998), and Wu and Ouyang (2000). Panda et al. (2008) examined the cyclic deterioration items. Wu et al. (2008) studied the maximum profit problem with the stock-dependent selling rate. They developed two inventory models all related to the conversion of the ramp type demand, and then examined the optimal solution for each case. However, in a realistic product life cycle, demand is increasing with time during the growth phase. Then, after reaching its peak, the demand becomes stable for a finite time period called the maturity phase. Thereafter, the demand starts decreasing with time and eventually reaching zero or constant.

In this work, we extend Hill's ramp type demand rate to quadratic trapezoidal type demand rate. Such type of demand pattern is generally seen in the case of any fad or seasonal goods coming to market. The demand rate for such items increases quadratic-ally with the time up to certain time and then ultimately stabilizes and becomes constant, and finally the demand rate approximately decreases to a constant, and then begins the next replenishment cycle. We think that such type of demand rate is quite natural and useful in real world market situation. One can think that our work may provide a solid foundation for the future study of this kind of important inventory models with quadratic trapezoidal type demand rate and preservation technology

2. ASSUMPTION AND NOTATIONS

The fundamental assumption and notations used in this paper are given as follows: The demand rate, $R(t)$, which is positive and consecutive, is assumed to be a quadratic trapezoidal type function of time, that is

$$R(t)=\begin{cases} b_1t+c_1t^2, & t\le\mu_1,\\ R_0, & \mu_1\le t\le\mu_2,\\ b_2t-c_2t^2, & \mu_2\le t\le T\end{cases} \tag{1}$$

Chose b_1, c_1, b_2 and c_2 such a way that $b_2t-c_2t^2$ should not be negative for $\mu_2\le t\le T$. Where μ_1 is the time point changing from the increasing quadratic demand to constant demand, and μ_2 is the time point changing from the constant demand to the decreasing demand.

- Replenishment rate is infinite, thus replenishment is instantaneous.
- $I(t)$ is the inventory level at any time t, $0\le t\le T$.
- T is the fixed length of each ordering cycle.
- θ is the constant rate of deterioration, $0<\theta<1$.
- t_1 is the time when the inventory level reaches zero.
- t_1^* is an optimal point.
- k_0 is the fixed ordering cost per order.
- k_1 is the cost of each deteriorated item.
- k_2 is the inventory holding cost per unit per unit of time.
- k_3 is the shortage cost per unit per unit of time.
- S is the maximum inventory level for the ordering cycle, such that $S=I(0)$.
- Q is the ordering quantity per cycle.
- $A_1(t_1)$ is the average total cost per unit time under the condition $t_1\le\mu_1$.
- $A_2(t_1)$ is the average total cost per unit time, for $\mu_1\le t_1\le\mu_2$.
- $A_3(t_1)$ is the average total cost per unit time, for $\mu_2\le t_1\le T$

3. MATHEMATICAL AND THEORETICAL RESULTS

Here, we consider the deteriorating inventory model with demand rate is trapezoidal type quadratic function. Replenishment occurs at time $t=0$ when the inventory level attains its maximum. For $t\in[0,\,t_1]$, the inventory level reduces due to both demand and deterioration. At time t_1, the inventory level reaches zero, then shortage is allowed to occur during the interval (t_1, T), and all of the demand during the shortage period (t_1, T) is completely backlogged. The total amount of backlogged items is replaced by the next replenishment. The rate of change of the inventory during the stock period $[0, t_1]$ and shortage period (t_1, T) is governed by the following differential equations:

$$\frac{dI(t)}{dt}+\theta I(t)+R(t)=0\,,0<t<t_1\,, \tag{2}$$

$$\frac{dI(t)}{dt}+R(t)=0\,,t_1<t<T\,, \tag{3}$$

with boundary condition $I(0)=S$ and $I(t_1)=0$. One can think about t_1, t_1 may occur within $[0,\,\mu_1]$ or $[\mu_1,\,\mu_2]$ or $[\mu_2,\,T]$. Hence in this paper we are going to discuss all three possible cases.

Case 1: $\quad 0<t_1\le\mu_1$

The quadratic trapezoidal type market demand and constant rate of deterioration, the inventory level gradually diminishes during the period $[0, t_1]$ and ultimately reaches to zero at time $t=t_1$. Then, from equations (2) and (3), we have

$$\frac{dI(t)}{dt}+\theta I(t)+b_1t+c_1t^2=0\,,0<t<t_1 \tag{4}$$

$$\frac{dI(t)}{dt}+b_1t+c_1t^2=0\,,t_1<t<\mu_1 \tag{5}$$

$$\frac{dI(t)}{dt}+R_0=0\,,\mu_1<t<\mu_2 \tag{6}$$

$$\frac{dI(t)}{dt}+b_2t-c_2t^2=0\,,\mu_2<t<T \tag{7}$$

Now solving the differential equations (4) – (7) with the condition $I(t_1)=0$ and continuous property of $I(t)$, we get

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$$I(t)=\left(\frac{b_1t_1+c_1t_1{}^2}{\theta}-\frac{b_1+2c_1t_1}{\theta^2}+\frac{2c_1}{\theta^3}\right)e^{\theta(t_1-t)}-\frac{b_1t+c_1t^2}{\theta}+\frac{b_1+2c_1t}{\theta^2}-\frac{2c_1}{\theta^3}$$

$$, 0\le t\le t_1 \quad (8)$$

$$I(t)=(t_1^2-t^2)\frac{b_1}{2}+(t_1^3-t^3)\frac{c_1}{3}\ ,t_1\le t\le \mu_1 \quad (9)$$

$$I(t)=-R_0t+(t_1^2+\mu_1^2)\frac{b_1}{2}+(t_1^3+2\mu_1^3)\frac{c_1}{3},$$

$$\mu_1\le t\le \mu_2 \quad (10)$$

$$I(t)=(t_1^2+\mu_1^2)\frac{b_1}{2}+(t_1^3+2\mu_1^3)\frac{c_1}{3},$$

$$-(t^2+\mu_2^2)\frac{b_2}{2}+(t^3+2\mu_2^3)\frac{c_2}{3}$$

$$\mu_2\le t\le T \quad (11)$$

The beginning inventory level can be computed as

$$S=I(0)=\left(-\frac{b_1}{\theta^2}+\frac{2c_1}{\theta^3}\right)(e^{\theta t_1}-1)+\left(\frac{b_1t_1+c_1t_1^2}{\theta}-\frac{2c_1t_1}{\theta^2}\right)e^{\theta t_1} \quad (12)$$

The total number of items which is perish in the interval [0, t_1], say D_T, is

$$D_T=S-\int_0^{t_1}R(t)dt=S-\int_0^{t_1}(b_1t+c_1t^2)dt$$

$$=\left(-\frac{b_1}{\theta^2}+\frac{2c_1}{\theta^3}\right)(e^{\theta t_1}-1)+\left(\frac{b_1t_1+c_1t_1^2}{\theta}-\frac{2c_1t_1}{\theta^2}\right)e^{\theta t_1}--\frac{b_1t_1^2}{2}-\frac{c_1t_1^3}{3} \quad (13)$$

The total amounts of inventory carried during the interval [0, t_1], say C_T, is

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

$$=\int_0^{t_1}\left[\left(\frac{c_1t_1{}^2}{\theta}-\frac{b_1+2c_1t_1}{\theta^2}+\frac{2c_1}{\theta^3}\right)e^{\theta(t_1-t)}-\frac{b_1t+c_1t^2}{\theta}+\frac{b_1+2c_1t}{\theta^2}-\frac{2c_1}{\theta^3}\right]dt$$

$$=\left(\frac{b_1t_1+c_1t_1{}^2}{\theta^2}-\frac{b_1+2c_1t_1}{\theta^3}+\frac{2c_1}{\theta^4}\right)(e^{\theta t_1}-1)$$

$$+\left(\frac{b_1}{\theta^2}-\frac{2c_1}{\theta^3}\right)t_1+\left(\frac{c_1}{\theta^2}-\frac{b_1}{2\theta}\right)t_1^2-\frac{c_1}{3\theta}t_1^3 \quad (14)$$

The total shortage quantity during the interval [t_1, T], say B_T, is

$$B_T=-\int_{t_1}^{T}I(t)dt$$

$$=-\int_{t_1}^{\mu_1}I(t)dt-\int_{\mu_1}^{\mu_2}I(t)dt-\int_{\mu_2}^{T}I(t)dt$$

$$=-\int_{t_1}^{\mu_1}\left[(t_1^2-t^2)\frac{b_1}{2}+(t_1^3-t^3)\frac{c_1}{3}\right]dt$$

$$=\int_{\mu_1}^{\mu_2}\left[-R_0t+(t_1^2+\mu_1^2)\frac{b_1}{2}+(t_1^3+2\mu_1^3)\frac{c_1}{3}\right]dt$$

$$=\int_{\mu_2}^{T}\left[(t_1^2+\mu_1^2)\frac{b_1}{2}+(t_1^3+2\mu_1^3)\frac{c_1}{3}-(t^2+\mu_2^2)\frac{b_2}{2}+(t^3+2\mu_2^3)\frac{c_2}{3}\right]dt$$

$$=-\frac{b_1}{2}t_1^2(\mu_1-t_1)+\frac{b_1}{6}(\mu_1^3-t_1^3)-\frac{c_1}{3}t_1^3(\mu_1-t_1)+\frac{c_1}{12}(\mu_1^4-t_1^4)+\frac{R_0}{2}(\mu_1^2-\mu_2^2)-\frac{b_1}{2}t_1^2(\mu_2-\mu_1)-\frac{b_1}{2}\mu_1^2(\mu_2-\mu_1)-\frac{c_1}{3}t_1^3(\mu_2-\mu_1)-\frac{2c_1}{3}\mu_1^3(\mu_2-\mu_1)-\frac{b_1}{2}t_1{}^2(T-\mu_2)-\frac{b_1}{2}\mu_1{}^2(T-\mu_2)$$

$$-\frac{c_1}{3}(t_1^3+2\mu_1^3)(T-\mu_2)+\frac{b_2}{6}(T^3-\mu_2^3)+\frac{b_2}{2}\mu_2^2(T-\mu_2)-\frac{c_2}{12}(T^4-\mu_2^4)-\frac{2c_2}{3}\mu_2^3(T-\mu_2) \quad (15)$$

The average total cost per unit time for $0 < t_1 \le \mu_1$ is given by

$$A_1(t_1) = \frac{1}{T}[k_0 + k_1 D_T + k_2 C_T + k_3 B_T] \quad (16)$$

The first order derivative of $A_1(t_1)$ with respect to t_1 is as follows:

$$\frac{dA_1(t_1)}{dt_1} = \frac{1}{T}\left[\left(k_1 + \frac{k_2}{\theta}\right)(e^{\theta t_1} - 1) + k_3(t_1 - T)\right] (b_1 t_1 + c_1 t_1^2) \quad (17)$$

The necessary condition for $A_1(t_1)$ to be minimized, is $\frac{dA_1(t_1)}{dt_1} = 0$, that is

$$\frac{1}{T}\left[\left(k_1 + \frac{k_2}{\theta}\right)(e^{\theta t_1} - 1) + k_3(t_1 - T)\right] (b_1 t_1 + c_1 t_1^2) = 0 \quad (18)$$

This implies that

$$\left[\left(k_1 + \frac{k_2}{\theta}\right)(e^{\theta t_1} - 1) + k_3(t_1 - T)\right] = 0 \quad (19)$$

Let $p(t_1) = \left(k_1 + \frac{k_2}{\theta}\right)(e^{\theta t_1} - 1) + k_3(t_1 - T)$ (20)

Since

$p(0) = -k_3 T < 0,\ p(T) = \left(k_1 + \frac{k_2}{\theta}\right)(e^{\theta T} - 1) > 0$ and

$p'(t_1) = \left(k_1 + \frac{k_1}{\theta}\right)e^{\theta t_1}\theta + k_3 > 0$, it implies that $p(t_1)$ is a strictly monotonically increasing function and equation (19) has a unique solution at t_1^*, for $t_1^* \in (0, T)$. Therefore, we have

Property-1

The constant deteriorating rate of an inventory model with quadratic trapezoidal type demand rate under the time interval $0 < t_1 \le \mu_1$, $A_1(t_1)$ attains its minimum at $t_1 = t_1^*$, where $p(t_1^*) = 0$ if $t_1^* < \mu_1$. On the other hand, $A_1(t_1)$ attains its minimum at $t_1^* = \mu_1$ if $t_1^* \ge \mu_1$.

The total back order amount at the end of the cycle is

$$\Delta_1 = -\frac{b_1}{2}(t_1^{*2} + \mu_1^2) - \frac{c_1}{3}(t_1^{*3} + 2\mu_1^3) + \frac{b_2}{2}(T^2 + \mu_2^2) - \frac{c_2}{3}(T^3 + 2\mu_2^3) \quad (21)$$

Therefore, the optimal order quantity, denoted by Q^*, is $Q^* = S^* + \Delta_1$, where S^* denote the optimal value of *S*.

Case-II, $\mu_1 \le t_1 \le \mu_2$

For the time period $t_1 \in [\mu_1, \mu_2]$, then, the differential equations governing the inventory model can be expressed as follows:

$$\frac{dI(t)}{dt} + \theta I(t) + b_1 t + c_1 t^2 = 0,\ 0 < t < \mu_1 \quad (22)$$

$$\frac{dI(t)}{dt} + \theta I(t) + R_0 = 0,\ \mu_1 < t < t_1 \quad (23)$$

$$\frac{dI(t)}{dt} + R_0 = 0,\ t_1 < t < \mu_2 \quad (24)$$

$$\frac{dI(t)}{dt} + b_2 t - c_2 t^2 = 0,\ \mu_2 < t < T \quad (25)$$

Solving differential equations (22) to (25), using *I(t₁)=0*, we get

$$I(t) = \left(\frac{R_0}{\theta}e^{\theta t_1} - \frac{b_1}{\theta^2}e^{\theta\mu_1}\right)e^{-\theta t} - \frac{b_1 t + c_1 t^2}{\theta} + \frac{b_1 + 2c_1 t}{\theta^2} - \frac{2c_1}{\theta^3} - \frac{2c_1\mu_1}{\theta^2}e^{\theta(\mu_1 - t)} + \frac{2c_1}{\theta^3}e^{\theta(\mu_1 - t)},\ 0 \le t \le \mu_1 \quad (26)$$

$$I(t) = \frac{R_0}{\theta}(e^{\theta(t_1 - t)} - 1),\ \mu_1 \le t \le t_1 \quad (27)$$

$$I(t) = R_0(t_1 - t),\ t_1 \le t \le \mu_2 \quad (28)$$

$$I(t) = R_0 t_1 - -\frac{b_2}{2}(t^2 + \mu_2^2) + \frac{c_2}{3}(t^3 + 2\mu_2^3),\ \mu_2 \le t \le T \quad (29)$$

The beginning inventory can be computed as

$$S = I(0) = \frac{R_0}{\theta}e^{\theta t_1} - \frac{b_1}{\theta^2}e^{\theta\mu_1} + \frac{b_1}{\theta^2} - \frac{2c_1}{\theta^3} - \frac{2c_1\mu_1}{\theta^2}e^{\theta\mu_1} + \frac{2c_1}{\theta^3}e^{\theta\mu_1} \quad (30)$$

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The total amount of items which is perish within the time interval [0, t_1] is

$$D_T = S - \int_0^{t_1} R(t)dt$$

$$= S - \int_0^{\mu_1} (b_1 t + c_1 t^2)dt - \int_{\mu_1}^{t_1} R_0 dt$$

$$= \frac{R_0}{\theta} e^{\theta t_1} - \left(\frac{b_1}{\theta^2} + \frac{2c_1\mu_1}{\theta^2} - \frac{2c_1}{\theta^3} \right) e^{\theta\mu_1} - R_0(t_1 - \mu_1)$$

$$+ b_1\left(\frac{1}{\theta^2} - \frac{\mu_1^2}{2} \right) - c_1\left(\frac{2}{\theta^3} + \frac{\mu_1^3}{3} \right) \quad (31)$$

The total amount of inventory carried during the time interval [0, t_1] is

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

$$= \int_0^{\mu_1} I(t)dt + \int_{\mu_1}^{t_1} I(t)dt$$

$$= \int_0^{\mu_1} \left[\begin{array}{l} \left(\frac{R_0}{\theta} e^{\theta t_1} - \frac{b_1}{\theta^2} e^{\theta\mu_1} \right) e^{-\theta t} - \frac{b_1 t + c_1 t^2}{\theta} \\ + \frac{b_1 + 2c_1 t}{\theta^2} - \frac{2c_1}{\theta^3} \\ - \frac{2c_1\mu_1}{\theta^2} e^{\theta(\mu_1 - t)} + \frac{2c_1}{\theta^3} e^{\theta(\mu_1 - t)} \end{array} \right] dt$$

$$+ \int_{\mu_1}^{t_1} \left[\frac{R_0}{\theta} (e^{\theta(t_1 - t)} - 1) \right] dt$$

$$= \frac{b_1}{\theta^3} + \frac{R_0}{\theta^2} e^{\theta t_1} - \frac{b_1}{\theta^3} e^{\theta\mu_1} -$$

$$+ \frac{b_1\mu_1}{\theta^2} - \frac{2c_1\mu_1}{\theta^3} e^{\theta\mu_1} - \frac{2c_1}{\theta^4} + \frac{2c_1}{\theta^4} e^{\theta\mu_1}$$

$$- \frac{R_0}{\theta^2} - \frac{R_0}{\theta}(t_1 - \mu_1) \quad (32)$$

The total amount of shortage during the interval [t_1, T]

$$B_T = -\int_{t_1}^{T} I(t)dt$$

$$= -\int_{t_1}^{\mu_2} I(t)dt - \int_{\mu_2}^{T} I(t)dt$$

$$= -\int_{t_1}^{\mu_2} R_0(t_1 - t)dt - \int_{\mu_2}^{T} \left[\begin{array}{l} R_0 t_1 - \frac{b_2}{2}(t^2 + \mu_2^2) \\ + \frac{c_2}{3}(t^3 + 2\mu_2^3) \end{array} \right] dt$$

$$= -R_0 t_1(\mu_2 - t_1) + \frac{R_0}{2}(\mu_2{}^2 - t_1{}^2)$$

$$- R_0 t_1(T - \mu_2) + \frac{b_2}{6}(T^3 - \mu_2{}^3)$$

$$+ \frac{b_2}{2}\mu_2^2(T - \mu_2) - \frac{c_2}{12}(T^4 - \mu_2{}^4)$$

$$- \frac{2c_2}{3}\mu_2^3(T - \mu_2) \quad (33)$$

Now, the average total cost per unit time under the condition $\mu_1 \le t_1 \le \mu_2$, can be obtained as

$$A_2(t_1) = \frac{1}{T}[k_0 + k_1 D_T + k_2 C_T + k_3 B_T] \quad (34)$$

The first order derivative of $A_2(t_1)$ with respect to t_1 isgiv

$$\frac{dA_2(t_1)}{dt_1} = \frac{R_0}{T}\left[\left(k_1 + \frac{k_2}{\theta} \right)(e^{\theta t_1} - 1) + k_3(t_1 - T) \right] \quad (35)$$

The required necessary condition for $A_2(t_1)$ to be minimized is $\frac{dA_2(t_1)}{dt_1} = 0$, that is

$$\left[\left(k_1 + \frac{k_2}{\theta} \right)(e^{\theta t_1} - 1) + k_3(t_1 - T) \right] = 0 \quad (36)$$

Let $p(t_1) = \left(k_1 + \frac{k_2}{\theta} \right)(e^{\theta t_1} - 1) + k_3(t_1 - T)$, (37)

since $p'(t_1) = \left(k_1 + \frac{k_1}{\theta} \right) e^{\theta t_1}\theta + k_3 > 0$, which implies that $p(t_1)$ is strictly monotonically increasing function during the interval $\mu_1 \le t_1 \le \mu_2$.

Property-2

The constant deteriorating rate of an inventory model with quadratic trapezoidal type demand function during the time interval $\mu_1 \le t_1 \le \mu_2$, $A_2(t_1)$ attains its minimum at $t_1^* = \mu_1$ if $t_1^* < \mu_1$ and $A_2(t_1)$ attains its minimum at $t_1^* = \mu_2$ if $\mu_2 < t_1^*$.

Now, we can calculate the total amount of back-order quantity at the end of the cycle is

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$$\Delta_2 = -R_0 t_1^* + \frac{b_2}{2}(T^2+\mu_2^2) - \frac{c_2}{3}(T^3+2\mu_2^3) \quad (38)$$

Therefore, the optimal order quantity denoted by Q^* is $Q^* = S^* + \Delta_2$, where S^* denotes the optimal vale of *S*.

Case-III $\mu_2 \le t_1 < T$

For the time interval $t_1 \in [\mu_2, T)$, then, the differential equations governing the inventory model can be expressed as follows:

$$\frac{dI(t)}{dt} + \theta I(t) + b_1 t + c_1 t^2 = 0, 0 < t < \mu_1 \quad (39)$$

$$\frac{dI(t)}{dt} + \theta I(t) + R_0 = 0, \mu_1 < t < \mu_2 \quad (40)$$

$$\frac{dI(t)}{dt} + \theta I(t) + b_2 t - c_2 t^2 = 0, \mu_2 < t < t_1 \quad (41)$$

$$\frac{dI(t)}{dt} + b_2 t - c_2 t^2 = 0, t_1 < t < T \quad (42)$$

Solving the differential equations (39)- (42) with $I(t_1)$=0, we can get

$$+\left(\frac{b_2-2c_2\mu_2}{\theta^2}+\frac{2c_2}{\theta^3}\right)e^{\theta(\mu_2-t)}+\left(\frac{2c_1}{\theta^3}-\frac{b_1+2c_1\mu_1}{\theta^2}\right)e^{\theta(\mu_1-t)},$$

$$0 \le t \le \mu_1 \quad (43)$$

$$I(t) = -\frac{R_0}{\theta} + \left(\frac{b_2 t_1 - c_2 t_1^2}{\theta} - \frac{b_2}{\theta^2} + \frac{2c_2 t_1}{\theta^2} - \frac{2c_2}{\theta^3}\right)e^{\theta(t_1-t)}$$

$$+\left(\frac{b_2-2c_2\mu_2}{\theta^2}+\frac{2c_2}{\theta^3}\right)e^{\theta(\mu_2-t)}, \mu_1 \le t \le \mu_2 \quad (44)$$

$$I(t) = \left(\frac{b_2 t_1 - c_2 t_1^2}{\theta} - \frac{b_2}{\theta^2} + \frac{2c_2 t_1}{\theta^2} - \frac{2c_2}{\theta^3}\right)e^{\theta(t_1-t)} + \frac{b_2-2c_2 t}{\theta^2} + \frac{2c_2}{\theta^3} - \frac{b_2 t - c_2 t^2}{\theta},$$

$$\mu_2 \le t \le t_1 \quad (45)$$

$$I(t) = \frac{b_2}{2}(t_1^2 - t^2) + \frac{c_2}{3}(t^3 - t_1^3), t_1 \le t \le T$$

(46)The total amount of inventory level at the beginning can be computed as

$$S = I(0) = \frac{b_1}{\theta^2} - \frac{2c_1}{\theta^3} + \left(\frac{b_2 t_1 - c_2 t_1^2}{\theta} - \frac{b_2}{\theta^2} + \frac{2c_2 t_1}{\theta^2} - \frac{2c_2}{\theta^3}\right)e^{\theta t_1}$$

$$+\left(\frac{b_2-2c_2\mu_2}{\theta^2}+\frac{2c_2}{\theta^3}\right)e^{\theta\mu_2}+\left(\frac{2c_1}{\theta^3}-\frac{b_1+2c_1\mu_1}{\theta^2}\right)e^{\theta\mu_1}$$

(47)

The total amount of items which is perish within the time interval [0, t_1] is

$$D_T = S - \int_0^{t_1} R(t)dt$$

$$= S - \int_0^{\mu_1}(b_1 t + c_1 t^2)dt - \int_{\mu_1}^{\mu_2} R_0 dt - \int_{\mu_2}^{t_1} b_2 t - c_2 t^2)dt$$

$$I(t) = \frac{b_1+2c_1 t}{\theta^2} - \frac{2c_1}{\theta^3} - \frac{b_1 t + c_1 t^2}{\theta}$$

$$+\left(\frac{b_2 t_1 - c_2 t_1^2}{\theta} - \frac{b_2}{\theta^2} + \frac{2c_2 t_1}{\theta^2} - \frac{2c_2}{\theta^3}\right)e^{\theta(t_1-t)}$$

$$-\frac{b_1}{\theta^2} - \frac{2c_1}{\theta^3} + \left(\frac{b_2 t_1 - c_2 t^2}{\theta} - \frac{b_2 - 2c_2 t_1}{\theta^2} - \frac{2c_2}{\theta^3}\right)e^{\theta t_1}$$

$$+\left(-\frac{b_1+2c_1\mu_1}{\theta^2}+\frac{2c_1}{\theta^3}\right)e^{\theta\mu_1} +$$

$$\left(\frac{b_2-2c_2\mu_2}{\theta^2}+\frac{2c_2}{\theta^3}\right)e^{\theta\mu_2} - -\frac{b_1}{2}\mu_1^2 - \frac{c_1}{3}\mu_1^3$$

$$-R_0(\mu_2-\mu_1) - \frac{b_2}{2}(t_1^2-\mu_2^2) + \frac{c_2}{3}(t_1^3-\mu_2^3)$$

(48)

The total amount of inventory carried during the time interval [0, t_1] is

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

$$= \int_0^{\mu_1} I(t)dt + \int_{\mu_1}^{\mu_2} I(t)dt + \int_{\mu_2}^{t_1} I(t)dt$$

$$= \int_0^{\mu_1}\left[\begin{array}{l}\frac{b_1+2c_1 t}{\theta^2} - \frac{2c_1}{\theta^3} - \frac{b_1 t + c_1 t^2}{\theta} + \\ \left(\frac{b_2 t_1 - c_2 t_1^2}{\theta} - \frac{b_2}{\theta^2} + \frac{2c_2 t_1}{\theta^2} - \frac{2c_2}{\theta^3}\right)e^{\theta(t_1-t)} \\ +\left(\frac{b_2-2c_2\mu_2}{\theta^2}+\frac{2c_2}{\theta^3}\right)e^{\theta(\mu_2-t)} \\ +\left(\frac{2c_1}{\theta^3}-\frac{b_1+2c_1\mu_1}{\theta^2}\right)e^{\theta(\mu_1-t)}\end{array}\right]dt$$

$$+\int_{\mu_1}^{\mu_2}\left[\begin{array}{l}-\frac{R_0}{\theta} + \left(\frac{b_2 t_1 - c_2 t_1^2}{\theta} - \frac{b_2}{\theta^2} + \frac{2c_2 t_1}{\theta^2} - \frac{2c_2}{\theta^3}\right)e^{\theta(t_1-t)} \\ +\left(\frac{b_2-2c_2\mu_2}{\theta^2}+\frac{2c_2}{\theta^3}\right)e^{\theta(\mu_2-t)}\end{array}\right]dt$$

$$+\int_{\mu_2}^{t_1}\left[\left(\frac{b_2 t_1 - c_2 t_1^2}{\theta} - \frac{b_2}{\theta^2} + \frac{2c_2 t_1}{\theta^2} - \frac{2c_2}{\theta^3}\right)e^{\theta(t_1-t)} + \frac{b_2-2c_2 t}{\theta^2} + \frac{2c_2}{\theta^3} - \frac{b_2 t - c_2 t^2}{\theta}\right]dt$$

$$=\left(\frac{b_2t_1-c_2t_1^2}{\theta}+\frac{2c_2t_1-b_2}{\theta^2}-\frac{2c_2}{\theta^3}\right)\left(\frac{e^{\theta t_1}-1}{\theta}\right)$$

$$+\left(\frac{b_2-2c_2\mu_2}{\theta^2}-\frac{2c_2}{\theta^3}\right)\left(\frac{e^{\theta\mu_2}-1}{\theta}\right)$$

$$+\left(\frac{2c_1}{\theta^3}-\frac{b_1+2c_1\mu_1}{\theta^2}\right)\left(\frac{e^{\theta\mu_1}-1}{\theta}\right)-\frac{b_1\mu_1^2}{2\theta}-\frac{c_1\mu_1^3}{3\theta}+\left(\frac{b_1}{\theta^2}-\frac{2c_1}{\theta^3}\right)\mu_1+\frac{c_1\mu_1^2}{\theta^2}$$

$$-\frac{R_0}{\theta}(\mu_2-\mu_1)-\frac{b_2}{2\theta}(t_1^2-\mu_2^2)+\frac{c_2}{3\theta}(t_1^3-\mu_2^3)$$

$$+\left(\frac{b_2}{\theta^2}-\frac{2c_2}{\theta^3}\right)(t_1-\mu_2)-\frac{c_2}{\theta^2}(t_1^2-\mu_2^2) \quad (49)$$

Total quantity of shortage during the time interval [t_1, T] is

$$B_T=-\int_{t_1}^{T}I(t)dt$$

$$=-\int_{t_1}^{T}\left[\frac{b_2}{2}(t_1^2-t^2)+\frac{c_2}{3}(t^3-t_1^3)\right]dt$$

$$=-\frac{b_2}{2}t_1^2(T-t_1)+\frac{b_2}{6}(T^3-t_1^{\,3})-\frac{c_2}{12}(T^4-t_1^4)$$

$$+\frac{c_2t_1^3}{3}(T-t_1) \quad (50)$$

Then, the total average cost per unit time under the time interval $\mu_2\le t_1\le T$, can be written as

$$A_3(t_1)=\frac{1}{T}[k_0+k_1D_T+k_2C_T+k_3B_T] \quad (51)$$

The first order derivative of $A_3(t_1)$ with respect to t_1 is as follows:

$$\frac{dA_3(t_1)}{dt_1}=\frac{1}{T}\left[\left(k_1+\frac{k_2}{\theta}\right)(e^{\theta t_1}-1)+k_3(t_1-T)\right](b_2t_1-c_2t_1^{\,2}) \quad (52)$$

The required necessary condition for $A_3(t_1)$ to be minimized is

$\frac{dA_3(t_1)}{dt_1}=0$, that is

$$\frac{1}{T}\left[\left(k_1+\frac{k_2}{\theta}\right)(e^{\theta t_1}-1)+k_3(t_1-T)\right] \quad (53)$$

$$(b_1t_1+c_1t_1^{\,2})=0$$

This implies that

$$\left[\left(k_1+\frac{k_2}{\theta}\right)(e^{\theta t_1}-1)+k_3(t_1-T)\right]=0 \quad (54)$$

Let $p(t_1)=\left[\left(k_1+\frac{k_2}{\theta}\right)(e^{\theta t_1}-1)+k_3(t_1-T)\right]$, (55)

since $p'(t_1)=\left(k_1+\frac{k_1}{\theta}\right)e^{\theta t_1}\theta+k_3>0$, which implies that $p(t_1)$ is strictly monotonically increasing function within the interval $t_1\in[\mu_2,T]$.

Property-3

In this case, the inventory model under the condition $\mu_2\le t_1<T$, $A_3(t_1)$ attains its minimum at $t_1=t_1^*$, where $p(t_1^*)=0$ if $\mu_2<t_1^*$. On the other hand, $A_3(t_1)$ attains its minimum at $t_1^*=\mu_2$ if $t_1^*<\mu_2$. Now, we can calculate the total back-order quantity at the end of the cycle is

$$\Delta_3=\frac{b_2}{2}(T^2-t_1^{*2})+\frac{c_2}{3}(t_1^{*3}-T^3).$$

Therefore, the optimal order quantity, denoted by Q^*, is $Q^*=S^*+\Delta_3$, where S^* denotes the optimal value of *S*. From the above three cases, we can derive the following results

Result-1

An inventory model having constant deteriorating rate with quadratic trapezoidal type demand, the optimal replenishment time is t_1^* and $A_1(t_1)$ attains its minimum at $t_1=t_1^*$ if and only if $t_1^*<\mu_1$. On the other hand, $A_2(t_1)$ attains its minimum at $t_1=t_1^*$ if and only if $\mu_1<t_1^*<\mu_2$ and $A_3(t_1)$ attains its minimum at $t_1=t_1^*$ if and only if $\mu_2<t_1^*$, where t_1^* is the unique solution of equation $p(t_1)=0$.

Example 1

We can consider suitable values of the following parameters as follows: T= 20 weeks, μ_1= 6 weeks, μ_2=15 weeks, b_1=10 unit, c_1= 5 unit, b_2=20 unit, c_2= 2 unit, $\theta=0.1$, k_0=$220, k_1= $3 per unit, k_2=$12 per unit, k_3=$4 per unit. By Using MATHEMATICA 8.0 the above data, we can find $p(\mu_1)$=168.1206>0, the optimal replenishment time t_1^*=3.41 weeks, the optimal order quantity Q^*, for each ordering cycle, is 3576.478 unit and the minimum cost $A_1(t_1^*)$=$4688.2

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Table

parameter	%	t_1^*	Q^*	$A_1(t_1^*)$
	+50	3.53	3674.30	4894.2
	+ 25	3.50	3664.02	4883.5
	+ 20	3.45	3584.112	4730.1
	+10	3.41	3576.478	4688.2
b_1	-10	3.30	3576.478	4626.4
	-20	3.27	3560.903	4610.7
	-25	3.20	3284.369	4577.6
	-50	3.17	3225.332	4566.9
	+50	3.07	3888.237	4331.4
	+25	3.31	3424.66	4874.7
	+20	3.35	3234.050	3814.8
	+10	3.44	3021.12 3	3665.3
c_1	-10	3.73	2734.464	3396.0
	-20	3.82	2494.192	3123.4
	-25	4.26	2124.375	3068.8
	-50	4.41	1912.005	2894.4
	+ 50	2.99	2887.633	4843.2
	+25	3.48	3331.537	4771.3
	+20	3.55	3379.185	4733.8
	+10	3.63	3476.768	4655.6
b_2	-10	3.69	3534.739	4596.7
	-20	3.76	3581.35	4534.2
	-25	3.88	3636.423	4412.5
	-50	4.75	3675.547	4385.4
	50	3.645	3658.4	4855.0
	25	3.583	3497.2	4839.7
	20	3.572	3484.5	4834.6
	10	3.557	3448.1	4826.4
c_2	-10	3.534	3436.3	4823.1
	-20	3.475	3401.2	4818.5
	-25	3.461	3382.3	4806.9
	-50	3.391	3232.4	4806.9
	+ 50	3.86	3665.4	4867.3
	+ 25	3.77	3584.7	4856.9
	+ 20	3.66	3563.2	4852.2
	+10	3.512	3533.4	4847.3
θ	-10	3.487	3489.7	4842.2
	-20	3.415	3477.8	4834.6
	-25	3.330	3465,4	4830.7
	-50	3.311	3443.6	4822.4
	+ 50	4.265	2824.5	3346.8
	+ 25	3.880	2753.8	3384.2
	+ 20	3.825	2757.2	3391.1
	+10	3.654	2631.8	3513.6
k_1	-10	3.057	2566.3	3544.2
	-20	2.879	2108.1	3573.2
	-25	2.533	2015.5	3604.9
	-50	1.865	1994.2	3604.9
	+ 50	2.936	2724.6	3674.2
	+25	3.833	2675.7	3624.1
	+20	3.714	2634.3	3600.5
	+ 10	3.685	2536.3	3557.4
k_2	-10	3.612	2222.1	3487.2
	- 20	3.467	2185.2	3426.2
	-25	3.345	2105.4	3385.1
	-50	3.292	1538.7	3114.8
	+50	4.265	2824.5	3346.8
	+ 25	3.884	2753	3384.2
	+ 20	3.825	2657.2	3391.1
	+ 10	3.654	2631.8	3513.6
k_3	-10	3.057	2566.3	3544.2
	-20	2.879	2108.1	3573.2
	-25	2.533	2015.5	3604.9
	-50	1.865	19994.2	3688.3

In the above table some sensitivity analysis of the model is performed by changing the parameter -50%, -25%, -20, -10, 10%,20%, 25%, and 50%, taking one at time and keeping the remaining parameters unaltered.

CONCLUSION 4

In a realistic product life cycle, demand is increasing with time during the growth phase. Then, after reaching its peak, the demand becomes stable for a finite time period called the maturity phase. Thereafter, the demand starts decreasing with time. Therefore, in this paper, we study the inventory model for constant deteriorating items with quadratic trapezoidal demand rate. We proposed an inventory replenishment policy for this type of inventory model. From the market information, we find that the quadratic trapezoidal type demand rate is more realistic than ramp type demand rate, constant demand rate and other time dependent demand rate Our paper provides an interesting topic for the future study of such kind of important inventory models, and at the same time, the following problems can be considered for future research work (1) How about the inventory model starting with shortages? (2) How about the inventory model with time dependent deteriorating rate instead of constant deteriorating rate?

5. REFERENCES:

[1] Abad, P. L. (1996). Optimal pricing and lot sizing under conditions of perish ability and partial back ordering. *Management Science*, 42, 1093-1104.

[2] Abad, P. L. (2001). Optimal price and order size for a reseller under partial back ordering. *Computers and Operations Research*, 28, 53-65.

[3] Benkherouf, L., Bluemner, A.and Aggoun, L. (2003). A diffusion inventory model for deteriorating items. *Applied Mathematics and Computation*, 138, 21-39.

[4] Bhattacharya, D. K. (2005). On multii item inventory. *European Journal of Operational Research*, 162, 786-791.

[5] Cheng, M., Zhang, B. and Wang, G. (2011). Optimal policy for deteriorating items with trapezoidal type demand and partial backlogging. *Applied Mathematical Modeling*, 35, 3552-3560.

[6] Chu, P., Yang, K. L., Liang, S. K. and Niu, T. (2004). Note on inventory model with a mixture of back orders and lost sales. *European Journal of Operational Research*, 159, 470-475.

[7] Chung, K. J., Chu, P. and Lan, S. P. (2000). A note on EOQ models for deteriorating items under stock dependent selling rate. *European Journal of Operational Research*, 124, 550-559.

[8] Chung, K. J. and Lin, C. N. (2001). Optimal inventory replenishment models for deteriorating items taking account of time discounting. *Computers and Operations Research*, 28, 67-83.

[9] Chung, M. and Wang, G. (2009). A note on the inventory model for deteriorating items with trapezoidal type demand rate. *Computers and Industrial Engineering*, 56, 1296-1300.

[10] Dave, U. (1989). A deterministic lot size inventory model with shortages and a linear trend in demand. *Naval Research Logistics*, 36, 507-514.

[11] Deng, S. (2005). Improved inventory models with ramp type demand and Weibull deterioration. *International Journal of Information and Management Sciences*, 16, 79-86.

[12] Deng, P. S., Lin, R. and Peter, Chu. P. (2007). A note on inventory models for deteriorating items with ramp type demand rate. *European Journal of Operational Research*, 178, 112-120.

[13] Gobinda Chandra Panda, Satyajit Sahoo1, Pravat Kumar Sukla,(2012) "Analysis of Constant Deteriorating Inventory Management with Quadratic Demand Rate ", ***American Journal of Operational Research*** *2012, 2(6): 98-10*

[14] G. Ch panda S sahoo., P.K sukla., (2013), A note on inventory model for ameliorating items with time dependent second order demand rate. ***LogForum*** *9 (1), 43-49*

[15] Ghare, P. M. and Schrader, G. P. (1963). A model for an exponentially decaying inventory, *Journal of Industrial Engineering*, 14, 5.

[16] Giri, B. C. and Chaudhuri, K. S. (1998). Deterministic models of perishable inventory with stock dependent demand rate and non-linear holding cost. *European Journal of Operational Research*, 105, 467-474.

[17] Giri, B. C., Jalan, A. K. and Chaudhuri, K. S. (2003). Economic order quantity model with Weibull deterioration distribution, shortage and ramp type demand, *International Journal of system and science*, 34, 237-243.

[18] Hennery, R. J. (1979). Inventory replenishment policy for increasing demand, Journal of The Operational Research Society, 30, 611-617.

[19] Hill, R. M. (1995). Inventory models for increasing demand followed by level demand. *Journal of The Operational Research Society*, 46, 1250-1259.

[20] Hung, K. C. (2011). An inventory model with generalized type demand, deterioration and back order rates. *European Journal of Operational Research*, 208, 239-242.

[21] Mandal, B. and Pal, A. K. (1998). Order level inventory system with ramp type demand rate for deteriorating items. *Journal of Interdisciplinary Mathematics*, 1, 49-66.

[22] Manna, S. K. and Chaudhuri, K. S. (2006). An EOQ model with ramp type demand rate, time dependent deterioration rate, unit production cost and shortages. *European Journal of Operational Research*, 171, 557-566.

[23] Mishra, V. K., Singh, L. S., Kumar, R. (2013). An inventory model for deteriorating items with time dependent demand and time varying holding cost under partial backlogging. *Journal of Industrial Engineering International*, 9, 4-8.

[24] Padmanabhan, G. (1990). Inventory model with a mixture of back-orders and lost sales. *International Journal of System Science*, 21, 1721-1726.

[25] P.K.Sukla(2012) An Inventory Ordering Policy Using Constant Deteriorating Items With Constant Demand **,IJERT** *Vol. 1 Issue 7, September*

[26] P.K.Sukla S.K.Sahu(2008) ,A note for weibul deteriorating model with time varying demand and partial back-ordering.***Acta Cienia Indica,****vol,xxxiv M,No,4, 1673-1670.*

[27] Panad, S., Senapati, S. and Basu, M. (2008). Optimal replenishment policy for perishable seasonal products in a season with ramp type time dependent demand.*Computers and Industrial Engineering*, 54, 301-314.

[28] Panda, S., Saha, S. and Basu, M. (2007). An EOQ model with generalized ramp type demand and Weibull distribution deterioration. *Asia-Pacific Journal of Operations Research*, 24, 93-109.

[29] Resh, M., Friedman, M. and Barbosa, L. C. (1979). On a general solution of the deterministic lot size problem with time proportional demand. *Operations Research*, 24, 718-725.

[30] Sachan, R. S. (1984). On policy inventory model for deteriorating items with time proportional demand. *Journal of The Operational Research Society*, 35, 1013-1019.

[31] Set, B. K., Sarkar, B. and Goswami, A. (2013). A two-warehouse inventory model with increasing demand and time varying deterioration. *Scientia Iranica E*, 19, 1969-1977.

[32] Teng, J. T. (1996). A deterministic replenishment model with linear trend in demand. *Operations Research Letters*, 19, 33-41.

[33] Teng, J. T., Chang, H. J., Dye, C. Y. and Hung, C. H. (2002). An optimal replenishment policy for deteriorating items with time varying demand and partial backlogging. *Operations Research Letters*, 30, 387-393.

[34] Wee, H. M. (1993). Economic production lot size model for deteriorating items with partial back ordering. *Computer and Industrial Engineering*, 24, 449-458.

[35] Wee, H. M. (1995). Joint price and replenishment policy for deteriorating inventory with declining market. *International Journal of Production Economics*, 40, 163-171.

[36] Wee, H. M. and Law, S. T. (1999). Economic production lot size for deteriorating items taking account of the time value of money. *Computers and Operations Research*, 26, 545-558.

[37] Whitin, T. M. (1957). Theory of inventory management. Princeton University Press, *Princeton NJ*, 62-72.

[38] Wu, J. W., Lin, C., Tan, B. and Lee, W. C. (1999). An EOQ with ramp type demand rate for deteriorating items with Weibull deterioration. *International Journal of Information and Management Sciences*, 10, 41-51.

[39] Wu, K. S. (2001). An EOQ inventory model for items with Weibull distribution deterioration, ramp type demand rate and partial back logging. *Production Planning and Control*, 12, 787-793.

[40] Wu, K. S. and Ouyang, L. Y. (2000). A replenishment policy for deteriorating items with ramp type demand rate. *Proceeding of National Science Council ROC (A)*, 24, 279-286.

[41] Wu, K. S., Ouyang, L. Y. and Yang, C. T. (2006). An optimal replenishment policy for non-instantaneous deteriorating items with stock dependent demand and partial back logging. *International Journal of Production Economics*, 101, 369-384.

[42] Wu, K. S., Ouyang, L. Y. and Yang, C. T. (2008). Retailer's optimal ordering policy for deteriorating items with ramp type demand under stock dependent consumption rate. *International Journal of Information and Management Sciences*, 19, 245-262.

[43] Shah, Nita H, Chaudhari Urmila and Jani Mrudul Y (2015), Optimal Policies for Time-Varying Deteriorating item with Preservation Technology under Selling Price and Trade Credit Dependent Quadratic demand in a Supply Chain, ,International Journal of Applied and Computational Mathematics 3(2) 363-379.

[44] Shah, Nita H, Chaudhari Urmila and Jani Mrudul Y (2016), Impact of future price increase on ordering policies for deteriorating polices for deteriorating items under under quadratic demand. 7(3), 423-436.

BIOGRAPHY

1. Pravat kumar sukla is working as a lecturer in mathematics Panchayat samiti college koksara, kalahandi, odisha, INDIA. He has obtained his M.sc and Ph.D in mathematics from Sambalpur University, odisha, India .he has published 11 research papers in different national and international journals. His research interests include inventory control.

3. Rajani Ballav Dash is Ex Reader in mathematics Revenshaw University, at present Visiting Faculty Revenshaw University, Cuttack. He has a retired principal, S.C.S (Autonomous) college, Puri, odisha Ex- Visiting Faculty Institute of mathematics and Applications, bbsr ,odisha.Ten students have completed Ph.D under guidance. He has published 50 research papers different national and international journals and NO of text books -14. His research interests include inventory control and Numerical Analysis, Operations Research (Theorical and applied), Graph Theory and fracture mechanics.