International Journal of u- and e- Service, Science and Technology
Vol.7, No.2 (2014), pp.51-62
http://dx.doi.org/10.14257/ijunesst.2014.7.2.05

The Integration of Supply Chain under the Environment of E-Commerce Based on the Deteriorating Inventory Model

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Abstract

As the industrial environment becomes more competitive, supply chain management has become essential. The objective of this research is to develop a multi-echelon inventory model for a deteriorating item and to derive an optimal joint total cost. Inventory models for the manufacturer and the retailer were developed when deteriorating rates were constant, and demand rate of customer decreased linearly with time and depended on retailers' current inventory level. The objective was to develop an optimal ordering strategy for retailers to minimize the average total cost of this inventory system. This paper establishes an inventory model of manufacturers and retailers, and gives the optimal production time algorithm. Then, we will carry out simulation test for example. We calculate the system of minimum average total cost that respectively from producers, retailers and integration. Thus, it confirms that the average total cost which from the supply chain integration is lower than from the manufacturer or retailer alone.

Keywords: *deteriorating rate, inventory model, E-commerce, supply chain environment*

1. Introduction

Since the beginning of the last century in the 70, the history of electronic commerce that from vision to mature is only used thirty or forty years. It is generally recognized and began to attract many consumers that become a new business model. This is inseparable with the popularity of the Internet at the end of last century 90's. No doubt, the IT technology is the incubator and propeller of electronic commerce. In less than 20 years of development, not only the electronic commerce show great commercial potential, but also change the way to people's life and production. It has become a phenomenal force of social progress. Electronic business supply chain and the traditional supply chain have many differences in supply chain management. For example, the supply chain has a higher visibility, information transfer and update faster, the technical barriers of information sharing between supply chain members is not exist, the channel of commodity stocks stored more focused, the logistics efficiency of consumer demand has become an important index of electric service level, and commodity pricing more dynamic and variability, etc.

As the market economy is increasingly mature, the competition between enterprises is getting more and more intense, more and more enterprises began to use supply chain

ISSN: 2005-4246 IJUNESST

management to improve their operation efficiency. Fresh agricultural products are deteriorating, so the efficiency of the supply chain is more strongly. In recent years, inventory management problem of fresh agricultural products supply chain management has become a hot topic. Raafat [1] and Goyal and Giribc [2] developed the theory of different demand rates, productivity and loss rates. They established the inventory model that includes the inflation, price discount and the duration of the perishable products. We can found these documents are considered a single echelon. The study of multi stage supply chain of perishable products inventory model began in recent years. Goyalsk and Gunaselarana [3] establish the inventory model of integrated market for perishable products. Rauh, Wumy and Weehm [4] establish a inventory model for three echelon integrated supply chain environment that productivity, loss rate and the customer the demand rate is a constant. Lawst and Wee [5] assume that the demand rate is a constant, taking into account the production inventory model for two echelon supply chain, the model includes the quality or quantity of the product increased with time. Yang and Wee [6] puts forward a win-win strategy) for an integrated vendor buyer perishable inventory system.

Deteriorating inventory models have been widely studied by several authors in recent years. Ghare and Schrader [7] were the first researchers to consider exponentially decaying inventory when the demand is constant. Covert and Philip [8] extended the model to consider deterioration with Weibull distribution. Other authors such as Dave [9] Elsayed and Teresi [10], Mak [11], Kang and Kim [12], and Heng *et al.,* [13] continued to refine the deterioration model. Dave and Elsayed and Teresi developed the optimal order level for deteriorating items. Subsequent, Mak, Kang and Kim considered a production lot size model for deteriorating inventory system. Heng *et al.,* developed an inventory model with finite replenishment rate, constant demand rate and exponential decay.

This paper establishes an inventory model of manufacturers and retailers, and gives the optimal production time algorithm. Then, we will carry out simulation test for example. We calculate the system of minimum average total cost that respectively from producers, retailers and integration. Thus, it confirms that the average total cost which from the supply chain integration is lower than from the manufacturer or retailer alone.

2. Establish the Inventory Model

Considering the product inventory problem that is the time range of T single metamorphic. The system consists of one manufacturer and one retailer [14-18]. Started from 0 time, we give a productivity to producers (productivity is constant) for continuous production, and only one times. The producers can stop the production until satisfied all the demand of retailers in$[0,t]$. Assume that the manufacturer's product will have continuous deterioration, and the deterioration rate is constant. Raw materials for manufacturers to directly into a production line, and we can regardless of the inventory problem. We only consider the inventory in manufacturer. The retailers order from the manufacturer for n times in$[0,t]$. Each separated by the same time T/N, they batch ordering one time (replenishment rate is infinite). Not allowing goods shortage, retailers order lead time is 0. Assume that the manufacturer and retailer of initial inventory level is 0. In order to avoid the system appear the phenomenon of out of stock in the beginning, the retailers are not ordering at time 0, but from the time T/N. The retailer's product also has the deterioration problem, and the deterioration rate is a constant determined. The demand rate of the customer for the product decreased linearly with the time increased, and depending on the time of T and the retailer's inventory levels of $I_r(t)$.It can be expressed as:

$$D_r(t, I_r(t)) = a - bt + \beta I_r(t).a > 0, b > 0, \beta > 0$$

Where the a is the market foundation, b is the coefficient of demand rate by time varying, and β is the coefficient of the current stock level of retailers. In addition, $a - bT \geq 0$ can guarantee the demand rate non negative in the whole operation cycle. The goal is to determine the retailer's order number (the retailer's optimal ordering strategy). Determination of the production time can make the minimum average total cost of the system (the optimal production strategy of producers).

The symbols used in this paper are shown in Table 1.

Table 1. The Table of the all Symbols is used in this Article

T	The total time range
T_p	The Production time
n	The number of retailer ordering from producer
n_p	The retailer's ordering number in T_p
t_e	the time from $n_p + 1$ to the end
$D_r(t, I_r(t))$	The number of customer demand in t
Q_i	The amount of retailer order in the cycle of i
Q_{st}	The number of retailer's total ordering in T
I_{st}	The number of inventory accumulation of retailer in T
M_i	The inventory levels of manufacturers in the cycle of i
P_{sp}	Producer 's production capacity in T
I_{sp}	The number of inventory accumulation of producer in T
$I_r(t)$	The inventory number of retailer in T
$I_p(t)$	The inventory number of producer in T
θ_r	The product deterioration rate of retailer
θ_p	The product deterioration rate of producer
K_r	The fixed cost of retailers for once order
c_r	The unit product ordering cost of retailer
h_r	The unit product inventory cost of retailer
q_r	The cost for processing the unit deterioration product of producer
K_p	The fixed cost of producer for once product
c_p	The unit product ordering cost of producer
h_p	The inventory cost of unit product of producer

q_p	The cost for processing the unit deterioration product of retailer
TC_r	The average total cost of retailer in T
TC_p	The average total cost of producer in T
TC	The average total cost of the inventory system in T

In this paper, the inventory system is shown in Figure 1 which consists of one producer and one retailer. Figure 1 shows the time range of *T*, the change curve of producer and retailer's inventory levels. Then, the cycle number and the zero time of producer and retailer are defined in Figure 1.

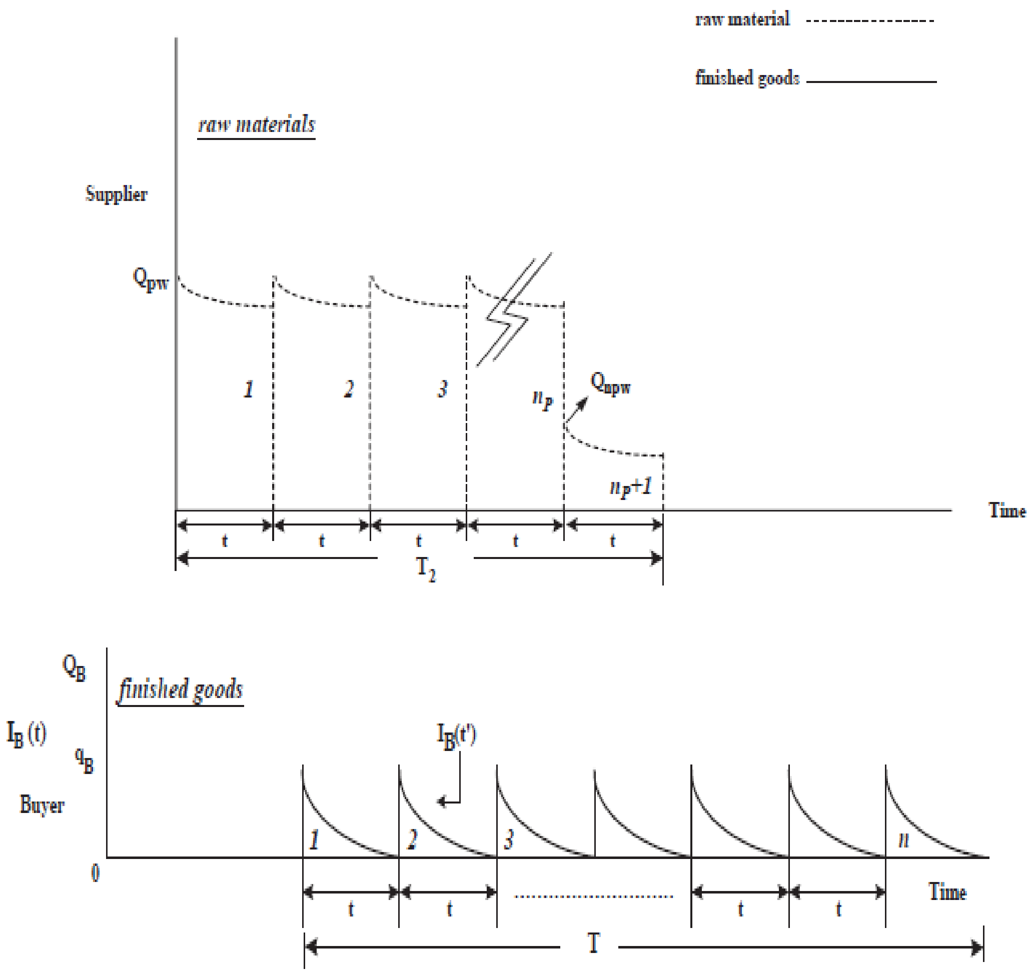

Figure 1. Inventory Level of Supply Chain

2.1. The Retailer Inventory Model

The retailer inventory model can be expressed as：

$$\frac{dI_r(t)}{dt} = -D_r(t, I_r(t)) - \theta_r I_r(t) = -a + bt - (\beta + \theta_r) I_r(t) \quad (1)$$

Where, $(i-1)T / n \le t < iT / n, i = 1, 2, \cdots, n$

Solving the formula (1) can be obtained the inventory levels of i th period.

$$I_r(t) = [\frac{a}{\beta+\theta_r} + \frac{b}{(\beta+\theta_r)^2}][\exp((\beta+\theta_r)(i\frac{T}{n} - t) - 1] - \frac{b}{\beta+\theta_r}[\frac{iT}{n}\exp\left((\beta+\theta)(\frac{iT}{n} - t)\right) - t] \quad (2)$$

Where, $(i-1)T / n \le t < iT / n, i = 1, 2, \cdots, n$

Solving the formula (2) can be obtained the retailer orders of i th period.

$$Q_i(t) = [\frac{a}{\beta+\theta_r} + \frac{b}{(\beta+\theta_r)^2}][\exp\left(\frac{T}{n}(\beta+\theta_r) - 1\right)] - \frac{b}{\beta+\theta_r}[\frac{iT}{n}\exp\left(\frac{T}{n}(\beta+\theta_r) - \frac{(i-1)T}{n}\right)] \quad (3)$$

The total amount of the order expressed as follows：

$$Q_{sr} = \sum_{i=1}^{n} Q_i$$
$$= [\frac{na}{\beta+\theta_r} + n\frac{b}{(\beta+\theta_r)^2}][\exp\left(\frac{T}{n}(\beta+\theta_r) - 1\right)] - \frac{b}{\beta+\theta_r} * [\frac{(n+1)T}{2}\exp\left(\frac{T}{n}(\beta+\theta_r) - \frac{(n-1)T}{n}\right)] \quad (4)$$

The total number of inventory of n period as shown:

$$I_{sr} = [\frac{a}{(\beta+\theta_r)^2} + \frac{b}{(\beta+\theta_r)^3}][n\exp\left(\frac{T}{n}(\beta+\theta_r)\right) - T(\beta+\theta_r) - n] - \frac{b}{(\beta+\theta_r)^2}[\frac{(n+1)T}{2}\exp\left(\frac{T}{n}(\beta+\theta_r) - \frac{(n-1)T}{n} - \frac{T^2}{2}(\beta+\theta_r)\right)] \quad (5)$$

The average total cost retailers (including ordering cost, holding cost and metamorphic cost) can expressed as the formula(6):

$$TC_r = K_r\frac{n}{T} + c_r\frac{Q_{sr}}{T} + h_r\frac{I_{sr}}{T} + q_r[Q_{sr} - aT + \frac{1}{2}bT^2 - \beta T_{sr}]\frac{1}{T} \quad (6)$$

2.2. The Producer Inventory Model

Because retailers are ordered in the initial phase of each cycle, so it only affects the initial inventory level of the manufacturer. When retailers order completion, inventory levels of producers no longer by the retailer's influence within each cycle, it only related to their productivity and product loss rate. We will analyze the inventory models of manufacturer in production stage and the stop production stage [19-21].

（1）The production stage $(0 \le t \le T_p)$

$$\frac{dI_r(t)}{dt} = P - \theta_p I_p(t) \tag{7}$$

Where, $(i-1)T/n \le t < iT/n, i = 1,2,\cdots,n_p$

At the beginning of the i th cycle of the Manufacturer's inventory level is $M_i = I_p[\left(\frac{(n-1)T}{n}\right)^+]$.

Solving the formula(7) can be obtained:

$$I_p(t) = [M_i - \frac{P}{\theta_p}]*[\exp\left(\theta_p(\frac{(i-1)T}{n} - t)\right)] + \frac{P}{\theta_p} \tag{8}$$

At the beginning of the $n_p + 1$ th cycle of inventory level of recurrence relations is $M_1 = 0$

$$M_1 = (M_{i-1} - \frac{P}{\theta_p})\exp(-\frac{\theta_p T}{n}) + \frac{P}{\theta_p} - Q_{i-1}, i = 1,2,\cdots,n_p+1 \tag{9}$$

Set

$$S_p = \sum_{i=1}^{n_p} \exp[-\theta_p(n_p - i)T/n] \tag{10}$$

$$W_p = \sum_{i=1}^{n_p} i*\exp[-\theta_p(n_p - i)T/n] \tag{11}$$

Then, we can get the $n_p + 1$ th cycle of inventory level from the formula (9)

$$\begin{aligned} M_{n_p+1} &= \frac{P}{\theta_p}[1 - \exp(-\theta_p \frac{T}{n})] - \sum_{i=1}^{n_p} Q_i \exp[-\theta_p \frac{(n_p - 1)T}{n}] \\ &= \frac{P}{\theta_p}[1 - \exp(-\theta_p \frac{T}{n})] - [\frac{a}{\beta + \theta_r} + \frac{b}{(\beta + \theta_r)^2}][\exp(\frac{T}{n}(\beta + \theta_r) - 1]S_p \\ &+ \frac{b}{\beta + \theta_r}\frac{T}{n}[\left(\exp\left((\beta + \theta)\frac{T}{n}\right) - 1\right)W_p + S_p] \end{aligned} \tag{12}$$

When the $i = n_p + 1, \frac{n_p T}{n} \le t \le \frac{n_p T}{n} + t_e$, Solving the formula(7) can be obtained the inventory level curve.

Then, we substituted the $t = \frac{n_p T}{n} + t_e$ into the formula (7).

We get the inventory level of producer in $t = T_p^-$ as below:

$$I_p(T_p^-) = [M_{n_p+1} - \frac{P}{\theta_p}]*\exp\left(-t_e\theta_p\right) + \frac{P}{\theta_p} \tag{13}$$

(2) The stop production stage $(T_p \le t \le T)$

$$\frac{dI_r(t)}{dt} = -\theta_p I_p(t) \qquad (14)$$

Where, $(i-1)T/n \le t < iT/n, i = 1, 2, \cdots, n$
Solving the formula(14) can be obtained:

$$I_p(t) = M_i * [\exp\left(\theta_p(\frac{(i-1)T}{n} - t)\right)] \qquad (15)$$

At the beginning of the $n - n_p - 1$ th cycle of inventory level of recurrence relations is

$M_{n+1} = 0$

$$M_1 \cong (M_{i-1} + Q_i)(1-\theta_p)^{-T/n}, i = n_p + 2, \cdots .n \qquad (16)$$

Set

$$S_n = \sum_{i=n_p+2}^{n_p} (1-\theta_p)^{-(i=n_p-1)T/n} \qquad (17)$$

$$W_p = \sum_{i=n_p+2}^{n_p} i * (1-\theta_p)^{-(i=n_p-1)T/n} \qquad (18)$$

Then, we can get the $n_p + 2$ th cycle of inventory level

$$M_{n_p+2} = \sum_{i=n_p+2}^{n_p} Q^i (1-\theta_p)^{-(i=n_p-1)T/n}$$

$$= [\frac{a}{\beta+\theta_r} + \frac{b}{(\beta+\theta_r)^2}][\exp\left(\frac{T}{n}(\beta+\theta)\right) - 1]S_n \qquad (19)$$

$$+ \frac{b}{\beta+\theta_r}\frac{T}{n}[\left(\exp\left((\beta+\theta_r)\frac{T}{n}\right) - 1\right)W_n + S_n]$$

When the $i = n_p + 2, \frac{n_p T}{n} + t_e \le t \le \frac{(n_p+1)T}{n}$. Solving the formula (14) can be obtained the inventory level curve.

Then, we substituted the $t = \frac{n_p T}{n} + t_e$ into the formula (14).

We get the inventory level of producer in $t = T_p^+$ as below：

$$I_p(T_p^+) = [M_{n_p+2} - Q_{n_p+1}] * (1-\theta_p)^{-(T/n - t_e)} \qquad (20)$$

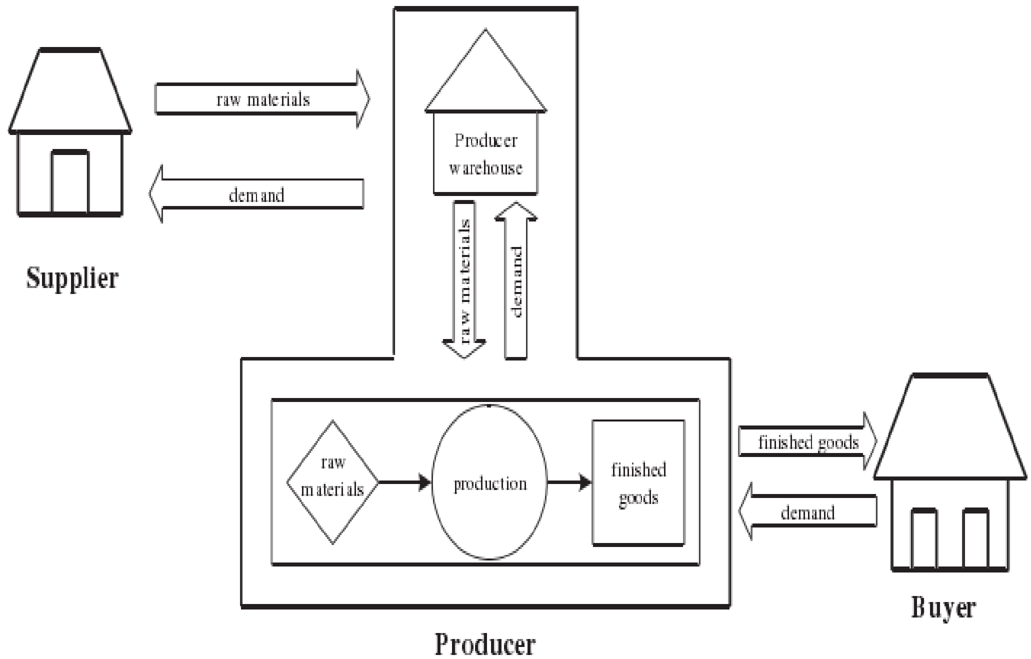

Figure 2. The Integrated Supply Chain System

3. The Simulation and Conclusion

We give the value of parameters of the inventory model in this article.

The buyer's parameter data: Demand rate of finished goods is 10,000 units per week. The ordering cost of finished goods is $400 per order; the receiving cost of finished goods is $25 per receiving; the holding cost of finished goods per unit per week is $16; the deteriorating cost of finished goods per unit is $120; the deterioration rate is 0.07.

The supplier's parameter data: The receiving cost of raw materials is $20 per receiving; the holding cost of raw materials per unit per week is $10; the deteriorated cost of raw materials per unit is $85, the deterioration rate is 0.09. The ordering cost of raw materials is $260 per order; the delivery cost of raw materials is $125 per delivery; the holding cost of raw materials per unit per week is $10; the deteriorated cost of raw materials per unit is $80, the deterioration rate is 0.2[22-24].

Table 2. The Cost Statement that the $n \le 100$

n	n_p	TC_B	TC_s	TC
1	0	247010	402354	649364
2	1	172712	193190	365902
3	1	87244	171493	258737
4	2	59411	153153	212564
5	2	49138	132419	181558
10	5	34868	90092	124960
20	10	27950	70309	98259
30	15	25814	65251	91066
35	17	25258	64253	89511

36	18	25120	64115	89234
37	18	25087	64024	89112
38	19	25011	63972	88983
39	20	24993	63952	88944
40	20	24667	63845	88512
45	23	24600	63837	88437
46	23	24556	63760	88317
47	24	24515	63867	88382
48	**24**	**24477**	**63811**	**88288**
49	25	24441	63931	88372
50	25	24408	63894	88301
55	28	24273	64291	88563
56	28	24251	64297	88548
57	29	24231	64457	88688
58	29	24213	64474	88688
59	30	24196	64642	88838
60	30	24181	64670	88851
70	35	24091	65860	89951
75	38	24080	66624	90704
76	38	24079	66706	90785
77	39	24080	66918	90998
78	39	24081	67004	91085
79	40	24083	67220	91303
80	41	24086	67453	91539
90	46	24137	69070	93207
100	51	24228	70809	95037

We can see from Table 2, the average total cost of the retailer has a minimum value which is $TC = 88288$ at $n = 48$ .Because the inventory cost is small; the total cost will be smaller. So, from the manufacturer's point of view, manufacturers hope that the retailer to order frequency as soon as possible.

The change trend of the average total cost of inventory system is shown in Figure 3; the figure depicts the number of less than 100. We can see from Figure 3, the average total cost is convex.

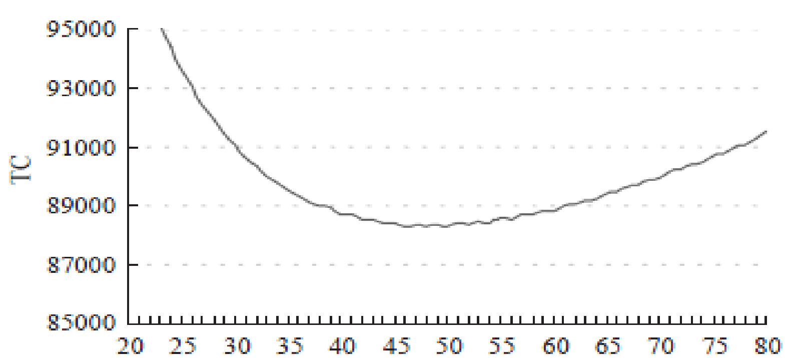

Figure 3. Change Trend of the Average Total Cost of Inventory System

It can be seen from Figure 4, the sensitivity change trend that the rates of deterioration affect on total cost. With the increase of the rate of deterioration, the total supply chain cost decrease. When the deterioration rate reaches a certain degree, the total cost of supply chain will tend to be stable. At this time, the rate of deterioration effect total cost is very small. When the deterioration rate reaches a threshold, the total cost will be in a relatively stable state. This means that if you want to increase the real control the total cost of supply chain, the most important thing that is control the other factor of the production process.

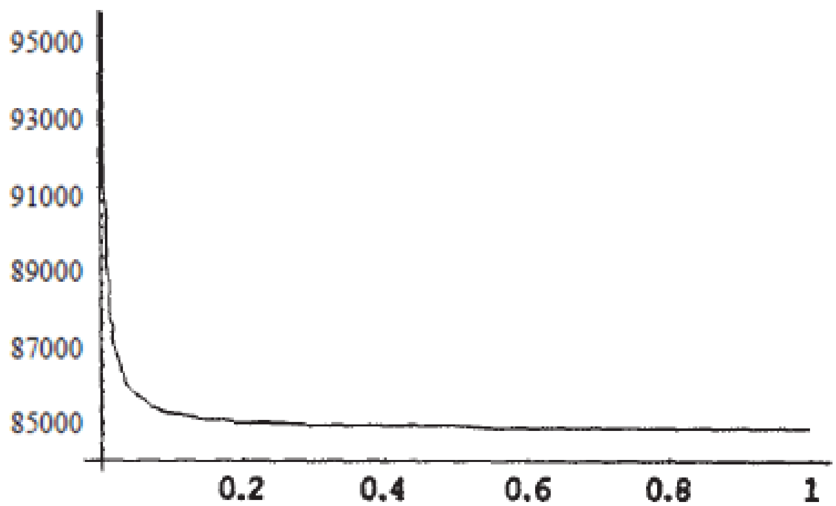

Figure 4. Sensitivity Change Trend

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