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INFLATION ON TWO SHOPS UNDER ONE MANAGEMENT WITH DISPLAYED STOCK LEVEL

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ABSTRACT: Now a days, due to globalization of market with the introduction of multinationals in the business, there is a trend among the business houses especially middle order retailers and small retailers of different multi-national products to compete with each other for sale and as result, an important problem arise in inventory control is to decide where to stock the goods. Furthermore, in some practical situations, when suppliers provide price discounts for bulk purchases or when the item under consideration is a seasonal product such as the output of harvest or the replenishment cost is higher than the other related cost, etc., the inventory manager may purchase more goods than can be stored in its own warehouse (OW). From economical point of views, they usually choose to rent other warehouses than rebuild a new warehouse. Thus, the excess quantities are stored in a rented warehouse (RW). The inventory costs in RW are usually higher than those in OW due to additional cost of maintenance, material handling, etc.

KEYWORDS*:* Globalization, Inventory, Economical point

INTRODUCTION

It is concerned with making good decisions among many alternatives. It has traditionally been concerned with finding effective solutions to specific operational problems. It has developed better methods, techniques and tools for doing so. Operations research not only includes solving specific problems but also designing problem-solving and implementation systems. These predict and prevent future problems, identify and solve current ones and implement and maintain these solutions under changing conditions. Operations research has enhanced organizations and experiences all around us. Notable instances in business management are planning industrial production, scheduling airlines and other transportation means and managing inventories in a supply chain. A successful application does not just run a computer program, but requires a model that suitably describes the situation and relevant data. A problem in the real world is modeled usually on mathematical terms then mathematical techniques with data analysis and computational algorithms are applied. By using techniques such as mathematical modeling to analyze complex situations, operations research gives executives the power to make more effective decisions and build more productive systems.

REVIEW OF LITERATURE

Whitin (1955) first presented an inventory model considering the effect of price dependent demand. Later, Kunreuther and Richard (1977), Lee and Rosenblatt (1986), Mukherjee (1987), and Abad (1996) presented inventory of joint pricing and inventory planning. The concept of two shops under a single management was introduced by Kar *et al*. (2011-a). In their study, they considered the stock-dependent demand for deteriorating items but they did not consider the shortage in the primary and secondary shop. Kar *et al.* (2011-b) also developed a deterministic inventory model of deteriorating items sold from two-shops under a single management. In that model, they considered shortage in the primary but not in secondary shop. Wee and Law (2011) applied the discounted cash-flow approach to a deterministic price-dependent demand inventory model where item deteriorates over time. Das and Maiti (2013) developed an inventory model of a differential item sold from two shops under single management with shortages and variable demand. Yang (2014) considered inflation in the two warehouse inventory model. Dey *et al.* (2006) presented an inventory of differential items selling from two shops under a single management with periodically increasing demand over a finite time-horizon. Mondal *et al.*

(2007) presented a single period inventory model of a deteriorating item sold from two shops with shortage. Dye *et al.* (2007) assumed a deterministic inventory model for deteriorating items with price-dependent demand. They allow for shortages and the unsatisfied demand is partially backlogged. Singh *et al.* (2009) developed a two-warehouse inventory model for deteriorating items with shortages under inflation and time-value of money. Maiti *et al.* (2009) and Banerjee and Sharma (2010) also presented inventory model with price dependent demand.

In the above cited references, most of the inventory models with two-shop system have been developed for differential items with or without shortages. But in all the above cited models, the researchers had ignored the effect of inflation and assumed all the cost parameters to be deterministic, whereas in the real life, it is not always so. So in order to fill this gap, the present researcher first time developed inventory models considering two-shops in inflationary environment and all the cost parameters were assumed to be fuzzy in nature.

In the proposed study, we have strived to study the inventory models with the phenomenon of two-warehouse for both non-defective and defective units purchased in a lot and selling separately at two different shops under a single management. The demand of the good units was stock dependent whereas the defective ones having price dependent demand only in an inflationary environment. In primary shop, non-defective units were sold with a profit. And the defective units, which are continuously transferred to the adjacent secondary shop, were sold after some re-work or repair at a reduced price even incurring a loss. Here shortages were allowed for both shops. It was also assumed that the rate of replenishment of units for the primary shop is infinite. In the secondary shop, this sells only the defective units, which were continuously transferred from the primary shop with variable rates. The researcher considered three situations for dealing with defective units depending upon the coincidence of the time periods at two shops. In the present model, three scenarios were studied: (1) the shortages of defective units occur earlier than the shortages at the primary shop, (2) at both shops shortages occur at the same time, and (3) at the secondary shop shortages occur after the occurrence of shortages at the primary shop. The optimization framework is presented to derive the optimal replenishment policy that maximizes the total profit. The models were illustrated with numerical examples and sensitivity analyses were used to study the behavior of the models.

NOTATIONS AND ASSUMPTIONS

In order to developed inventory models of differential units for primary and secondary shops under a single management, the following common assumptions and notations were used:

Notations

C_s = "in-no-time" sorting cost for shortage units only.

C_0 = unit cost of the differential item. For i^{th} (i = 1, 2) shop,

p_i = selling price per unit item and $p_i = M_i C_0$.

$(H_i + \phi t)$ = holding cost per unit quantity per unit time.

U_i = set-up cost per scheduling period.

r = denotes the inflation rate.

Q_i = optimum inventory level.

M_i = mark-up price with $M_i > 1$ and $0 < M_2 < M_1$ (M_2 is decision variable).

S_i = shortage level at the end of scheduling period.

G_i = shortage cost per unit quantity per unit time.

$q_i(t)$ = inventory level at any time t.

NR_i = net revenue from ith shop.

TC_i = total cost at the i^{th} shop.

π = the total average profit from both the shops.

(Suffices i = 1 and 2 represent the parameters related to the primary and the secondary shops

respectively).
In addition to above notations, the following assumptions were also considered:

Assumptions

1. Demand for good units is deterministic and function of current stock level given by $D_1(q_1(t))$ = $a_1 + b_1 q_1(t)$ where a_1, b_1 are positive constants.
2. Defective unit at any time t is a fraction of on-hand inventory level and is equal to $\theta q_1(t)$, where θ is constant and $0 < \theta < 1$. These defective units are continuously transferred to the secondary shop.
3. To meet the shortages for good units, it is required to procure S differential units out of which good and defective units are $(1 - \theta) S$ $(= S_1)$ and θS respectively.
4. Shortages are allowed and these are fully backlogged.
5. As shortages for good and defective units are met after sorting the differential units "in-no-time", sorting cost for shortage units only is dependent on shortage quantity of differential units and is given by
   $C_s = kS^{\beta}$
   where k, β ($\beta < 1$) are positive constants. The continuous sorting cost of defective units at the time of selling of good units at the primary shop is included in the set-up cost as this job is done by the permanent employees of the management.

TWO-SHOP INVENTORY MODEL IN AN INFLATIONARY ENVIRONMENT

The literature survey revealed that no researcher has until now developed the two-shop inventory model with inflationary environment. The researcher has first time considered the effect of inflation in two-shops to make the model more realistic.

In most of the inventory models with two shops as mentioned above, the inflation was discarded. It has been done probably with of the belief that the inflation would not influence the inventory policy to any significant degree. However, in the last several years most of the countries have suffered from large-scale inflation and sharp decline in the purchasing power of money. As a result, while determining the optimal inventory policy, the effects of inflation cannot be ignored.

Clearly, there is need for the reformulation of the optimal inventory control policies taking into account the above mentioned factors. In the present study, a sincere attempt was made to study the situation when the differential item, units of which are not in perfect conditions, sold from two-shops-primary and secondary shop, under one management. The stock-dependent demand was taken into consideration. In order to make our study more suitable to the present day market, research model was developed for an inflationary environment. The model has been developed for a finite planning horizon in which shortages were allowed.

FORMULATION AND SOLUTION OF THE MODEL

Primary Shop

In the present study, initially the inventory stock level of the system of differential units Q_1 gradually declines mainly to meet up demand of goods units and the defective units, which are continuously transferred to the secondary shop up to $t = t_1$, and the stock level reaches zero at $t = t_1$. After $t = t_1$, shortages are allowed only for good units up to time $t = t_1 + t_2$. At time $t = t_1 + t_2$, shortage level is S_1 for goods units and to meet this shortage, S units of differential units are procured and stored instantaneously. The differential equations describing the inventory level $q_1(t)$ in the interval $0 \le t \le t_1 + t_2$ is given by

$$q_1^{\cdot}(t) = \begin{cases} -\theta q_1(t) - D_1\left(q_1(t)\right), & 0 \le t \le t_1 \\ -D_1\left(q_1(t)\right) \quad , & t_1 \le t \le t_1 + t_2 \end{cases} \qquad \ldots(1.1)$$

With the conditions, $q_1(t)=Q_1$, 0 and $-S_1$ at $t=0$, t_1 and t_1+t_2 respectively.
Therefore, taking $D_1\left(q_1(t)\right)=a_1+b_1q_1(t)$, the solutions of the above equations are

$$q_1(t)=\begin{cases}\frac{a_1}{\alpha}\left[e^{\alpha(t_1-t)}-1\right], & 0\le t\le t_1\\ \frac{a_1}{b_1}\left[e^{b_1(t_1-t)}-1\right], & t_1\le t\le t_1+t_2\end{cases}\quad \text{where}\quad \alpha=b_1+\theta. \qquad \ldots(1.2)$$

If D_u be the total defective units during the interval (0, t_1+t_2), then

$$D_u=\int_0^{t_1}\theta\, q_1(t)\,dt+\theta S=\frac{\theta}{\alpha}(Q_1-a_1t_1)+\theta S \qquad \ldots(1.3)$$

where Q_1 and S are given by

$$Q_1=q_1(0)=\frac{a_1}{\alpha}\left(e^{\alpha t_1}-1\right),\ S_1=q_1(t_1+t_2)=\frac{a_1}{b_1}\left(1-e^{-b_1t_2}\right)\text{and } S=\frac{S_1}{1-\theta}. \qquad \ldots(1.4)$$

The total cost for the primary shop is given by
TC_1 = Purchase cost + Holding cost + Shortage cost + Sorting cost + Setup cost

$$=C_0(Q_1+S)+\int_0^{t_1}\left(q_1(t)\right)(H_1+\phi t)e^{-rt}dt+G_1\int_{t_1}^{t_1+t_2}\left(-q_1(t)\right)e^{-rt}dt+kS^{\beta}+U_1 \qquad \ldots(1.5)$$

Net revenue cost for the primary shop is given by

$$NR_1=M_1C_0\left\{\frac{b_1}{\alpha}Q_1+(1-\theta)S+\frac{a_1\theta t_1}{\alpha}\right\}\left\{\frac{1}{R}\left(1-e^{-R(t_1+t_2)}\right)\right\} \qquad \ldots(1.6)$$

Here, we obtain the total cost and net revenue cost for the primary shop as given in the equations (1.5) and (1.6). These equations are used to calculate the total average profit in the section 1.1.1.

Secondary Shop

At the time of sale, the defective units are spotted at the primary shop and then transferred to the secondary shop, at $t = 0$, the amount of inventory in this shop at the beginning of the schedule is zero. It is assumed that initially the amount of defective units received from the primary shop is more than sufficient to meet the demand of defective units, i.e., $\theta q_1(t)>D_2$. So the inventory level is raised at a rate $\theta q_1(t)-D_2$ and after some time it will be zero, i.e. $\theta q_1(t)=D_2$ at $t=t_3$, ($0\le t_3\le t_1$), (say). Hence, at $t=t_3$, the process of building up of inventory will be stopped and stock attains its maximum level Q_2. Thus, one can get t_3 from the relation $\theta q_1(t)=D_2$ as in scenario-1.

$$t_3=t_1-\frac{1}{\alpha}\log\left(1+\frac{\alpha D_2}{a_1\theta}\right) \qquad \ldots(1.7)$$

After $t=t_3$, the supply from the primary shop is short of the demand for defective units, i.e. $\theta q_1(t)<D_2$ and then to fulfill the demand, stock decreases at the rate $D_2-\theta q_1(t)$ units. After some time, this stock reduces to zero. Thus three scenarios arise depending upon the instants at which the stocks at the primary and the secondary shop are depleted completely. In each scenario, total number of selling units at the secondary shop is equal to the number of defective units that are transferred from the primary shop. But, the available defective units θS obtained out of the differential stock S may be less than, equal to or greater than the actual shortage S_2 in the secondary shop. In these three cases, net revenue NR_2 can be written as follows:

$$NR_2=\begin{cases}M_2C_0\left\{\frac{b_1}{\alpha}Q_1+(1-\theta)S+\frac{a_1\theta t_1}{\alpha}\right\}\left\{\frac{1}{R}\left(1-e^{-R(t_1+t_2)}\right)\right\} & \text{if}\quad \theta S\le S_2\\ M_2C_0\left\{\frac{b_1}{\alpha}Q_1+(1-\theta)S+\frac{a_1\theta t_1}{\alpha}\right\}\left\{\frac{1}{R}\left(1-e^{-R(t_1+t_2)}\right)\right\}+m_2'C_0(\theta S-S_2) & \text{if}\quad \theta S\ge S_2\end{cases} \qquad \ldots(1.8)$$

where, $m_2'\left(0 < m_2' \ll M_2\right)$ is the pre-determined markup price for the excess amount, as the excess amount is sold immediately at a much reduced price and the secondary shop starts from zero inventory at the beginning of the scheduling period.

SCENARIO-1.1

In this scenario, the researcher has considered the situation when shortages at the secondary shop occur earlier than the occurrence of shortages at the primary shop.

According the assumptions, in this case, the amount of stock is zero initially; the defective units are sold in the adjacent secondary shop. Let the stock Q_2 becomes zero at $t = t_3 + t_4$ and after that, shortages are allowed. But there will be some gradual decreasing supply of defective units from the primary shop up to $t = t_1$. So during $(t_3 + t_4, t_1)$ shortages increase at the rate $D_2 - \theta q_1(t)$ and attain shortages level S_2' at $t = t_1$. After $t = t_1$, supply from the primary shop totally stops and shortage increases only due to demand up to $t = t_1 + t_2$ when shortage level is S_2.

The differential equations governing the instantaneous state of inventory $q_2(t)$ are

$$q_2'(t) = \begin{cases} \theta q_1(t) - D_2, & 0 \le t \le t_3 \\ \theta q_1(t) - D_2, & t_3 \le t \le t_3 + t_4 \\ \theta q_1(t) - D_2, & t_3 + t_4 \le t \le t_1 \\ -D_2, & t_1 \le t \le t_1 + t_2 \end{cases}$$

With the boundary conditions

$$q_2(t) = \begin{cases} 0 & \text{at } t = 0 \text{ and } t = t_3 + t_4 \\ -S_2' \text{ and } -S_2, & \text{at } t = t_1 \text{ and } t = t_1 + t_2 \end{cases}$$

The solutions of the above equations are

$$q_2(t) = \begin{cases} -\{\alpha Y + D_2\} t + Y e^{\alpha t_1}\left(1 - e^{-\alpha t}\right), & 0 \le t \le t_3 \\ \{\alpha Y + D_2\}\left(t_3 + t_4 - t\right) - Y e^{\alpha t_1}\left(e^{-\alpha t} - e^{-\alpha(t_3+t_4)}\right), & t_3 \le t \le t_3 + t_4 \\ -\{\alpha Y + D_2\}\left(t - t_3 - t_4\right) - Y e^{\alpha t_1}\left(e^{-\alpha t} - e^{-\alpha(t_3+t_4)}\right), & t_3 + t_4 \le t \le t_1 \\ -S_2 + D_2\left(t_1 + t_2 - t\right), & t_1 \le t \le t_1 + t_2 \end{cases} \qquad \ldots(1.9)$$

Since $q_2(t)$ is continuous at $t = t_3$, one can get an equation related by t_3 and t_4 as follows

$$\{\alpha Y + D_2\}\left(t_3 + t_4\right) - Y e^{\alpha t_1}\left(1 - e^{-\alpha(t_3+t_4)}\right) = 0, \text{ where } Y = a_1\theta/\alpha^2. \qquad \ldots(1.10)$$

Inventory level at $t = t_3$ and the shortage levels at $t = t_1, t_1 + t_2$ are respectively given by

$$Q_2 = -\{\alpha Y + D_2\} t_3 + Y e^{\alpha t_1}\left(1 - e^{-\alpha t_3}\right) = \{\alpha Y + D_2\} t_4 + Y e^{\alpha(t_1 - t_3)}\left(1 - e^{-\alpha t_4}\right) \qquad \ldots(1.11)$$

$$S_2' = \left(\alpha Y + D_2\right) t_1 - Y\left(e^{\alpha t_1} - 1\right) \qquad \ldots(1.12)$$

$$S_2 = \left(\alpha Y + D_2\right) t_1 - Y\left(e^{\alpha t_1} - 1\right) + D_2 t_2 \qquad \ldots(1.13)$$

The available deteriorated units θS obtained out of the differential stock S may be less than, equal to or greater than the actual shortages S in the secondary shop. In these cases, the relations between t_1 and t_2 can be written as follows:

Case-1.1a: When $S_2 = \theta S$, then t_1 and t_2 are related by

$$\alpha Y t_1 + D\left(t_1 + t_2\right) - \theta\left(\frac{Q_1}{\alpha} + S\right) = 0 \qquad \ldots(1.14)$$

Case-1.1b: When $S_2 > \theta S$, then t_1, t_2 and m_2 satisfying the in equation

$$\alpha Y t_1 + D(t_1+t_2) - \theta\left(\frac{Q_1}{\alpha}+S\right) > 0 \qquad \ldots(1.15)$$

Case-1.1c: When $S_2 < \theta S$, then t_1, t_2 and m_2 satisfying the in equation

$$\alpha Y t_1 + D(t_1+t_2) - \theta\left(\frac{Q_1}{\alpha}+S\right) < 0 \qquad \ldots(1.16)$$

Therefore total cost in this scenario is given by

$$TC_2 = \left(\int_0^{t_3}(H_2+\varphi t)q_2(t)e^{-rt}dt + \int_{t_3}^{t_3+t_4}(H_2+\varphi t)q_2(t)e^{-rt}dt\right)$$

$$+G_2\left(\int_{t_3+t_4}^{t_1}\left(-q_2(t)\right)e^{-rt}dt + \int_{t_1}^{t_1+t_2}\left(-q_2(t)\right)e^{-rt}dt\right)+U_2 \qquad \ldots(1.17)$$

In this scenario, we obtain the total cost for the secondary shop as given in the equation (1.17), when shortages at the secondary shop occur earlier than the occurrence of shortages at the primary shop.

SCENARIO-1.2

In the present scenario, the researcher has assumed the situation when shortages at both the shops occur exactly at the same time. Stock is exhausted at $t = t_1$, and then shortages are allowed. As the shortages at both shops occur at the same time, to meet demand of deteriorated units shortages increase at the rate D_2 up to $t = t_1 + t_2$ when shortage level is S_2.

The differential equations governing the instantaneous state of inventory $q_2(t)$ is given by

$$q_2'(t) = \begin{cases} \theta q_1(t) - D_2, & 0 \le t \le t_3 \\ \theta q_1(t) - D_2, & t_3 \le t \le t_1 \\ -D_2, & t_1 \le t \le t_1+t_2 \end{cases}$$

With the boundary conditions

$$q_2(t) = \begin{cases} 0 & \text{at } t=0 \text{ and } t=t_1 \\ Q_2 \text{ and } -S_2, & \text{at } t=t_3 \text{ and } t=t_1+t_2 \text{ respectively} \end{cases}$$

The solutions of the above equations are

$$q_2(t) = \begin{cases} -\{\alpha Y + D_2\}t + Ye^{\alpha t_1}\left(1-e^{-\alpha t}\right), & 0 \le t \le t_3 \\ \{\alpha Y + D_2\}(t_1 - t) + Ye^{\alpha t_1}\left(1-e^{-\alpha t}\right), & t_3 \le t \le t_1 \\ -D_2(t-t_1), & t_1 \le t \le t_1+t_2 \end{cases} \qquad \ldots(1.18)$$

Since $q_2(t)$ is continuous at $t = t_3$, one can get t_1 from the following equation

$$\{\alpha Y + D_2\}t_1 + Y\left(e^{\alpha t_1} - 1\right) = 0 \qquad \ldots(1.19)$$

Inventory level at $t = t_3$ and the shortage level at $t = t_1 + t_2$ are respectively given by

$$Q_2 = -\{\alpha Y + D_2\}t_3 + Ye^{\alpha t_1}\left(1-e^{-\alpha t_3}\right) = \{\alpha Y + D_2\}(t_1 - t_3) + Y\left(1-e^{-\alpha(t_1-t_3)}\right) \qquad \ldots(1.20)$$

$$S_2 = D_2 t_2 \qquad \ldots(1.21)$$

Case-1.2a: When $S_2 = \theta S$, t_2 is obtained from

$$D_2 t_2 - \frac{a_1\theta}{b_1(1-\theta)}\left(1-e^{b_1 t_2}\right) = 0 \qquad \ldots(1.22)$$

Case-1.2b & 1.2c: When $S_2 > \theta S$ or $S_2 < \theta S$ then t_2 and m_2 satisfying the equation:

$$D_2 t_2 - \frac{a_1\theta}{b_1(1-\theta)}\left(1-e^{b_1 t_2}\right) > 0 \quad (\text{or} < 0) \qquad \ldots(1.23)$$

One can get the above results directly from the scenario-1 by putting $t_3 + t_4 = t_1$ and $S_2 = 0$.
Therefore the total cost in this scenario is given by

$$TC_2 = \left(\int_0^{t_3}(H_2+\varphi t)q_2(t)e^{-rt}dt + \int_{t_3}^{t_1}(H_2+\varphi t)q_2(t)e^{-rt}dt\right) + G_2\int_{t_1}^{t_1+t_2}\left(-q_2(t)\right)e^{-rt}dt + U_2 \quad \ldots(1.24)$$

In this scenario, we obtain the total cost for the secondary shop as given in the equation (1.24), when shortages at both the shops occur exactly at the same time.

CONCLUSION

In this study a model has been developed for differential items sold from two shops under the single management. For the primary shop, the demand rate is stock-dependent and for the secondary shop, the demand rate is price-dependent. Holding cost is taken as time dependent and shortages are permitted in inventory with fully backlogging for both shops. Here, three different scenarios are presented for the secondary shop. Retailers purchased the items in a lot from wholesalers and sold the fresh (non-defective) and deteriorated (defective) ones in separate shop. In totality the whole study has been done under the implications of inflation, gives it a viability that makes it more pragmatic and acceptable. The setup that has been chosen boasts of uniqueness in terms of the conditions under which the model has been developed.

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