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A Two-Warehouse Inventory Model with stock-dependent Demand rate and Constant quantity release Rule

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Abstract

In this paper, we've projected a two-warehouse inventory model for deteriorating things beneath the impact of inflation and continuance of cash, wherever demand is stock-dependent. We have consider two different warehouses here Own Warehouse (OW) in which time-varying linear deterioration was thought-about and Rented Warehouse (RW) within which deterioration was considered Weibull distributed. Here, shortages were allowed and partially backlogged. Every time constant (J) number of quantity without damage rule is transferred from the RW to the OW. The target here is to seek out the optimum amount to that ought to be ordered and also the optimum variety of cycles during which the number from RW should be transferred to OW to maximize world wide web profit per unit time. The model has additionally been exemplified with the many numerical examples. The results have additionally been understood diagrammatically.

Keywords: *Two-warehouse system, J-release rule, Stock-dependent demand, Weibull distribution*.

1. Introduction

In any Inventory system Inflation plays an important role: it will increase the value of products. To safeguard from the economic process, throughout the inflation regime, the organization prefers to stay a better inventory, thereby increasing the mixture demand. Further this extra inventory desires additional space for storing that's expedited by a rented warehouse. Ignoring the consequences of your time worth of cash and inflation may yield dishonest results. The warehouse storage capability is outlined because the quantity of space for storing required accommodating the materials to be keep to fulfill a desired service level that specifies the degree of space for storing availableness. Stock things to be delivered precisely once required square measure impractical. Therefore, it's necessary to analyze the influence of warehouse capability in varied inventory policy issues. In recent years, varied researchers have mentioned a two warehouse inventory system. This type of system was first mentioned by Hartely. Hartely conferred a basic two-warehouse model, within which the value of transporting a unit from rented warehouse (RW) to possess warehouse (OW) wasn't thought-about. Sarma developed a settled inventory model with infinite refilling rate and 2 levels of storage. In this model, he extended Hartely's model by introducing the transportation value. Murdeshwar and Sathe [27] extended this model to the case of finite refilling rate. Dave [25] additional mentioned the cases of bulk unleash pattern for each finite and infinite refilling rates. He corrected the errors in Murdeshwar and Sathe [27] and gave a whole answer for the model given by Sarma. Within the on top of cited references, deterioration development wasn't taken under consideration.

The assumption that the products in inventory forever preserve their physical characteristics isn't true normally as a result of their square measure some things that square measure subject to risks of breakage, evaporation, devolution etc. Decay, modification or spoilage that forestalls the things from getting used for its original purpose is typically termed as deterioration. Food items, prescription drugs, photographic material, chemicals and hot substances, to call solely many things square measure amongst those within which considerable deterioration will happen throughout the traditional storage of the units. the primary decide to get best refilling policies for deteriorating things was created by Ghare and Schrader, un agency derived a revised style of the economic order amount (EOQ) model presumptuous decay. Later, presumptuous the deterioration in each warehouses taken as constant, Sarma [26] extended his earlier model to the case of infinite refilling rate with shortages. Pakkala and Achary [23, 24] extended the two-warehouse inventory model for deteriorating things with finite refilling rate and shortages, taking time as distinct and continuous variable, severally. Pakkala and Achary [21] conferred a two level storage inventory model for deteriorating things with bulk unharness rule. In these models mentioned on top of, the demand rate was assumed to be constant. Afterward, the concepts of time-varying demand and stock-dependent demand were thought of by other authors, like Goswami and Chaudhuri [22], Bhunia and Maiti [20], Benkherouf [19], and Kar Bhunia and Maiti [17].

In addition, because of high rate of inflation, the results of inflation and duration of cash area unit very important in sensible setting, particularly within the developing national market. To relax the belief of no inflationary effects on prices, Buzacott [15] and Misra [14] at the same time developed EOQ models with constant demand and one rate of inflation for all associated prices. Due to the factors mentioned on top of, Yang [13] provided a two-warehouse inventory model for one item with constant demand and shortages underneath inflation. rather than the classical read of accumulating shortages at the tip of every replacement cycle, an alternate model within which every cycle begins with shortages has been planned here. Zhou and Yang [12] studied stock-dependent demand while not shortage and deterioration with amount based mostly transportation price. Wee et al. [11] thought of a two-warehouse model with constant demand and weibull distribution deterioration underneath inflation. Yang [10] extended Yang's [12] to include partial backlogging then compared the two-warehouse models supported the minimum price approach. Jaggi et al. [9] conferred the optimum inventory replacement policy for deteriorating things underneath inflationary conditions employing a discounted income (DCF) approach over a finite time horizon. Hsieh et al. [8] developed a settled inventory model for deteriorating things with two warehouses by minimizing cyberspace gift price of the entire price. In this model, they allowed shortages that were fully backlogged. Ghosh and Chakrabarty [7] urged an order-level inventory model with two levels of storage for deteriorating things. The inventory control in RW was transferred to OW in bulk size (K) wherever, K was but the capability of OW until the stock in RW gets exhausted Associate in nursingd there was an associated transportation price. Shortages were allowed and totally backlogged. Jaggi and Verma [6] developed a two-warehouse inventory model with linear trend in demand underneath the inflationary conditions with constant deterioration rate. Singh et al. [5] developed a listing model for deteriorating things with shortages and stock-dependent demand underneath inflation for two-shops underneath one management. Singh et al. [4] conferred a settled two-warehouse inventory model for deteriorating things with sock-dependent demand and shortages. Kumar et al. [3] developed an inventory model with time – dependent demand and limited storage facility under inflation. Kumar et al. [2] presented a two-warehouse inventory model with three – component demand rate in fuzzy environment. Kumar, N., Singh, S.R., Tomar J [1] presented a two-warehouse inventory model with multivariate demand.

In this paper, we have projected a two-warehouse inventory model for deteriorating things underneath the impact of inflation and demand is stock-dependent. In one amongst the warehouse (OW), time-varying linear deterioration was thought-about and within the alternative (RW) weibull distributed deterioration was studied. Here, shortages were allowed and partially backlogged. The stock is transferred from the RW to the OW following a constant quantity rule. The target here is to seek out the optimum amount ought to be ordered and therefore the optimum range of cycles within which the number from RW should be transferred to OW to maximize internet profit per unit time. The model has additionally been exemplified with the many numerical examples within the later a part of this paper.

2. Assumptions and Notations

The mathematical model developed in this paper is based on the following assumptions:

1. The demand rate is deterministic and is a function of on-hand inventory level.
2. Shortages are allowed. Unsatisfied demand is backlogged, and the fraction of shortages backordered is $1/(1 + x)$, where x is the waiting time up to the next replenishment and is a positive constant.
3. Deterioration rate in owned warehouse (OW) is time dependent.
4. Deterioration rate of the item in rented warehouse (RW) follows a two parameter Weibull distribution.
5. There is no replacement or repair of deteriorating items during the period under consideration.
6. The OW has a fixed capacity of W units and the RW has unlimited capacity.
7. The holding costs in RW are higher than those in OW.
8. Inflation and time value of money are considered.
9. The transfer of stocks from RW to W follows a J-release rule.
10. Lead time is zero and the replenishment rate is infinite.

2.1 Notations:

R(t) Demand rate, where $R(t) = a + b\,I(t)$, a and b are positive constants where $a > b$.

W Capacity of OW.

R Amount of goods stored in RW.

S Per unit selling price of the item.
r Constant representing the difference between the discount rate and inflation rate.

P Purchasing cost per unit item.

h_o Holding cost per unit per unit time in OW.

h_r Holding cost per unit per unit time in RW, $h_r > h_o$.

s Shortage cost per unit per unit time.

π Opportunity cost unit per unit time.

A Ordering cost per cycle.

$I_{ow}(t)$ Inventory level at any time t in OW.

$I_{rw}(t)$ Inventory level at any time t in RW.

D(t) Rate of deterioration in OW where $D(t) = \theta t$, is a positive constant where $0 < \ll 1$.

f(t) Two parameter probability density function for the rate of deterioration, $f(t) = \alpha\beta t^{\beta-1}e^{-\alpha\beta t}$ where α is the scale parameter ($\alpha > 0$), β is the shape parameter ($\beta > 0$).

Z(t) Weibull instantaneous rate function for the stocked items in RW, $Z(t) = (f(t) / -e^{\alpha\beta t}) = \alpha\beta t^{\beta-1}$

3. Formulation of the Model

In the development of the model, a company purchases S^1 ($S^1 > W$) units out of which W units are kept in OW and ($S^1 - W$) = R units are kept in RW, is being assumed. Initially, the demands are not using the stocks of RW until the stock level drops to ($W - K$) units at the end of T_1. At this stage, K ($K \leq W$) units are transported from RW to OW. As a result, the stock level of OW again becomes W and the stocks of OW are used to meet further demands.

This process continues until the stock level in RW is fully exhausted. After the last shipment, only W units are used to satisfy the demand during the interval [Tn-1, Tn] and then the shortages occur and completely backlogged during the interval [Tn, T]. The process is shown in the following figures.

$$\frac{dI_0(t)}{dt} = -M(t)I_0(t) - R(t); \qquad T_i \leq t \leq T_{i-1}$$

$$\frac{dI_0(t)}{dt} = -\theta t I_0(t) - \left(a + bI_0(t)\right); \qquad T_i \leq t \leq T_{i-1}$$

$$\frac{dI_0(t)}{dt} = -(\theta t + b)I_0(t) - a; \qquad T_i \leq t \leq T_{i-1} \qquad (1)$$

With boundary conditions $I_0(T_i) = W$.

For $i = n$, $I_0(T_i) = I_0(T_n) = 0$; Here $T_n = T$.

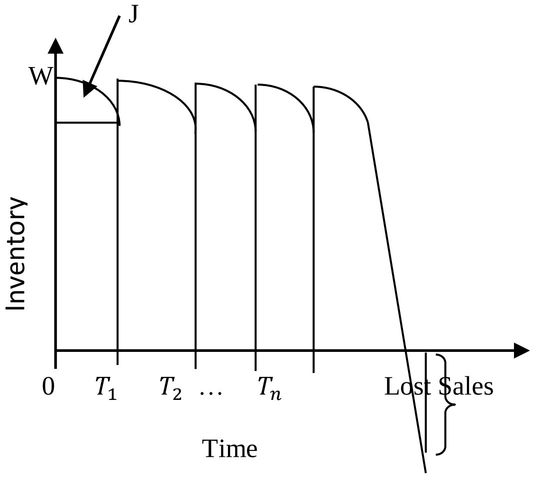

Fig.1 Inventory in Own-Warehouse

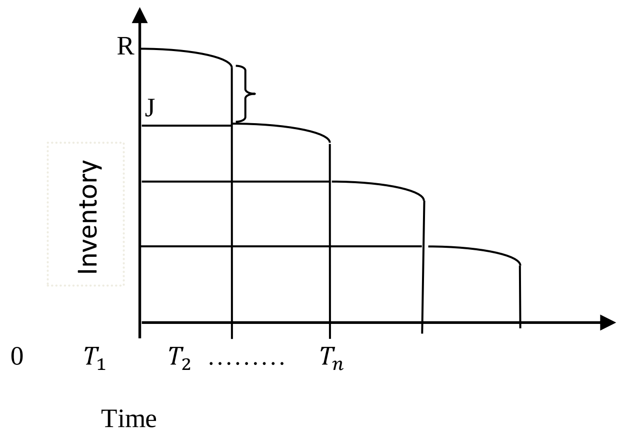

Fig.2 Inventory in Rented-Warehouse

When shortages occur within$(T_n, \bar{T})$; We have the following

$\frac{dI_0(t)}{dt} = \frac{-R(t)}{1+\delta(\bar{T}-t)}$; $T_n = T \leq t \leq \bar{T}$ With boundary condition $I_0(T_n) = 0$.

$$\frac{dI_0(t)}{dt} = \frac{-(a + bI_0(t))}{1 + \delta(\bar{T} - t)} \; ; \qquad T_n = T \le t \le \bar{T} \tag{2}$$

Using boundary condition the solution of (1) is given as follows:

$$\frac{dI_0(t)}{dt} + (\theta t + b)I_0(t) = -a$$

$$\text{I.F.} = e^{\int p(x)dx} = e^{\int(\theta t + b)dx} = e^{\frac{t^2}{2}\theta + bt}$$

$$I_0(t)e^{\frac{t^2}{2}\theta + bt} = \int_{T_i}^{t} (-a)e^{\frac{t^2}{2}\theta + bt}\, dt + c$$

$$= -a\left[\frac{e^{\frac{t^2}{2}\theta + bt}}{b + \theta t}\right]_{T_i}^{t} + c$$

$$= -a\left[\frac{e^{\frac{t^2}{2}\theta + bt}}{b + \theta t} - \frac{e^{\frac{T_i^2}{2}\theta + bT_i}}{b + \theta T_i}\right] + c \tag{3}$$

Let us use the boundary condition $I_0(T_i) = W$, We get

$$c = We^{\frac{T_i^2}{2}\theta + bT_i} \tag{4}$$

Let us put this value in (3) we get

$$I_0(t) = -a\left[\frac{1}{b + \theta t} - \frac{e^{\frac{(T_i^2 - t^2)}{2}\theta + b(T_i - t)}}{b + \theta T_i}\right] + We^{\frac{(T_i^2 - t^2)}{2}\theta + b(T_i - t)} \tag{5}$$

Solving (2) we get

$$\frac{dI_0(t)}{dt} + \frac{bI_0(t)}{1 + \delta(\bar{T} - t)} = \frac{-a}{1 + \delta(\bar{T} - t)}$$

$$I.F. = e^{\int \frac{b\, dt}{1 + \delta(\bar{T} - t)}} = \left(1 + \delta(\bar{T} - t)\right)^{-b/\delta}$$

$$I_0(t)\left(1 + \delta(\bar{T} - t)\right)^{-b/\delta} = \int_{T_n}^{t} \left(1 + \delta(\bar{T} - t)\right)^{-b/\delta}\left(\frac{-a}{1 + \delta(\bar{T} - t)}\right)dt$$

$$I_0(t)\left(1 + \delta(\bar{T} - t)\right)^{-b/\delta} = \frac{-a}{b}\left[\left(1 + \delta(\bar{T} - t)\right)^{-b/\delta} - \left(1 + \delta(\bar{T} - T_n)\right)^{-b/\delta}\right]$$

$$I_0(t) = \frac{-a}{b}\left[1 - \left(\frac{\left(1 + \delta(\bar{T} - T_n)\right)}{\left(1 + \delta(\bar{T} - t)\right)}\right)^{-b/\delta}\right] \tag{6}$$

The RW (Rented Warehouse) system can be represented by

$$\frac{dI_r(t)}{dt} = -Z(t)I_r(t)\,; \qquad T_i \le t \le T_{i+1} \tag{7}$$

With boundary conditions $I_r(0) = R$

$I_r(T_{i+1}) = I_r(T_i) - J$ for i = 1, 2, 3….n-2

Solving (7) using boundary conditions we get

$$\frac{dI_r(t)}{dt} = -\alpha\beta t^{\beta-1} I_r(t)$$

Integrating both sides we get

$$\ln I_r(t) = -\,\alpha t^{\beta} + c$$

Let us put t = 0 we get

$$\ln I_r(0) = c \Rightarrow c = \ln R$$

$$\ln I_r(t) = -\,\alpha t^{\beta} + \ln R \Rightarrow I_r(t) = Re^{-\alpha t^{\beta}}\,; 0 \le t \le T_1 \tag{8}$$

$$I_r(t) = Re^{-\alpha t^{\beta}} = (I_r(T_1) - J)e^{-\alpha((T_2)^{\beta}-(t)^{\beta})}\,;\ T_1 \le t \le T_2$$

$$I_r(t) = (I_r(T_2) - J)e^{-\alpha((T_3)^{\beta}-(t)^{\beta})}\,;\ T_2 \le t \le T_3$$

In general

$$I_r(t) = (I_r(T_i) - J)e^{-\alpha((T_{i+1})^{\beta}-(t)^{\beta})}\,;\ T_2 \le t \le T_3 \quad \text{i = 1, 2, 3….n-2.} \tag{9}$$

Holding Costs

(i) In OW

Inventory is available during $T_i \le t \le T_{i+1}$; i $= 0, 1, 2, 3 \ldots.$ n $-$ 1. Hence the holding cost needs to be computed during these time period

$$H_{ow} = \sum_{i=0}^{n-1} h_o\, e^{-r\,T_i} \int_{T_i}^{T_{i+1}} I_0(t)e^{-rt}\,dt \tag{10}$$

(ii) In RW

Inventory is available during $T_i \le t \le T_{i+1}$; i $= 0, 1, 2, 3 \ldots.$ n $-$ 2. Hence the holding cost needs to be computed during these time period

$$H_{Rw} = \sum_{i=0}^{n-2} h_r\, e^{-r\,T_i} \int_{T_i}^{T_{i+1}} I_r(t)e^{-rt}\,dt \tag{11}$$

Shortage Cost

Shortages occurs during the period $T_n \le t \le \bar{T}$. Hence the shortage cost is:

$$SC = se^{-r\,T_n} \int_{T_n}^{\bar{T}} \big(-I_0(t)\big)e^{-rt}\,dt \tag{12}$$

Opportunity Cost

Opportunity cost due to lost sales occurs during the period $T_n \le t \le \bar{T}$.

$$OC = \pi e^{-r\,T_n} \int_{T_n}^{\bar{T}} \left(1 - \frac{1}{1+\delta(\bar{T}-t)}\right) R(t) e^{-rt}\, dt \tag{13}$$

Sales Revenue

Since the inventory is available for sale during $T_i \le t \le T_{i+1}$; $\mathrm{i} = 0, 1, 2, 3 \ldots.\mathrm{n}-1$ revenue can be gain in this time only revenue gained during this time can be obtained by the following expression;

$$Sales\ Revenue = \sum_{i=1}^{n-1} Se^{-r\,T_i} \int_{T_i}^{T_{i+1}} D(t) e^{-rt}\, dt \tag{14}$$

Transportation cost

This cost incurred during Inventory transferred from the RW to OW at T_i, i= 0, 1, 2,..., n-1, therefore we have

$$TC = T_c \sum_{i=1}^{n-1} e^{-r\,T_i} \tag{15}$$

Total profit

The present worth net profit is found by deduction of all the costs from the sales profit. Using the equations from (9) to (16),

$$P = Sales\ Revenue - A - S \cdot P - H_{ow} - H_{Rw} - SC - TC - OC$$

$$= \sum_{i=1}^{n-1} Se^{-r\,T_i} \int_{T_i}^{T_{i+1}} D(t)e^{-rt}\, dt - A - S \cdot P - \sum_{i=0}^{n-1} h_o\, e^{-r\,T_i} \int_{T_i}^{T_{i+1}} I_0(t) e^{-rt}\, dt - \sum_{i=0}^{n-2} h_r\, e^{-r\,T_i} \int_{T_i}^{T_{i+1}} I_r(t) e^{-rt}\, dt$$
$$- se^{-r\,T_n} \int_{T_n}^{\bar{T}} \big(-I_0(t)\big) e^{-rt}\, dt - T_c \sum_{i=1}^{n-1} e^{-r\,T_i}$$
$$- \pi e^{-r\,T_n} \int_{T_n}^{\bar{T}} \left(1 - \frac{1}{1+\delta(\bar{T}-t)}\right) R(t) e^{-rt}\, dt \tag{16}$$

Our main objective here is to find that quantity, which should be stored in the RW, and the number of times the inventory should be transferred from the RW to the OW so that the net profit may be maximized. This is being discussed in the following numerical examples, taking different parameters.

4. Numerical Example

For an inventory system, the following data for solving the equations of the model was taken into consideration:

$a = 100, b = 2, \alpha = 0.005, \beta = 1, W = \text{Capacity of OW} = 200, \theta = 0.01, s = 1, P = 2,$
$H = 1, F = 1, T_c = 50\ r = 0.05, S = \text{Selling price} = 10, A = 50.$

With these values the solutions of the system for integral values of n i.e. 1, 2 ...5 were found as follows:

Time values for different number of cycles							Optimal values for different number of cycles					
n	T1	T2	T3	T4	T5	T6	R^*	Cost*	Revenue	Shortage Cost	Net Profit	NP/T
1	1	1.5	–	–	–	–	300	6456.248	4012	875.356	5998.356	1157.369
2	1	1.5	2	–	–	–	700	9621.578	14054	1724.576	4578.545	879.356
3	1	1.5	2	2.5	–	–	1100	12784.924	18241	2046.754	3856.548	578.456
4	1	1.5	2	2.5	3	-	1500	15246.248	21652	2435.654	2957.345	345.645
5	1	1.5	2	2.5	3	3.5	1900	18974.546	22989	2756.548	1987.364	145.567

* R is taken randomly depends on cycle.
* Cost = Ordering cost + Present item cost + Holding cost + Opportunity cost + Trans. Cos.

It was observed that as the number of cycles increased, the net profit decreased, but the net profit per unit time was found to be maximum for n =1. Consecutively, it was observed that the net profit as well as the net profit per unit time was found to decrease for the increasing number of cycles.

5. Conclusion

In this study, we have considered two warehouses, shortages allowed. Holding cost and deterioration costs are different in OW and RW due to different preservation environments. The inventory costs (including holding cost and deterioration cost) in RW were assumed to be higher than those in OW. To reduce the inventory costs, it would be economical for firms to store goods in OW before RW, and clear the stocks in RW before OW. The stock is transferred from the RW to the OW following a bulk release rule. Most of the researchers till now have ignored the effects of deterioration in both the warehouses or had considered a constant rate of deterioration. But in the present study deterioration taken as linear time dependent in OW and weibull distribution type deterioration rate in RW. The model is solved for different system parameters for up to five cycles and the optimal solution is selected from amongst the available solutions. The outcome showed that the net profit per unit time was found to be maximum for the first cycle. Consecutively, it is observed that the net profit as well as the net profit per unit time was found to decrease for increasing number of cycles

The present model is applicable for food grains like paddy, rice, wheat, etc., as the demand of the food grains increases with time for a fixed time horizon, i.e., for a calendar year. It is also applicable for other items where the demand is dependent linearly with time. For future research one can take variable ordering cost.

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