South East Asian J. of Mathematics and Mathematical Sciences
Vol. 19, No. 3 (2023), pp. 459-466

DOI: 10.56827/SEAJMMS.2023.1903.35 **ISSN (Online): 2582-0850**

ISSN (Print): 0972-7752

COST INVENTORY MODEL CONSIDERING THE INTRODUCTION OF NEW PRODUCTS IN THE MARKET

Neha Soni, Sushma Duraphe and Geeta Modi

Department of Mathematics,
Govt. Motilal Vigyan Mahavidyalaya,
Bhopal - 462008, Madhya Pradesh, INDIA

E-mail : sonineina@gmail.com, duraphesu565@radiffmail.com,
modi.geeta@gmail.com

(**Received:** *Jun. 26, 2023* **Accepted:** *Dec. 23, 2023* **Published:** *Dec. 30, 2023)*

Abstract: In this paper, an inventory models has been developed for introducing a new product in the market involving different costs. The demand is assumed as exponentially increasing and production is demand dependent. This proposed model a constant amount was invested for the advertisement to increase demand for new products. A mathematical model is developed by using differential equations. The objective of this model is to find the total cost and to minimize the total cost. The model is illustrated by numerical examples and sensitivity analysis of optimal solution with respect to parameters.

Keywords and Phrases: Inventory model, deterioration, advertisement, Total Cost (TC), Economic order quantity (EOQ).

2020 Mathematics Subject Classification: 90B05.

1. Introduction

Inventory plays a very important role for any business organization. Inventory management refers to the process of ordering, storing, using, and selling a company's inventory. Its involves so many costs such as ordering, holding, production costs, etc. In previous research various models were investigated for minimizing inventory costs and maximizing the profit. Such as Economic Order Quantity model, deterioration based model, model with demand is a function of time, so on, but in these models everyone has focused on different costs. Several researchers developed inventory model in which demand depends on the stock level but no one talks about marketing strategy and not included the costs of advertisement in their model. The advertisement is the most effective way to find out the quality and requirements of any product. Often people do not know what they want then advertisement plays a very important role to fulfill their requirements. So advertisement cost is directly connected to overall inventory cost. It is also concluded that if we introduce our new product into the market then its demand depends on the advertisement. So we add advertisement cost in our model. After that in any business transaction, controlling and maintaining the inventories of deteriorating items is a major issue. Goods are deteriorating because the values of the goods go down with time. So deterioration cost is also added to all costs. In this model, all types of costs were taken together such as production cost, holding cost, deterioration cost, production setup cost, shortage cost, and advertisement cost. The aim of our model is to minimize total cost. In this model, we plan some strategies to minimize inventory costs.

1. Using the EOQ model to minimize both set-up cost and holding cost.
2. Maintain the quality of our product.
3. Focus on marketing strategy to sell the product before deterioration.
4. Using innovative ways of display of products to attract more customers.

Background of research

The literature works related to this work were also studies and some are discussed here: Tripathi et al. (2017) established inventory model with exponential time-dependent demand and time- dependent time-dependent deterioration. Hill (1995) considers a product subject to a period of increasing demand, according to a general power law, followed by a period of level demand. Tang et al. (2013) extended the constant demand to a linear non-decreasing demand function of time and incorporate a permissible delay in payment under two levels of trade credit into their model. Riza et al. (2018) developed the implementation of EOQ model for reducing inventory cost. Shah and Pandey (2009) designed a deteriorating inventory model in which demand depends on advertisement and stock display. Chowdhury et al. (2015) observed that when large quantities seen in the market then people are attracted to buy more goods. This behavior of the customer suggests that demand varies in proportion to the stock level. Shukla and yadav (2013) designed EOQ inventory model for deteriorating items with exponential time dependent demand rate. Verma and Verma (2014) developed inventory model with exponentially decreasing demand and linearly increasing deterioration. Sekar and Uthayakumar (2017) reported four stages of the production inventory model for deteriorating goods in which three (Beginning, growth and maturity) different stages of production and a decline phase are considered and take exponentially increasing demand. Khedlekar et al. (2017) studied both the deteriorating seasonal product preservation technology investment and pricing strategies. Tripathi (2013) designed inventory model with different demand rate and different holding cost. Tripathi & Aneja (2017) studied inventory model for stock dependent demand and time varying holding cost under different trade credits. Rani (2020) designed an integrated EPQ inventory model for delayed deteriorating items with time and price dependent demand with inflation under discount policy.

2. Notations

$I(t)$ = Inventory level with respect to time t,
D = Demand,
θ = Deterioration rate,
C_p = Production cost per unit time,
C_o = Ordering cost,
C_h = Holding cost per unit time,
C_d = Deterioration cost,
C_a = Advertisement cost,
TC = Total cost.

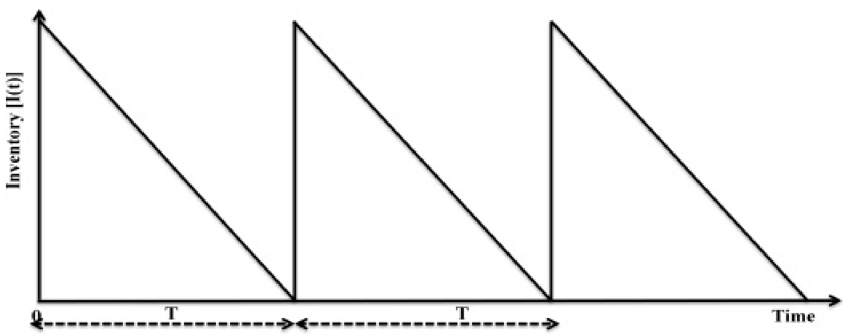

Figure 2.1: Graphical representation of inventory

3. Assumption

In this model, the demand for the product is assumed to increase exponentially as given by the function ae^{bt}, where a & b are scale parameter $a > 0$, $0 < b < 1$. Production is always greater than or equal to the demand rate. The order quantity to replenish inventory arrives all at once when the inventory level drops to zero. Lead time is zero. Shortages are not allowed, deterioration rate is constant. We consider the constant cost of advertisement in this model.

4. Mathematical model

The rate of change of inventory level due to demand & deterioration rate during a positive stock period $[0, T]$ is given by following differential equations

$$\frac{dI(t)}{dt} + \theta I(t) = D(t), \qquad 0 < t < T, \tag{1}$$

Considering $D(t) = ae^{bt}$.
Where $I(t)$ is the Inventory level at the start of period $t = 0$.
The solution of a given differential equation is with a condition $I(T) = 0$.

$$I(t) = \frac{a}{\theta + b}\left[e^{(\theta+b)T-\theta t} - e^{bt}\right]. \tag{2}$$

Total cost (TC)

The total cost comprises the sum of the production cost, ordering cost, holding cost, deteriorating cost, and advertisement cost. They are grouped after evaluating the above cost individually.

4.1.1 Production cost

Production cost includes, labor, raw materials, consumable manufacturing supplies, general overhead, etc. The items are produced during the periods $(0, T)$. Hence, the production cost during the above periods is calculated by:

$$PC = c_p \int_0^T D(t), \tag{3}$$

where c_p = production cost per unit time

$$= c_p \int_0^T ae^{bt} dt,$$

$$= c_p \frac{a}{b}\left[e^{bT} - 1\right]. \tag{4}$$

4.1.2 Production setup cost/ordering cost

At the start of the production process, the supplier has to get the equipment ready. The production setup cost occurs when $t = 0$ in the interval $(0, T)$. Therefore, the production setup cost is given by:

$$SC = c_0, \tag{5}$$

4.1.3 Holding cost

Since it is necessary to keep the items in stock before selling so holding cost is:

$$HC = c_h \int_0^T I(t)dt, \tag{6}$$

Where c_h= holding cost per unit time

$$= C_h \frac{a}{\theta + b}\left[\frac{e^{bT}(e^{\theta T} - 1)}{\theta} - \frac{(e^{bT} - 1)}{b}\right], \tag{7}$$

4.1.4 Deterioration cost

Deterioration means decay, evaporation, obsolescence, and loss of quality of a commodity. When the items are stored in an inventory to meet the customer's demand, it deteriorated in this period but we introduce a new product so we take deterioration constant. Then

$$DC = \theta c_d, \tag{8}$$

where, θ = deterioration rate.

4.1.5 Advertisement cost

In this model, we produce a new product in the market. So advertisement plays a very important role to increase demand for the product. So we take a constant amount of advertisements in the model.

$$AC = c_a, \tag{9}$$

Total cost (TC)

The total cost function for the proposed inventory model is defined as follows: TC = Production cost + Holding cost + Deterioration cost + Production Setup cost + Advertisement cost.

$$TC = PC + SC + HC + DC + AC,$$

$$TC = c_p \frac{a}{b}\left[e^{bT} - 1\right] + c_0 + c_h \frac{a}{\theta + b}\left[\frac{e^{bT}(e^{\theta T} - 1)}{\theta} - \frac{(e^{bT} - 1)}{b}\right] + \theta c_d + c_a. \tag{10}$$

Total cost per unit time

$$TC = \frac{1}{T}\left\{c_p \frac{a}{b}\left[e^{bT} - 1\right] + c_0 + c_h \frac{a}{\theta + b}\left[\frac{e^{bT}(e^{\theta T} - 1)}{\theta} - \frac{(e^{bT} - 1)}{b}\right] + \theta c_d + c_a\right\}. \tag{11}$$

The Taylor's series is used for finding optimal solution in exponential terms. In this series third and higher powers are neglected.

The objective is to determine **optimum value of T** so that **TC** is minimum, we differentiate partially Eq. (11) with respect to T and equate to zero

$$\frac{\partial(TC)}{\partial T} = 0 \tag{12}$$

The solution of equation (12) satisfy the condition

$$\frac{\partial^2(TC)}{\partial T^2} > 0, \quad \text{for all} \;\; T > 0.$$

So the total cost is minimum.

Numerical example

For the numerical illustration of the developed model, the values of various parameters in proper units can be taken as follows:

$$C_p = 5,\; C_o = 80,\; C_a = 40,\; C_d = 1.2,\; C_h = 1.0,\; a = 12,\; b = 0.2,\; \theta = 0.1$$

Solving Equation (12) with the above parameters, we obtain $T^* = 3.163$. On substitution of the optimal value T^* in Equation (11), we obtain the minimum total cost per unit time $TC^* = 274.82$.

Sensitivity analysis

We now study the effect of changes in the value of the system parameters a, b, c_h and c_o. The sensitivity analysis is performed by changing one parameter at a time and keeping the remaining parameters unchanged. The result shows that the parameters c_h and a are highly sensitive with the total average inventory cost and parameters b and c_o are slightly sensitive with the total average inventory cost.

Table 1. sensitivity with various parameter v/s total inventory cost

a	TC	b	TC	c_h	TC	c_o	TC
12	274.82	0.2	274.82	1.0	274.82	80	274.82
14	292.25	0.3	255.41	2.0	413.72	100	281.14
16	328.79	0.4	238.91	3.0	552.62	120	287.47
18	364.98	0.5	224.44	4.0	691.52	140	293.79

5. Conclusion

In this article, we design an inventory model for introducing a new product in the market by considering all the costs that involve to produced the product and selling the product in the market. We assumed that the demand is an increasing function and the rate of deterioration is constant. The proposed model is suitable for those essential items their demand never we declined. By solving mathematical model we minimize the total inventory cost. The model has been verified by the numerical example along with sensitivity analysis. For the future study, the proposed model extend by taking demand exponentially declining function of time, demand is depends on advertisement and stock display and also can take variable deterioration rate with respect to time.

Acknowledgements

The authors are very thankful to referees for their comments and valuable suggestions that improved the quality of the article.

References

[1] Chowdhury, R. R., Ghosh, S. K., & Chaudhuri, K. S., An inventory model for deteriorating items with stock and price sensitive demand, International Journal of Applied and Computational Mathematics, 1 (2015), 187-201.

[2] Hill, R. M., Inventory models for increasing demand followed by level demand, Journal of the Operational Research Society, 46(10) (1995), 1250-1259.

[3] Khedlekar, U. K., Namdeo, A., & Chandel, R. P. S., Pricing strategy with exponential declining demand using preservation cost, Int. J. Oper. Res, 14(1) (2017), 1-10.

[4] Rani, M., An Integrated EPQ inventory model for delayed deteriorating items with time and price dependent demand with inflation under discount policy, Int J Innov Sci Res Technol, 5(5) (2020), 1115-1119.

[5] Riza, M., Purba, H. H., & Mukhlisin, The implementation of economic order quantity for reducing inventory cost, Research in Logistics & Production, 8(3) (2018), 207-216.

[6] Shah, N. H., & Pandey, P., Deteriorating inventory model when demand depends on advertisement and stock display, International Journal of Operations Research, 6(2) (2009), 33-44.

[7] Shukla, H., Shukla, V., & Yadava, S., EOQ model for deteriorating items with exponential demand rate and shortages, Uncertain Supply Chain Management, 1(2) (2013), 67-76.

[8] Sekar, T., & Uthayakumar, R., A manufacturing inventory model for exponentially increasing demand with preservation technology and shortage, Int. J. Oper. Res, 15(2) (2018), 61-70.

[9] Teng, J. T., Yang, H. L., & Chern, M. S., An inventory model for increasing demand under two levels of trade credit linked to order quantity, Applied Mathematical Modelling, 37(14-15) (2013), 7624-7632.

[10] Tripathi, R., Inventory model with different demand rate and different holding cost, International Journal of Industrial Engineering Computations, 4(3) (2013), 437-446.

[11] Tripathi, R. P., & Aneja, S., Inventory models for stock-dependent demand and time varying holding cost under different trade credits, Yugoslav Journal of Operations Research, 28(1) (2017).

[12] Tripathi, R. P., Pareek, S., & Kaur, M., Inventory model with exponential time-dependent demand rate, variable deterioration, shortages and production cost, International journal of applied and computational mathematics, 3 (2017), 1407-1419.

[13] Verma, V. K., & Verma, B. B., An Inventory Model with Exponentially Decreasing Demand and Linearly Increasing Deterioration, International Journal of Physical, Chemical and Mathematical Sciences, 3(1) (2014).