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PRESERVATION-BASED INVENTORY MODEL WITH THE EFFECT OF LEARNING UNDER THE CONDITIONS OF CARBON EMISSIONS

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ABSTRACT

The present chapter developed a preservation-based inventory model under the condition of carbon emissions and the effect of learning on perishable goods. Carbon emissions exit from many sources and affect the greening level of the environment. It is considered that carbon emissions exit due to electricity and also for many more reasons. Finally, total inventory cost will be minimized concerning the cycle length. For the validation of this model, a numerical example has been given and briefly justified with the help of sensitivity analysis. The effect of inventory parameters has shown separately in the sensitivity section.

1. INTRODUCTION

Huang and Chung (2003) enhanced Goyal's (1985) inventory formulation with the modeling of total cost reduction under the assistance of financing policy along with payment rebate scheme. An arithmetic model was investigated for optimum cost and batch size which presume that buying quantity and selling price are dissimilar below credit financing policy when demand is taken to be a function of the selling price. An inventory model for defective items with deterministic nature was formulated by Huang (2003) under the algebraic approach.

Huang (2007) recommended efficiently progressing the EOQ model and specified new suggestions on how to observe the optimal lot size for the retailer. Teng et al. (2006) arranged a two-level credit financing inventory model in which the total order is optimized below the permissible delay in amount. Teng and Goyal (2007) introduced a stock model for the buyers when the buyer used the credit policy provided by the seller in the industrial sector.

Huang and Hsu (2008) expanded the credit financing scheme with the modification of a partial credit scheme. Jaggi et al. (2008) introduced an EOQ formulation for the two-level credit policy with credit-dependent demand. Huang's (2007) research tasks have been

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improved by Teng and Chang (2009) with a two-level credit financing scheme which is helpful for the consumers. Shah et al. (2010) has provided a model with an integrated approach under the trade credit scheme for deteriorating goods. The factors affected the cost of airplanes examined by Wright (1936). The learning effect on seller's ordering policy for defective items with financing policy was suggested by Jayaswal (2019). The total manufacturing of profit-making models for defective quality items is subjected to the effect of learning described by Jaber et al. (2008). In the field of business, there is some problems between seller and buyer regarding optimal profit as well total cost from the both side and such type of problems have been tried to short out by Adad and Jaggi (2003) with the help of mathematical model in which shown effects of credit financing policy. Shinn et al. (2003) calculated the maximum price for the seller as well as lot size using the policy of credit financing. The total cost acts as major role in the inventory system. An inventory model has been presented by Hung and Chung (2003) which is the extended form of Goyal (1985) and has been given how to minimize the total cost under credit financing and payment rebate policy. A mathematical model has been developed for best costing and batch sizing in which assuming that purchase quantity and selling price both are different under credit financing policy when demand is a function of selling price. The EOQ model has been developed to easy manner as per suggested by Hung (2007) and given new idea how to find out the optimal lot size for the seller. Luo (2007) has been proposed an inventory model for the good coordination between seller and buyer under the credit financing policy. A stock model has been formulated for the optimal economic order quantity as guided by Sarmah et al. (2007) and in this model, a seller has connected to the many buyers under the credit financing to got more profit through coordinated strategy. In recent times, authors improved stock representation with the two-level credit policy. An inventory mathematical representation has been improved by Hung (2003) using the two-level credit policy and demand is stimulated as per consideration. The research work of Goyal et al. (1985) has been generalized by Ouyang (2005) with the help of credit financing policy and payment rebate. A two-level credit financing inventory model has been prepared by Teng et al. (2006) and in this model optimized the order quantity under the permissible delay in payment. In the quality of items damages as time passes due to presence of deterioration which cannot ignore when the items is deteriorating items. Most of items like electronic items, mobiles phones, and chemicals, etc. lose their quality due to presence of deterioration over time. Depreciation is one of type of deterioration. The impact of decaying items on fashion the items was proposed by Whitin (1957). Ghare et al. (1963) developed EOQ model where deterioration rate is constant. Demand rate is the most essential factors in the classical inventory model for mathematical model. Actually, demand rate changes with time in different situation. A lot of companies have more competition to arrange good quality items to their clients and meet good feedback in the modern market. The good quality means high reliability. Some renowned author derived a model for inventory where demand rate is a function of time. Wu (2001) developed a mathematical model for decaying items where deteriorating rate follows Weibull distribution and the pattern of demand rate is ramp type. After that a lot of inventory model with learning effect with different approach have been presented. In this flow like. Wight (1936) gave the concept of learning and presented the mathematical model in which the aero plane cost is affected by learning effect, Jayaswal et al. (2019) proposed an EOQ model with credit financing under learning effects for defective items. Jayaswal et al. (2020) presented a model with credit financing and learning effects under inspection process for decaying defective quality item

The research work of Huang (2003) has been investigated by Huang (2006) and improved this model by using two-level credit financing and restricted storage space. A sock model has been presented by Teng and Goyal for the customers when customer used to credit policy provided by buyer during the business. The construction of economic order quantity has been balanced by Huang (2007) which is the extended form of Haung (2003) with the help of two-level credit financing policy. An inventory model has improved for organization by Su et al. (2007) with the help of credit financing policy.

A two-level credit financing model has developed by Huang and Hsu (2008) with the help of partial credit policy. An economic order quantity formulation has been presented by Jaggi et al. (2008) under two-level credit policy with credit dependent demand. Research task of the Huang (2007) have modified by Teng and Chang (2009) with the policy of two-level credit financing system which is the benefit for the customers. A model has been developed by Chen and Kang (2009-a) for business system under two-level credit policy with price dependent demand and conciliation situation. A lot of review article has been provided by Shah et at. (2010) for the inventory system under two-level credit financing policy. A mathematical model with the effect of credit financing and inflation on EOQ has been developed by Tiwari et al. (2016) for decaying items under two-warehouse concept. In the similar way, a mathematical model for defective and decaying items has been developed by Tiwari, Wee as well as Sarkar (2017) under the two-level credit financing and demand is a function of time. In recently, an inventory model for decaying items with expiration dates has been proposed by Tiwari et al. (2018) with the help of partial backlogging concept and two-level credit financing policy under supply chain process. Relative increment in the levels of carbon emissions are majorly developed because of the modes of transport by which they are commuted. In order to maintain the standard emission norms, the index of carbon emissions are need to be checked by the organization to sustain their due quality standards and thus promote their brand value. Considering this, a case study was brought up by renowned author with a reference from cement industry to estimate the levels of carbon emissions in the year 2020. Following this, some researchers proposed a model with hybrid methodology to run industries with low levels of carbon emissions, additionally provided choices on how to deal with climatic variations as well as global warming and overheating. Further, most of the authors focused on the vulnerability behind choosing the transportation routes so that low levels of carbon emissions can be derived in reduced time for congested as well as non - congested routes which are presently in use. Later, many studies were established by researchers which provided models with transportation cost that involved carbon emission costs within themselves. Another research was done by research studied considering mainly on the ways to reduce the number of freights. Most of the researchers provided with a three-tier system concerning types of transportation and carbon emission costs. Later, continuing in the same year, a lot of observations of authors worked specifically on carbon cap along with trade protocols, and readers also gave the similar model but the demand was dependent on sustainability and price of the product. Then authors studied a joint problem with respect to inventory and location, and researchers also gave joint model with respect to manufacturer and supplier. In recent years, many studies concerning the same has been cited. A major works and some authors created models which were integrated considering the carbon emissions. The emissions coming from China shale gas were observed by most of them authors. Since sustainable drive is the prime need of the environment, considering this another study was put forth by researchers are involving a sustainable price sensitive demand-based model to reduce the effect of carbon emissions. Some renowned authors Inspected the national carbon inventory of India. Moreover, authors described the acquisition of carbon emissions grant involving the impacts of training on the production techniques. Lately, some researchers gave a better approach by assuring the shipment delivery vehicle will only be used while returning the defectives. The proposed study reviews on notions of managing the defective items using the best-known approaches, which in turn attempts to create a cleaner, greener and sustainable surrounding. There are numerous industries that are making efforts to significantly make the best use of all defectives as well as used items. This not only interests the retailers but instead benefit the overall supply chain. For instance, since 2013, H&M (Hennes and Mauritz) have been offering clothes which are made by the process of recycling. They insist on to their customers to return their used clothes no matter what their fabric is or what their condition is. They take all your clothes worn or torn and then give you a voucher for one bag of used old clothes, which provides 15% off on the next purchase. They further quote, “Don’t let Fashion go to Waste.” Since H&M is a worldwide popular brand in the fast fashion world, it is known to sell almost 150 million tons of clothes and footwear. But eventually, once the customer uses their products, they are either dumped on landfills or are burnt off. Neither of which intend to promote sustainable drive. In the view of this H&M has made a commitment that by the year 2030, all their clothes will be produced using the sustainable techniques. And, this sustainable technique involves garment recycling process. The big question is, what do they do when these old clothes are dropped off by their customers? Once the used clothes reach them, they are then differentiated into three categories, namely, rewear which are again sold to be worn again in some secondary market, reuse which are turned into new type clothes, and lastly, recycle which are turned into fabrics. According the statistical data available for now, more than 32,000 tons of clothes have already been turned into new clothes. Or, practically if compared, 32,000 tons of clothes are equivalent to 100 million t-shirts. These minimal efforts by such large firms have a great impact on the society. There are many other big brands that offers such policies like Primark, Zara, Eileen Fisher etc. Large scale collaborations can be found very effective in long term which majorly prospects the need for sustainable drive. An inventory model has been presented by Hung and Chung (2003) which is the extended form of Goyal (1985) which explained how to minimize the total cost under credit financing and payment rebate policy. A mathematical model has been developed for best costing and batch sizing in which assuming that purchase quantity and selling price both are different under credit financing policy when demand is a function of selling price. The EOQ model has been developed to easy manner as per suggested by Hung (2007) and given new idea how to find out the optimal lot size for the seller. Luo (2007) has been proposed an inventory model for the good coordination between seller and buyer under the credit financing policy. The research work of Goyal et al. (1985) has been generalized by Su et al. (2007) with the help of credit financing policy and payment rebate. A two-level credit financing inventory model has been prepared by Teng et al. (2006) and in this model the order quantity optimized under the permissible delay in payment. The research work of Huang (2003) has been investigated by Huang (2006) and improved this model by using two-level credit financing and restricted storage space. 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(2010) for the inventory system under two-level credit financing policy. Wright (1936) analyzed that factor affecting the cost of airplane. Jayaswal et al. (2019) has proposed the effects of learning on retailer ordering policy for imperfect quality items with trade credit financing. Jaber et al. (2008) has explained economic production quantity model for items with imperfect quality subjected to learning effects. . As we know, the perishable items deteriorate in short period and as soon as damage due to deterioration rate and deterioration can be ignored. Deterioration of perishable can try to control with the help of preservation environment but extra charge bears to the seller or buyer. The preservation cost added in model this for more profit for buyer. Learning effect minimizes the holding cost and ordering cost because the holding cost and ordering cost are follow the effect of the learning. In particular business transactions, the supplier usually provides an admissible delay in settlement to its vendor to encourage further sales. Additionally, the demand for the commodity is inversely proportional to the function of the sales price, which is non-linear and, in some situations, a holding cost rises over time. Moreover, many goods often deteriorate consistently and shall not be sold after their expiration dates. This study analyses a model for perishable products with a maximum life span with price-dependent demand and trade credit by assimilating these variations and under the supposition of time-varying holding cost. Furthermore, to diminish the rate of deterioration, investment for preservation technology is often taken into account beforehand. Based on real-life circumstances, shortages are admitted and backlogged partially, with an exponential rise in wait time before the new good emerges. The key ambition is to calculate the optimum investment under preservation, sales price, and cycle time using the classical optimization algorithm to maximize the vendor's net profit. Additionally, to clarify the outcomes, the numerical illustrations are addressed, and the sensitivity analysis of significant parameters is eventually implemented. Jayaswal et al. (2021) described an inventory model for items of deteriorating nature under preservation technology. An optimum order quantity model for an imperfect quality item with deterioration under credit scheme and learning considerations was established by Jayaswal et al. (2021). An EOQ model under the conditions of carbon emissions, Inflation and learning for deteriorating imperfect quality items described by Alamri et al. (2022) and Ahmad et al. (2023).

2. ASSUMPTIONS AND NOTATION

2.1 Assumptions

- The replacement continuation is permitted.
- The inclusion of shortages is not considered.
- The time horizon plane is measured as finite.
- The storage and ordering costs are affected by learning.
- The constant demand rate is assumed.
- Lots have a deterioration rate which is taken as a constant.
- Lead time is taken as negligible.
- Carbon tax policy is allowed.
- Preservation scheme is allowed.

2.2 Assumptions

D	Rate of demand
ξ	The cost of preservation
A	Set up cost for inventory
P	Item cost for selling
θ	The cost of deterioration
C	The cost for purchasing items affected by learning
h	The cost for holding items affected by learning
C_1 and C_2	Fixed ordering cost
h_1 and h_2	Fixed holding cost
β	Learning rate
n	Number of shipment
Q	Lot size
T	Cycle time
c_1	Constant carbon emission per carrying cost
γ	Greening cost-sensitive parameter, $\gamma > 0$;
V_1	Changeable carbon emission per carrying cost
$I(t)$	The inventory stock at$0 \le t \le T$
$\pi(t)$	Total average cost for buyer

3. MATHEMATICAL FORMULATION

In the initial, when $t = 0$, the inventory level is Q. Let $I(t)$ be the level of inventory in the time interval $[0, T]$and it reduces due to the deterioration and demand both. After that, the total inventory is finished when $t = T$.

Mathematically, the inventory level and time relationship are given in the form of a differential equation with boundary conditions given below:

$$\frac{dI(t)}{dt} + I(t)\theta = -D \text{, when } t \in [0, T] \quad (1)$$

Under some circumstances, $I(0) = Q$ and $I(T) = 0$.

The level of inventory at the time t can be calculated with help of equation (1) using ODE which is given below and taken as the general solution of equation (1) (figure 1).

$$I(t) = \left(De^{\theta(T-t)} - D\right)\frac{1}{\theta}, \text{ when } t \in [0, T] \quad (2) \qquad (2)$$

Now, we want to find out the value of inventory level at the initial then putting $t = 0$ in the equation (2), we get

$$Q = I(0) = \left(e^{\theta T}D - D\right)\frac{1}{\theta} \qquad (3)$$

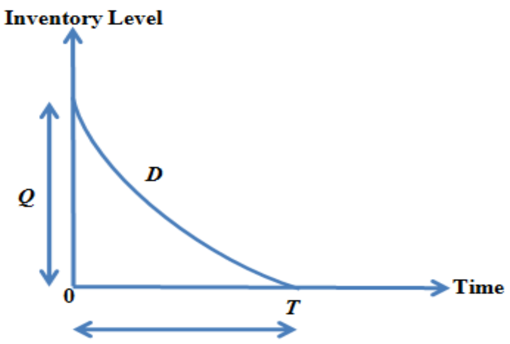

Figure 1. Inventory-Time graph

The costs for the present scenario are given below:

The set cost per cycle, $A = \left(\frac{C_1}{T} + \frac{C_2}{Tn^{\beta}}\right)$ (4)

Holding cost per cycle,

$$IHC = \frac{\left(h_1 D + \frac{h_2 D}{n\beta}\right)}{\theta^2 T}\left(e^{\theta T} - \theta T - 1\right) \qquad (5)$$

Deterioration cost per cycle,

$$D_c = CQ - CDT = \frac{CDe^{\theta T}}{\theta T} - CD - \frac{CD}{\theta T} \qquad (6)$$

Preservation cost, $PV = \xi T$ (7)

Carbon Tax(CT) = $(c_1 + V_1(T))\gamma$ (8)

Now, total cost for this scenario is given by

$$\pi(T) = \left[\frac{PV}{T} + \frac{D_c}{T} + \frac{A}{T} + \frac{IHC}{T} + \frac{CT}{T}\right] \qquad (9)$$

4. SOLUTION PROCESS

For the optimization for cycle length, we have to take, $\frac{d\pi(T)}{dT} = 0$ which give

$$\boldsymbol{T = T_1}(\text{SAY}) = \sqrt{\frac{2\left(C_1 + \frac{C_2}{n^{\beta}}\right)}{C_1 D\left\{h_1 + \frac{h_2}{n^{\beta}} + C(\theta)\right\}}} \qquad (10)$$

Now, we calculate the second derivatives

$$\frac{d\pi(T)}{dT} = -\frac{\left(C_1 + \frac{C_2}{n\beta}\right)}{T^2} + \frac{\left(h_1 + \frac{h_2}{n\beta}\right)D}{2} + \frac{CD\theta}{2}$$

and $\frac{d^2\pi(T)}{dT^2} = \frac{2\left(C_1 + \frac{C_2}{n\beta}\right)}{T^3}$ (11)

which gives $\frac{d^2\pi(T_1)}{dT^2} = \frac{2\left(C_1 + \frac{C_2}{n\beta}\right)}{{T_1}^3} > 0$ (12)

From (12), shows the convexity of total inventory cost, so the optimal cycle length is given by:

$$T = T_1(\text{say}) = \sqrt{\frac{2\left(C_1 + \frac{C_2}{n\beta}\right)}{C_1 D\left\{h_1 + \frac{h_2}{n\beta} + C\theta\right\}}} \qquad (13)$$

4.1 Numerical example

In this section, a numerical illustration is presented for the verification of the model.

Take $D = 500\ units, h_1 = 2, h_2 = 1, C_1 = 30, C_2 = 10, \beta = 0.23, \theta = 0.20, \xi = 0.15\ per\ item, C = \$50, c_1 = 2, V_1 = 4, \gamma = 5$

After the calculation we get the following optimum results:

Optimal cycle length, $T^* = 2.2364\ years$, Number of shipments, $n = 5$,

Minimum inventory total cost, $\pi(T^*) = 4053\ \$\ per\ year$.

5. SENSITIVITY ANALYSIS

The present section analyzes the effect of changes in system parameters on the optimal cycle length and optimal total cost (table 1-4, figure 2).

Table 1. The effect of learning rate on the cycle time and total average cost

Learning rate β	**Cycle length T (Year)**	**Retailer's total cost $\pi(T)$ (\$)**
0.23	0.2464	4053
0.24	0.2464	4047
0.25	0.2465	4040
0.26	0.2464	4032
0.27	0.2464	4028

Table 2. The effect of shipment on the cycle time and total average cost

Number of shipments (n)	**Cycle length T (year)**	**Retailer's total Cost $\pi(T)$ (\$)**
1	0.2440	5433
2	0.2445	5347
3	0.2448	5303
4	0.2452	5274
5	0.2465	4053

Table 3. The effect of deteriorating rate on the cycle time and total average cost

Deterioration rate θ	Cycle time T (Year)	Retailer's total cost $\pi(T)$ ($)
0.10	2.5126	4597
0.15	1.6497	4925
0.20	0.2364	4053
0.25	0.1873	4580
0.30	0.091	4809

Table 4. The effect of preservation cost on the cycle time and total average cost

Preservation cost ξ /items	Cycle length T (year)	Retailer's total Cost ($\pi(T)$$)
0.15	0.2364	4053
1.15	0.2364	4154
2.15	0.2364	4355
3.15	0.2364	4456

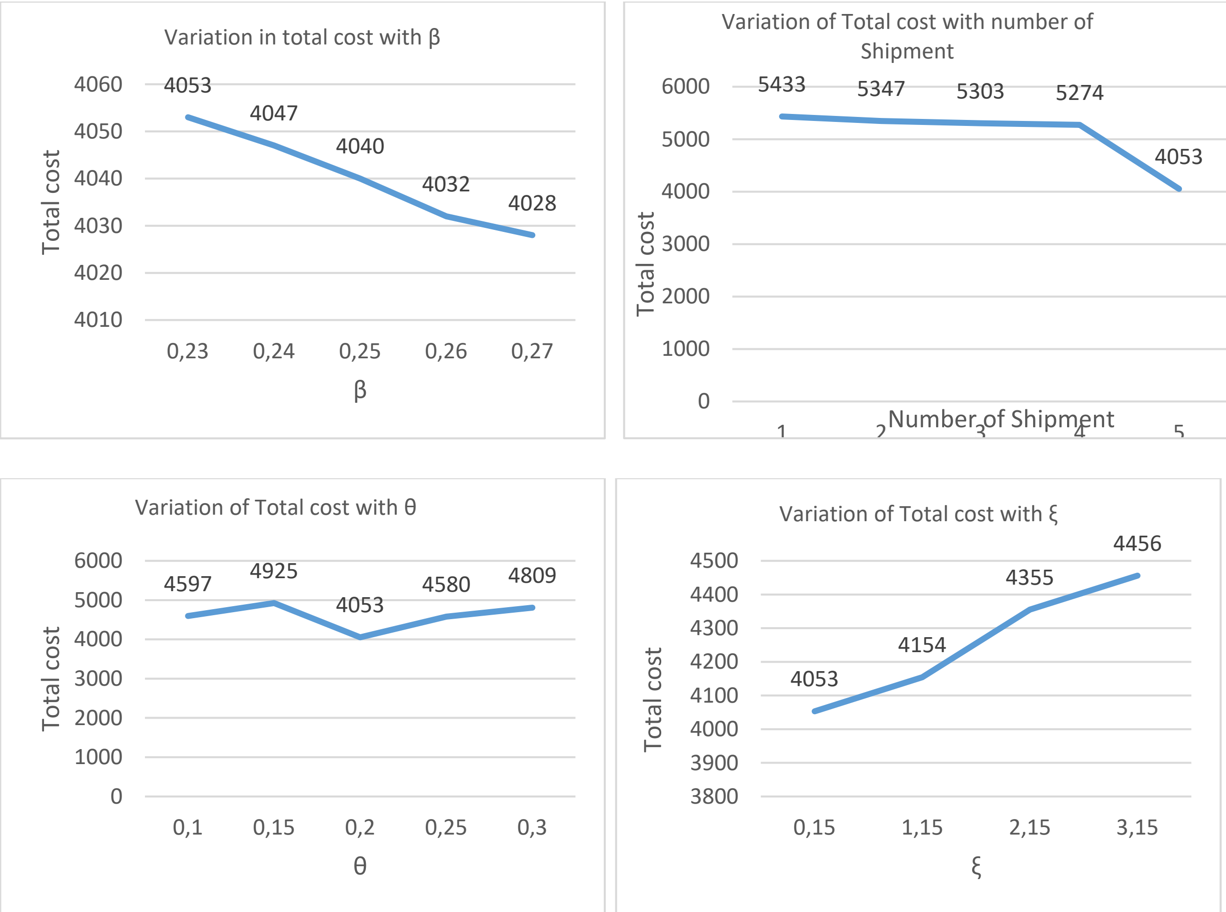

Figure 2. Variation of Total cost with different parameters

6. MANAGERIAL INSIGHTS AND OBSERVATIONS FROM THE TABLE

From table 1, it is seen that if the rate of learning is increased from 0.23 to 0.27, total inventory cost decreases when the learning rate is increased and the cycle length is almost fixed.

From table 2, if the shipments number increases, from 1 to 5 then the cycle length is increased up to 5th shipment. It is also examined that if the number of shipments increases, the retailer's total inventory cost decreases while cycle length is steadily increased.

Table 3, reveal that as the deterioration rate increases slowly and the cycle time initially decreases, the total inventory cost concerning to the deterioration rate increases.

From table 4, it is concluded that if the preservation cost is increased, the cycle length is fixed while the total inventory cost is increased.

7. CONCLUSION

This paper solves the problem of ordering policy especially cycle length when an item is perishable. In this paper, some important results have been shown in sensitivity analysis and also represented how does use this in the ordering policy. The mathematical analysis detected together clearly suggested that the existence of preservation and the effect of learning had a positive effect on the total inventory cost. The existing model can be reconstructed with the trade credit policy and shortages. The present paper extended the model developed by Jaggi et al. (2011) with the help of learning. This paper is different from previous model due to this concept. The learning effect was defined when a new task was learnt due to the repetition of a particular task or a set of tasks. This paper has tried to develop a mathematical formula to determine cycle length and the corresponding total profit for the buyer with the help of the trade credit financing with learning effects applied over the holding cost, the ordering cost as well as the defective percentage for deteriorating articles with imperfect quality under inflation. Eventually, we have concluded that results of this model showed that the number of defective units and cost reduces as learning increases and followed a form similar to the logistic curve. Slow learning resulted in order quantities that were larger than their EOQ values and learning became faster, hence it was recommended to order in lots less frequently. Findings together with mathematical analysis clearly suggested that the presence of trade credit and learning effect had an affirmative impact on retailer ordering policy. Present work improves for more sensible positions such as supply reliant and two-level trade-credit policies, etc. This article has tried to develop a mathematical formula to determine cycle length and the corresponding total cost with learning effects applied over the holding cost, the ordering cost. Eventually, we have concluded that results of this model showed that the retailer's whole cost reduces as learning increases. When items are perishable then preservation should be must to control the deterioration rate but the total cost almost increases. This article reveals that learning concept is very beneficial to get less inventory cost in real scenario. Findings together with mathematical analysis clearly recommended that the existence of preservation and the effect of leaning had a positive effect on whole cost. Present work improves for more sensible positions such as supply reliant and cloudy environment etc. This paper explains the ordering policy with the effect of learning for decaying items under shortages where the demand rate is a function of reliability of item and time factor. The novelty of this paper is that, the total average cost can be manageable by learning effects. Moreover, as shown in the table 3. It can be say that the parameter of demand rate, effect of learning and shipment has a positive effect on the ordering policy. The ordering cost, holding cost, deterioration cost and shortages cost reduce as shipment increases due to present of leaning effect. It is suggested that present study is only valid for buyer's ordering policy and it is not valid for production model. Present work enhances the more sensible position for instance as supply chain management and two-level trade-credit policies.

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