

## Impact of Carbon Emissions on the Ordering Policies for Perishable Items Under Preservation Technology

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### Abstract

Our proposed model deals with impact of carbon emissions on the ordering policies for perishable items under preservation technology. The emission of carbon units come from many sources like transportations, storage of waste products and various type of gases like carbon dioxide, Sulphur dioxide and methane etc. The emission of carbon affects the ordering policies and the quality of perishable items day by day reduces as passes time. The perishable product has high deterioration rate and its quality fast reduces. The preservation technology preserves the quality of the perishable items and control the fast deterioration rate. The demand of the perishable item depends on the selling price. In this order, we minimized the buyer's total inventory cost with respect to cycle time. The numerical analysis is presented for the justification of proposed model. The sensitivity analysis and future work also explained in this paper.

Keywords: Inventory, EOQ, preservation technology, carbon emission, Perishable items, Preservation, Deterioration

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### Abstract

#### 1. Introduction

Basically, the perishable products depreciate in a lesser period and fast damage its quality due to high deterioration rate and deterioration can be ignored because it is natural process but it can be control by using of preservation technology and extra charge bears to the seller or buyer. The preservation cost has been incorporated into the model to increase profitability for the buyer. Additionally, to address carbon emissions, we have included a carbon emission cost component. We also review relevant literature by several renowned authors who have studied inventory models for deteriorating items. In this context, contributions have been made by Malik and Singh (2013), Malik et al. (2017), Malik et al. (2017), Malik and Sharma (2011), Vikram et al. (2016), and Singh and Malik (2010). These researchers proposed various ordering policies and inventory models for deteriorating items, each employing different approaches under diverse considerations.

Some researchers have studied inventory models using trade credit policies. Teng et al. (2006) created a model that helps decide how much to order when trade credit is offered at different levels. Teng and Goyal (2007) built a model for buyers who use credit given by suppliers in industries. Adad and Jaggi (2003) improved the basic EOQ model by adding trade credit for items that can spoil. Shinn and Hwang (2003) worked on finding the best price and order size for retailers using credit. Luo (2007) made an EOQ model for non-perishable items under trade credit. Hung (2007) made the EOQ model easier and gave ideas to find the best order size. Hung and Chung (2003) expanded Goyal's (1985) model to show how credit and payment rebates can lower costs. Huang (2003) also worked in this area, and later in 2006, updated the model by adding two levels of credit and limited storage space.

Teng and Goyal (2007) created a stock model for buyers who use credit given by suppliers in industry. Later, Teng and Chang (2009) improved Huang's (2007) work by adding a two-level credit system to help customers. Huang (2007) also updated his earlier model (Huang, 2003) by using this two-level credit scheme to increase order quantities. Jayaswal (2019) studied how learning affects sellers' ordering policies for defective items when trade credit is used. Sheikh and Patel (2017) improved a two-warehouse model for items that spoil, by adding shortages and letting demand change over time. Huang and Hsu (2008) expanded the two-level credit model by adding a partial credit option. Shah et al. (2010) wrote many papers about inventory systems with two-level credit financing. Chen and Kang (2010) made a model for industry that includes price-based demand and customer satisfaction under a two-level credit policy.

Jaggi et al. (2008) proposed an EOQ model with a two-level credit system where demand depends on credit. Mandal and Giri (2017) developed a supply chain inventory model with imperfect quality in a two-warehouse system where demand changes with stock levels. We have also looked at recent studies that improved earlier models using new ideas. For example, Yadav et al. (2022) created an inventory model for items that deteriorate under variable demand rates. Singh and Malik (2010) developed an economic order quantity (EOQ) model with flexible demand in realistic situations. Kumar (2021) proposed an EOQ formula for a fuzzy (uncertain) environment. Malik and Garg (2021) created an inventory model for a two-warehouse system under uncertain conditions. Yadav et al. (2022) designed a fuzzy inventory model for deteriorating items with changing demand.

Mandal (2023) also proposed an inventory model for items that deteriorate under variable demand. The learning effect is a mathematical tool that helps reduce total fuzzy costs based on the number of shipments. Several authors have studied learning in inventory systems. Jayaswal et al. (2019) developed a learning-based model with trade credit for imperfect quality items under inspection. Jayaswal et al. (2021) presented a model combining imperfect quality, trade credit, and inspection for deteriorating items. In another 2021 study, they proposed an inventory model using preservation technology for perishable items under learning effects. Alamri et al. (2023) introduced a model considering carbon emissions from a different perspective. Alsaedi et al. (2023) developed an inventory model with ordering policies, carbon

emissions, and preservation technology. Malik et al. (2024) contributed a new approach to green supply chains by studying trade credit under inflationary conditions.

## 2. Assumptions and Notations

The mathematical model is derived using following notations and assumptions.

### 2.1 Assumptions

- Time horizon is divided into infinite section of same length.
- The demand rate depends on selling price.
- The strategy of carbon emission is allowed.
- The preservation technology is allowed.
- There are no shortages in this model.
- The lead-time is considered to be zero.
- Unit purchasing cost is less than the unit selling price.
- No replacement policy of perishable items during cycle length.

### 2.2 Notations

$D(p) = aP^{-e}$	Demand rate of the product (unit /year)
$\xi$	Preservation cost (\$/unit item)
$A$	Ordering cost which follows the learning effect (\$/order)
$A^1$	Carbon emission cost due to ordering cost (\$)
$P$	Selling price per unit (\$)
$\theta$	Decaying rate (time)
$C$	Unit purchase cost (\$)
$h$	Unit holding cost which follows the learning effect. (\$/unit/year)
$h^1$	Carbon emission cost due to holding cost (\$)
$Q$	Order quantity (unit)
$T$	Cycle length (year)
$q(t)$	The inventory level in the interval, $0 \leq t \leq T$
$K(T)$	The total inventory cost for the system (\$)

### 3. Mathematical formulation

From the figure 1, we are assuming that the inventory level at time  $t$  is  $q(t)$  and also considered that the inventory level at  $t = 0$  is  $Q$ . The inventory level of perishable item is reducing due to demand and deteriorating. The whole inventory level is finished at  $t = T$ . The inventory level of the perishable item is obeying differential equation and is presented below;

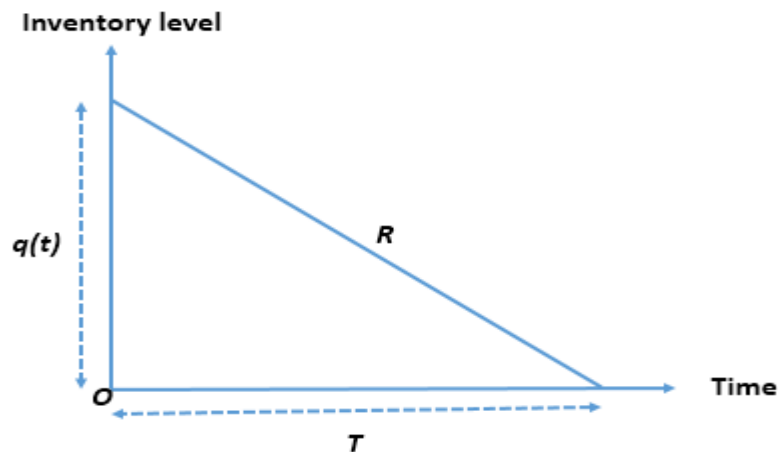


Figure 1: Process of inventory level with time

$$\frac{dq(t)}{dt} + \theta q(t) = -R, t \in [0, T], \quad \dots(1)$$

The boundary condition of the given differential equation from the equation (1),  $q(0) = Q$  and  $q(T) = 0$ .

After the solving the equation with help of boundary condition the inventory level at time  $t$  is

$$q(t) = \left( \frac{R}{\theta} e^{\theta(T-t)} - \frac{R}{\theta} \right) \quad \dots(2)$$

and the inventory level at  $t = 0$ , we get

$$Q = q(0) = \left( \frac{R}{\theta} e^{\theta T} - \frac{R}{\theta} \right) \quad \dots(3)$$

Now, we calculated some inventory cost by using of equation (3)

Ordering cost per cycle,

$$OC = \frac{1}{T} A \quad \dots(4)$$

Carbon emission cost due to ordering shipment per cycle,

$$C_{EA} = \frac{1}{T} A^1 \quad \dots(5)$$

Holding cost per cycle,

$$IHC = \frac{hR}{\theta^2 T} (e^{\theta T} - \theta T - 1) \quad \dots(6)$$

Carbon emission cost due to storage of items per cycle

$$C_{EH} = \frac{h^1}{\theta^2 T} (R e^{\theta T} - R \theta T - R) \quad \dots(7)$$

Deterioration cost per unit time

$$CD = C(Q - RT) = \frac{CR}{\theta T} (e^{\theta T} - \theta T - 1) \quad \dots(8)$$

Preservation cost

$$PV = \xi T \quad \dots(9)$$

Now, the total inventory cost per unit time is

$$K(T) = \frac{1}{T} [IHC + C_{EA} + C_{EH} + OC + CD + PV] \quad \dots(10)$$

The values of the costs from the equations (4) to (9) and replaced in to equation (10), we get

$$K(T) = \frac{1}{T} \left[ \frac{hR}{\theta^2 T} (e^{\theta T} - \theta T - 1) + \frac{1}{T} A^1 + \frac{h^1 R}{\theta^2 T} (e^{\theta T} - \theta T - 1) + \frac{1}{T} A + \frac{CR}{\theta T} (e^{\theta T} - \theta T - 1) + \xi T \right] \dots(11)$$

#### 4. Solution Method

In this section, we calculate the decision variable using the properties of maxima and minima.

We calculate the optimal cycle time and for the optimal cycle time  $T$ , we set  $\frac{dK(T)}{dT} = 0$

which give th cycle time

$$T = T_1(\text{say}) = \sqrt{\frac{2(A + A^1)}{aP^{-e} \{h + h^1\}}} \quad \dots(12)$$

Now, we calculate the second derivatives

$$\frac{dK(T)}{dT} = -\frac{(A + A^1)}{T^2} + \frac{((h + h^1))(R)}{2} + \frac{CR\theta}{2} \quad \dots(13)$$

$$\text{and } \frac{d^2 K(T)}{dT^2} = \frac{2(A + A^1)}{T^3} \quad \dots(14)$$

$$\text{which gives, } \frac{d^2 K(T)}{dT^2} = \frac{2((A + A^1))}{T_1^3} > 0 \quad \dots(15)$$

From (15), shows the convexity of total inventory cost, hence the optimal cycle length is that;

$$T = T_1(\text{say}) = \sqrt{\frac{2(A + A^1)}{aP^{-e}\{h + h^1\}}} \quad \dots(16)$$

#### 4.1 Numerical example

Table 1: Inventory parameters and decision variable

Fixed holding cost	$h = 2(\$)$
Fixed ordering cost	$A = 30(\$)$
Carbon emission cost due to shipment	$A^1 = 4(\$)$
Decaying rate	$\theta = 0.23$
Selling price	90 (\$)
Supporting parameters for demand rate	$e = 0.00045$ and $a = 0.0087$
Preservation cost	$\varepsilon = 0.15 (\$)$
Carbon emission cost due to storage	$h^1 = 1(\$)$
Purchasing cost	$C = 50 (\$)$
Optimal cycle time	$T^* = 0.3265$ (year)
Minimum inventory cost	$K(T^*) = 4246 (\$)$

#### 5. Sensitive analysis

In this section, we analysed the impact of inventory parameters on the optimal cycle time and total inventory cost. the impact of carbon emission cost, deterioration rate, and preservation cost have been presented from the Table 2 to Table 7.

Table 2: Impact of holding cost on the cycle time and total inventory cost per cycle.

Holding cost $h$	Cycle length $T$ (Year)	Retailer's total fuzzy cost $K(T^*)$ (\$)
2	0.3265	4246
2.5	0.3265	4282
3.0	0.3265	4298

Table 3: Impact of carbon emission cost due to storage on the cycle time and total inventory cost per cycle.

Carbon emission cost $C_{EH}$	Cycle length $T$ (Year)	Retailer's total fuzzy cost $K(T^*)$ (\$)
1	0.3265	4246
1.5	0.3265	4265
2.0	0.3265	4275

Table 4: Impact of ordering cost on the cycle time and total inventory cost per cycle.

Ordering cost $A$	Cycle length $T$ (Year)	Retailer's total fuzzy cost $K(T^*)$ (\$)
30.00	0.3265	4246
30.50	0.3265	4263
40.00	0.3265	4285

Table 5: Impact of carbon emission cost due to shipment on the cycle time and total inventory cost per cycle.

Carbon emission cost $C_{EA}$	Cycle length $T$ (Year)	Retailer's total fuzzy cost $K(T^*)$ (\$)
4.00	0.3265	4246
4.50	0.3265	4254
5.00	0.3265	4264

Table 6: Impact of the decaying rate on cycle time and whole cost.

Deterioration rate $\theta$	Cycle time $T$ (Year)	Retailer's total fuzzy cost $K(T^*)$ (\$)
0.10	0.4356	3047
0.15	0.4076	3765
0.20	0.3265	4246

Table 7. Impact of the preservation cost on retailer's cycle time and whole cost

Preservation cost $\xi$ /items	Cycle length $T$ (year)	Retailer's total fuzzy cost $K(T^*)$ (\$)
0.15	0.3265	4246
1.15	0.3265	4253
2.15	0.3265	4267
3.15	0.3265	4281

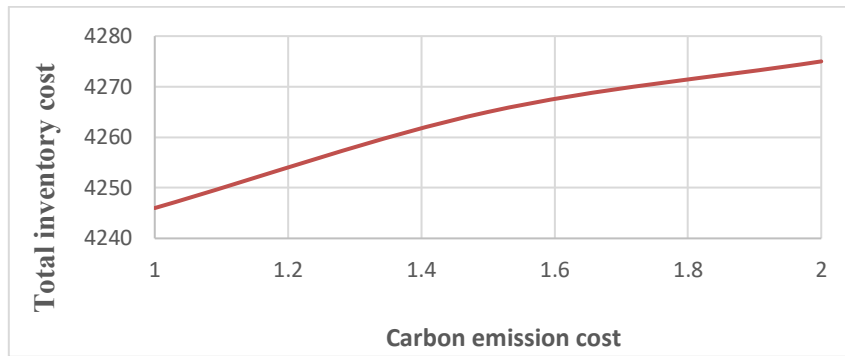


Figure 2: Impact of carbon emission cost due to storage of itemson total inventory cost

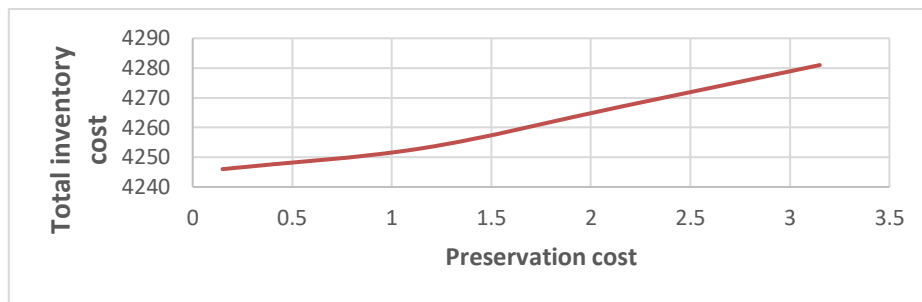


Figure 3: Impact of preservation cost on total inventory cost

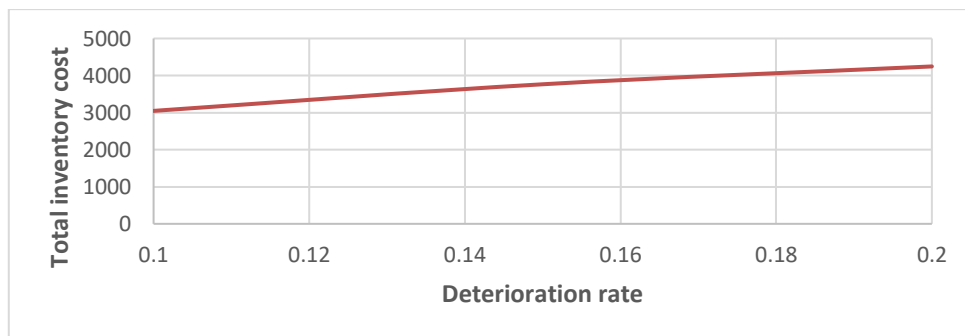


Figure 4: Impact of deterioration on the total cost

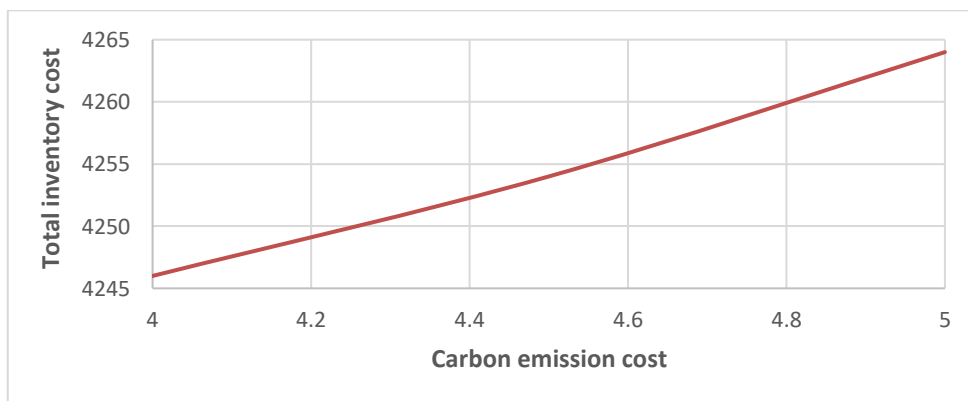


Figure 5: Impact of carbon emission cost due to shipment of items on the total cost

### 5.1 Observations and Managerial insights

- From Table-2 it is found that the holding cost increases, retailer's total cost also increases but the cycle time remains constant. Hence the retailer gets more information for the exercise of holding of units.
- From Table-3 and figure 2, it is found that the carbon emission cost due to storage increases, retailer's total cost also increases but the cycle time remains constant. Hence the retailer gets more information for the exercise of carbon emission cost.
- From table-4, it is found that the ordering cost increases, retailer's total cost also increases but the cycle time remains constant. Hence the retailer gets more information for the exercise of shipments.
- From the Table 5 and Figure 5 it is found that the carbon emission cost due to shipments increases, retailer's total cost also increases but the cycle time remains constant. Hence the retailer gets more information for the exercise of carbon emission cost due to shipments.
- From the Table 6 and Figure 4, it is found that the deterioration rate increases, retailer's total cost also increases and the cycle time also decreases.
- From table-7 and Figure 3, it is found that the preservation cost is increased up to 0.15 to 3.15 and cycle length is fixed while the seller's overall cost is increased.

## 6. Conclusion

Our proposed model deals a model with impact of carbon emissions on the ordering policies for perishable items under preservation technology where demand rate depends on the selling price. All costs like preservation, ordering, carbon emission due to storage and shipments are gave positive effect regarding the total inventory cost. Observations and managerial insights are shown more positive results during ordering policies for the decision maker. The proposed model is more applicable where the retailer deals with perishable items during transaction of business. This article has tried to develop an arithmetic formula to decide cycle length and the correlation with overall cost with the effect of some costs. In this framework the items disclose that learning notion it is very helpful to get less inventory value. Our proposed study can improve by using of waste management strategy, trade credit policy and inflation situations.

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