International Journal of Mathematical, Engineering and Management Sciences
Vol. 10, No. 6, 2201-2222, 2025
https://doi.org/10.33889/IJMEMS.2025.10.6.102

Ram Arti Publishers

A Trade-Credit Policy for Deteriorating Items with Hybrid Type Demand and Carbon Emission under the Impact of Inflation

Tejpal Meedal
Department of Mathematics & Statistics,
Manipal University Jaipur, Jaipur, Rajasthan, India.
E-mail: tejpalmeedal95@gmail.com

Himanshu Rathore
Department of Mathematics & Statistics,
Manipal University Jaipur, Jaipur, Rajasthan, India.
Corresponding author: himanshu.rathore@jaipur.manipal.edu

Sushil Bhawaria
Department of Applied Sciences,
Global Institute of Technology, Sitapura, Jaipur, Rajasthan, India.
E-mail: sushilbhawaria01@gmail.com

Gireesh Kumar
Department of Computer Science and Engineering,
Manipal University Jaipur, Jaipur, Rajasthan, India.
E-mail: gireesh.kumar@jaipur.manipal.edu

(Received on February 27, 2025; Revised on May 29, 2025 & August 14, 2025; Accepted on September 10, 2025)

Abstract
In this work, EOQ model develops for decaying items with hybrid demand and green technology under the impact of inflation. Carbon reduction plays a vital role in the green inventory system and in demand which is affected by items price. Moreover, the selling price and green technology investment (*GTI*) dependent hybrid demand has been considered. Preservation technology (PT) used to control the deterioration of the items. The retailer is allowed distinct period to occupy cash flow by supplier. Transportation and storing inventory process both are the sources of the (CE) carbon emission, and to manage the carbon emission carbon tax regulation considered. Our major goal is to optimize retailer's selling price, to get maximum total profit, and green technology cost for constant deteriorating items with fixed expiry date. To find the optimal values of the decision parameters, the classical optimization method has been implemented. The optimal values of the total profit function with decision variables as cycle length and selling price are calculated with the help of mathematica-7. For authentication of the results, numerical illustration is done, and concave graphs well present the optimality of the total profit function. Finally, the analysis part carried to show the variations in the parameters.

Keywords- Inflation, Green technology, Hybrid demand, Trade-credit, Preservation technology.

1. Introduction

In the 21st century global warming is too powerful a global issue. In short words, global warming has a long-term effect on the globe that results in calamitous environmental change. Carbon emissions from many industries, companies, kiln's, warehouses etc. are one of the causes of global warming. Regarding carbon emissions many countries and local governments around the world have implemented carbon taxes. The governments collect carbon emission fees which are known as carbon tax. For the carbon emission, many prominent researchers described the different carbon emission policies involving carbon tax and cap and trade credit policies. Preservation technology has emerged as a vital field of research, focusing on the protection and conservation of cultural heritage and biological materials for future generations. The rapid deterioration of historical artifacts, manuscripts, and biological specimens due to environmental factors, human neglect, or intentional destruction has underscored the need for innovative preservation methods. This paper explores the latest advancements in preservation technology, including nanotechnology, and advanced materials, and their applications in safeguarding cultural heritage and biological materials. By examining the current state of preservation technology, this research aims to contribute to the development of more effective strategies for preserving our collective heritage and promoting a deeper understanding of the past. Inflation, a sustained increase in the general price level of goods and services in an economy, is a complex and multifaceted economic phenomenon that has far-reaching implications for individuals, businesses, and policymakers. As a key macroeconomic variable, inflation affects the purchasing power of consumers, the profitability of firms, and the overall stability of the economy.

This paper aims to explore the causes and consequences of inflation, including its impact on economic growth, income distribution, and monetary policy. By examining the theoretical frameworks and empirical evidence on inflation, this research seeks to contribute to a deeper understanding of this critical economic issue and inform policy decisions that promote price stability and sustainable economic growth. The rest of the paper has been organized as follows. Section 2 provides the work done by prominent researchers. Next Section 3, assumptions and notations have been given. Mathematical formulation and cost calculation of the model considered are given in subsequent Sections 4 and 5. Section 6 shows the solution process of the model. In next Section 7, illustration has been given. To illustrate the proposed model numerical example for both cases discussed in Section 8. The marginal insights of the current study are presented in Section 9. At last conclusion and future scope are made in Section 10.

2. Literature Review

Recent advancements in inventory management have led to the development of innovative models that address pressing concern such as sustainability, carbon emissions, and items deterioration. Notably, Singh & Mishra (2022) pioneered an inventory control model for bad quality items considering transport and industry carbon emission. Bhawaria & Rathore (2022) introduced production inventory model tailored to imperfect items specially focusing on hybrid demand function to showcasing the importance of demand patterns recognition. Furthermore, other notable contributions include Singh & Choudhary (2021) considered to be an imperfect inventory model for deteriorating items with carbon emission and defective rate of product. Sebatjane (2024) proposed a production inventory model for deteriorating items and supply chain system under various carbon emission regulations. Ahmad et al. (2023) formulated inventory model with selling price dependent demand and greening effect. Preservation techniques were applied to control the deterioration. Additionally, Yadav et al. (2023) established two-warehouse inventory models for low quality items with carbon emissions. Muthusamy et al. (2024) developed a production model for fragment quality items with different carbon emission policies and green technology. Recent studies, such as Pervin (2024) proposed sustainable inventory model to reduce the carbon emission by applying green items and deterioration controlled by preservation technology. Yang et al. (2024) developed SCM to determine the impact of carbon tariffs and policies in the environment.

Transportation and storage capacity play a significant role in inventory management. Both relate to carbon emission and energy consumption, which increases carbon emission. Carbon emission from vehicles and storage places are a cost to society that becomes extra charge in economic order quantity models, according to Bonney & Jaber (2011). Roy et al. (2024) developed vendor-buyer model under the fuzzy environment and game theory approach. Especially, they focused on fuel consumption by transportation. San-Jose et al. (2024) analyzed sustainable inventory model for goods and demand function follows power patterns with time. Peng et al. (2024), Roy & Ghosh (2024), Zhang et al. (2024), and Song et al. (2025) developed inventory models for carbon emission by road transportation, fuel consumption and storage of the items. Mashud et al. (2024) formulated three echelon supply chain models with green technology, variable demand and option for vehicle selection. Liu et al. (2024) assessed transportation efficiency across different areas with super efficiency SBM model. Carbon emissions by transportation and storage various prominent researchers and authors research carried by Bharti et al. (2024), Kumar et al. (2024a), Lekaki et al. (2024), Lin & Bai (2024), Li et al. (2024), Lu et al. (2024), Xu et al. (2024), and Zhao et al. (2024).

Deteriorating items experience constant mass loss, but preservation technologies may help decay items to be consumed. Retailers with direct consumers' relationships detract stock deterioration through warehouses. Producer storage systems have maximum deterioration rate. Then, preservation technology applied to control the deterioration of the items, and many authors and researchers worked on preservation technology with different demand patterns. Bhawaria & Rathore (2023) presented EPQ model for deteriorating items under the impact of inflation. And preservation techniques are used to control the deterioration. Bhawaria et al. (2023) described a reverse logistics model for deteriorating items with preservation technology and learning effect under the inflationary environment. Rathore et al. (2024) developed optimal inventory policy with ramp type demand in the two-warehouse environment. Sharma & Rathore (2024) developed inventory models for deteriorating items with preservation investment and entire work studied under the impact of inflation. Sharma & Mandal (2024) established economic order quantity EOQ model for low quality commodities with preservation technology and advance payment policy. Demand was dependent on the selling price and stock level. Pal et al. (2024) investigated the model for decaying items under inflationary conditions. Preservation technology used to control deterioration of spoilage items. Padiyar et al. (2024) proposed inventory model for instantaneous decaying items with preservation investment under the impact of inflation. Kumar et al. (2023a) have developed inventory model for non-instantaneous deteriorating items with trade credit policy, and they allowed partially backlogging shortages under the impact of inflation.

Empirical and theoretical analysis demonstrates that green technology encompasses a broad area of agriculture, scientific research, material science, and hydrology. Various green techniques aim to reduce the carbon emission of CO_2, SO_2 and other gases to stop environmental change. Together preservation technology provides extra protection to deteriorating items. Both technologies are effective to reduce carbon emission from industries, transportation, storage, and warehouses. Further, for green technology and preservation technology several researchers worked like as Kumar et al. (2024b) addressed two storage inventory models for deteriorating items with FPO algorithm and selling price dependent demand. Priyan et al. (2024) explored sustainable inventory policies in the pandemic conditions considering transportation cost, green technology, storage, production, and carbon emission. Gupta & Khanna (2024) investigated the effect of carbon emission on producer industries. These policies aim to reduce carbon emissions. Kar et al. (2024) proposed multi-item green inventory model with uncertain finite time horizon and constraints. And in this work green technology is applied to fruits, vegetables and other seasonal items. Mendis et al. (2024) examined wood preservation technology and green technology. In the same area many researchers worked like Dao et al. (2011), Zehner (2011), Jeong et al. (2012), Esmaeilnezhad et al. (2017), Jiang al. (2024) and Kumar et al (2024c). Kumar et al. (2023b) investigated EOQ model for deteriorating items with partially backordering and they invested in green technology to reduce carbon emission. Yadav et al. (2021) proposed supply chain inventory model with positive and negative cross price elasticity of demand.

Few studies have explored the joint impact of preservation techniques and green technology on inventory decisions for deteriorating items. Most EOQ models assume a single demand pattern, whereas real-world demand often exhibits hybrid characteristics. The combined effects of inflation and carbon emissions on inventory decisions for deteriorating items have not been thoroughly investigated. In the current study, the

EOQ model has been developed by incorporating preservation technology, rate of inflation, hybrid demand function which is dependent on selling price and green technology investment.

3. Notations and Assumptions

In this section, in developing the trade-credit policy for deteriorating items with hybrid demand, the following notations and assumptions are considered. All notations have been presented in their appropriate units for clarity and consistency.

Notations		***Description***
A	:	Ordering cost (*$* per order)
c_0	:	Purchasing cost excluding transportation cost (*$* per unit)
c_t	:	Transportation cost of items from supplier to retailer ($ per unit)
H	:	Holding cost (*$* per unit)
e_H	:	Carbon emission from holding process per cycle (ton/unit)
e_t	:	Carbon emission during delivery (ton/ unit)
Q	:	Replenishment quantity
f	:	Green technology investment cost per unit per cycle
$g(f)$	:	Carbon emission function
p	:	Selling price
T	:	Replenishment cycle time
$D(p,f)$	:	Demand function
σ	:	Carbon tax (*$* per Kg)
d_1	:	Travelled distance (Kilometers)
μ_1	:	Green technology efficiency factor
μ_2	:	Green technology emission factor
I_e	:	Interest earned
I_C	:	Interest charged, where $I_C \geq I_e$
M	:	Delay in payment received by buyer by seller
τ_θ	:	Deterioration rate of items
ξ	:	Preservation technology cost
$\dot{c}$	:	Carbon emission from holding inventory and transportation before investing in GT (ton per unit)
$\hat{C}_f$	:	Carbon emission from holding inventory and transportation after investing in GT (ton per unit)
$I(t)$	:	Inventory level at time
b	:	Preservation technology constant

Assumptions

(a) Economic order quantity model has been developed for single type item.
(b) The replenishment rate is instant.
(c) Planning horizon is infinite.
(d) The cost for holding items is constant in the warehouse.
(e) The deterioration rate of the items is constant and defined as constant rate
$\tau_\theta = (\theta - m(\xi))$, where $m(\xi) = e^{-b\xi}$.
(f) Carbon emissions in climate are caused due to delivery of the items and holding process in storage of items. (Bonney & Jaber, 2011; Chen et al., 2013; Hasan et al., 2021).
(g) Consider carbon emission reduction as a green investment function, which balances the environmental benefits and the cost of adopting green technologies. Carbon emissions have environmental impacts which are not directly related to inflation. The function is given as follows:
$g(f) = \mu_1 f - \mu_2 f^2$
where $f < \frac{\mu_1}{\mu_2}, \mu_1 > 0, \mu_2 > 0$ denotes efficiency factor and emission factor of green technology

respectively.

(h) The demand function depends on selling price and green technology investment (*GTI*) as carbon reduction function defined as

$D\,(p, f) = \tau(x_1 - yp) + (1-\tau)x_2 p^{-\gamma} + \alpha + \beta g(f) - \gamma p$

where; $0 \leq t \leq 1, x_1 > 0, x_2 > 0, y > 0, \frac{x_1}{y} \geq p, \alpha > 0, \beta > 0, 0 < \gamma < 1$ and $y > 1$.

where, α shows scale parameter, β shows the coefficient of green technology function ($g(f)$) and γ denotes the price elasticity. The demand function is non-linear due to - γ and the remaining part is linear. Here, *p* shows linearity and non-linearity with price elasticity γ.

(i) It is assumed that the green technology considered is to reduce carbon emission level with carbon tax policies.
(j) Lead time is negligible or zero.
(k) Shortages are not allowed.
(l) Due to a permissible delay in payment the retailers may earn interest in customers' payment, interest earn per unit per year. Retailer will have to settle account at M, credit period offered by the supplier. Retailer will pay interest on un-purchased items with I_c rate, interest charged to supplier (Soni et al., 2010; Saha & Jani, 2024).

4. Mathematical Model Formulation

According to notation and assumptions, inventory level of deteriorating items at time *t* during interval $[0,T]$ is decreased by impact of deterioration and demand. The inventory level at the time '*t*' is governed by following differential equations. **Figure 1** depicts the functioning of inventory model.

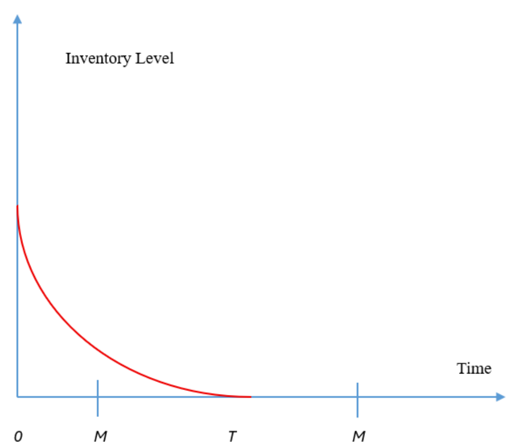

Figure 1. Inventory functioning.

$$\frac{dI(t)}{dt} + \tau_\theta I(t) = -D(p, f) \quad (1)$$

$0 \leq t \leq T$

Solution of the Equation (1) using condition $I(T) = 0$, Equation (1) reduces into

$$I(t) = \frac{D(p,f)(e^{\tau_\theta(T-t)} - 1)}{\tau_\theta} \quad (2)$$

The order quantity per replenishment cycle time is

$$Q = I(0) = \frac{D(p,f)(e^{\tau_\theta(T)}-1)}{\tau_\theta} \tag{3}$$

In this study total carbon emission for shipping is measure by $\frac{D(p,f)}{Q} d_1 e_t$.
Carbon emission during storage process for certain intervals are accumulated as

$$e_H \int_0^T I(t)dt \tag{4}$$

The solution of the Equation (4) is

$$= \frac{D(p,f)e_H}{\tau_\theta}\left[\frac{(e^{\tau_\theta(T)}+1)}{\tau_\theta} + T\right] \tag{5}$$

Now, total carbon emission during delivery from supplier to retailer and carbon emission from storage process is

$$\dot{c} = \frac{D(p,f)}{Q} d_1 e_t + e_H \int_0^T I(t)dt \tag{6}$$

$$\dot{c} = \frac{D(p,f)}{Q} d_1 e_t - \frac{D(p,f)}{\tau_\theta}\left[\frac{e^{\tau_\theta T}+1}{\tau_\theta} + 1\right] \tag{7}$$

By investing amount f, then the carbon emission reduction function is
$g(f) = \mu_1 f - \mu_2 f^2$ where $f < \frac{\mu_1}{\mu_2}$.

Here, after investing in GT, the total carbon emission is calculated as

$$\hat{C}_f = \frac{D(p,f)d_1 e_t}{Q} + e_H \int_0^T I(t)dt - g(f) \tag{8}$$

$$\hat{C}_f = \frac{D(p,f)d_1 e_t}{Q} - \frac{D(p,f)e_H}{\tau_\theta}\left[\frac{e^{\tau_\theta T}+1}{\tau_\theta} + T\right] - \mu_1 \mathrm{f} - \mu_2 \mathrm{f}^2 \tag{9}$$

5. Cost Calculation

In this section, the various costs related to the model have been calculated as given below:

- ***Sales Revenue:*** Sales revenue generated from items selling prices refers to the net income generated by any company or firm from selling its item over a special period. The sales revenue over the total cycle length and under the inflationary environment is calculated as

$$S_r = p(\int_0^T D(p,f)e^{-rt}dt \tag{10}$$

$$S_r = \frac{pD(p,f)(1-e^{-rt})}{r} \tag{11}$$

- ***Purchasing Cost*:** Purchasing cost of items in the inventory system refers to the total cost incurred by purchaser (retailer) to receive the items from manufacturer. The value of Purchasing cost (P_c) is given by

$$P_c = (c_0 + c_t)Q \tag{12}$$

$$P_c = \left(\frac{D(p,f)}{Q} d_1 e_t - \frac{D(p,f)}{\tau_\theta}\left[\frac{e^{\tau_\theta T}+1}{\tau_\theta} + 1\right] + \frac{D(p,f)d_1 e_t}{Q} - \frac{D(p,f)e_H}{\tau_\theta}\left[\frac{e^{\tau_\theta T}+1}{\tau_\theta} + T\right] - \mu_1 \mathrm{f} - \mu_2 \mathrm{f}^2\right) \frac{D(p,f)(e^{\tau_\theta(T)}-1)}{\tau_\theta} \tag{13}$$

- ***Holding Cost*:** Holding cost refers to all expenditures transacted to maintain the inventory level over a fixed period. Holding costs are associated with items stored in stock. The holding cost for deteriorating items in storage, under inflationary conditions, is determined by Equation (14).

Holding cost is calculated per cycle is given by

$$H_c = H\int_0^T I(t)e^{-rt}dt \tag{14}$$

$$H_c = \frac{HD(p,f)}{\tau_\theta}\left[\frac{e^{T\tau_\theta} - e^{Tr\tau_\theta}}{\tau_\theta(1+r)} + \frac{1+e^{-rt}}{r}\right] \tag{15}$$

- ***Ordering Cost*:** The ordering cost of products refers to all expenditures allied with placing and getting orders from commodities. Ordering costs comprise the transportation cost, administrative cost and many other costs to complete order.

$$OC = A \tag{16}$$

- ***Green Technology Investment Cost*:** Green technology investment refers to the expenditure incurred in implementing environmentally friendly techniques within supply chain (SCM) to reduce carbon emission. Hence, the green technology cost formulated as

$$GTC = f \tag{17}$$

- ***Preservation Technology Cost*:** Preservation technology cost refers to the expenditures incurred to stop the deterioration and adopting friendly environment within supply chain (SC) to detract the deterioration and carbon emission. So, the preservation technology cost under the impact of inflation calculated as

$$PTC = \int_0^T \xi e^{-rt}dt \tag{18}$$

The trade credit period is given by supplier to its retailer is M, and then these two cases are considered as case-1 and case-2 are explained below:

$\boldsymbol{Case - 1.\ M < T}$

For case-1 buyers need to pay interest for products after M time. Therefore, the interest charged is calculated below. **Figure 2** represents graphical representation of this case as-

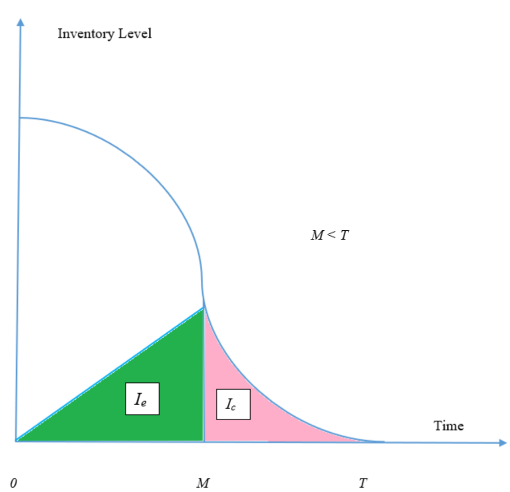

Figure 2. Trade credit case $M < T$.

$$IC = c_0 I_c \int_M^T I(t) e^{-rt} dt \tag{19}$$

$$IC = \frac{\frac{D(p,f)}{Q} d_1 e_t - \frac{D(p,f)}{\tau_\theta}\left[\frac{e^{\tau_\theta T}+1}{\tau_\theta}+1\right]\left[-e^{T(\tau_\theta - r)}+e^{\tau_\theta T - rM}+e^{-rT}-e^{-rM}\right]}{r\tau_\theta} \tag{20}$$

For case-1 interest earned calculated during interval [*0, M*] by retailer.

$$IE_1 = pI_e \int_0^M D(p,f) e^{-rt} dt \tag{21}$$

$$IE_1 = pI_e D(p,f)\left[Me^{-rM} + \frac{(1-e^{-rM})}{r}\right] \tag{22}$$

The total profit function after applying trade credit policy

$$TP_1 = [S_r - OC - HC - PC - PTC - GTC - IC_1 + IE_1] \tag{23}$$

For carbon emission the government decides the carbon tax and every emitter must pay for greenhouse gases per unit they emit. Customers and business organizations will take steps or adopt new techniques to lessen their emissions to keep away from paying extra tax.

So, in this case after applying the carbon tax policy, total profit of retailer per year.

$$TP_1 = \frac{1}{T}\left[[S_r - OC - HC - PC - PTC - GTC - IC_1 + IE_1] - \sigma \hat{C}_f\right] \tag{24}$$

Problem-1 in this case, the maximization problem is as follows:

Maximize $TP_1 = \frac{1}{T}(\beta, p, T)$

Subject to $p > 0, T > 0, \beta > 0, and\ M < T$ (25)

$\boldsymbol{Case - 2. M \geq T}$

In the case-2 replenishment cycle time is $M \geq T$. And all items are sold out during settlement; retailers calculate interest at time T and supplier charges no interest because all items are sold out and profit will be increase and profit described in the sensitivity analysis in case 2. Hence, the interest accumulated per order during time *M* is solved and the graphical presentation in **Figure 3** explained this case as-

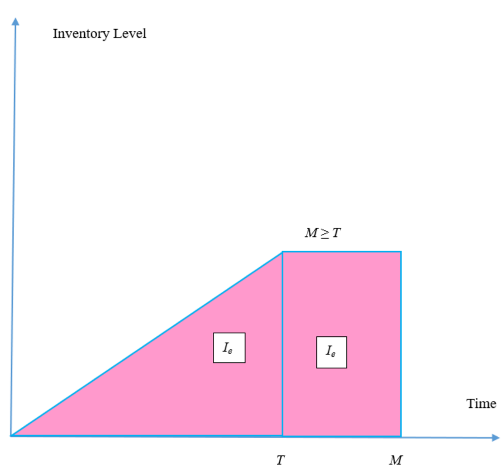

Figure 3. Trade credit case $M \geq T$.

$$IE_2 = pI_e[\int_0^T D(p,f)tdt + D(p,f)T(M-T)] \tag{26}$$

$$IE_2 = pI_e[D(p,f)T + D(p,f)T(M-T)] \tag{27}$$

Now, the total profit function for case- 2 is

$$TP_2 = [S_r - OC - HC - PC - PTC - GTC + IE_2] \tag{28}$$

After applying the carbon emission tax policy for case-2 the total profit function is

$$TP_2 = \frac{1}{T}\left[[S_r - OC - HC - PC - PTC - GTC + IE_2] - \sigma \hat{C}_f\right] \tag{29}$$

Problem-2 in this case, the maximization problem is as follows:
Maximize $TP_2 = \frac{1}{T}(\beta, p, T)$
Subject to $p > 0, T > 0, \beta > 0, and\ M \geq T$ (30)

6. Solution Process to Determine Optimal Value and Concavity of the Model

Equations (24) and (28) are the maximize profit function. For both equations necessary conditions are-
Step 1: First-order necessary conditions

Compute the first-order partial derivatives of the total profit function $TP(\beta, p, T)$ with respect to each variable and set them equal to zero:

$$\frac{\partial TP(\beta,p,T)}{\partial \beta} = 0, \qquad \frac{\partial TP(\beta,p,T)}{\partial p} = 0, \qquad \frac{\partial TP(\beta,p,T)}{\partial T} = 0.$$

Step 2: Evaluate the signs of the partial derivatives to understand the direction of change:

$$\frac{\partial TP(\beta,p,T)}{\partial \xi} < 0, \frac{\partial TP(\beta,p,T)}{\partial p} < 0, \frac{\partial TP(\beta,p,T)}{\partial T} < 0.$$

Step 3: Second-order sufficient conditions (Hessian Matrix Analysis)

Compute the second-order partial derivatives:

$$\frac{\partial^2 TP(\beta,p,T)}{\partial \beta^2} = \left(\frac{\partial^2 TP}{\partial T^2}\right)\left(\frac{\partial^2 TP}{\partial p^2}\right)$$

$$\frac{\partial^2 TP(\beta,p,T)}{\partial \beta \partial T} = \left(\frac{\partial^2 TP}{\partial T \partial \beta}\right)\left(\frac{\partial^2 TP}{\partial p^2}\right) - \left(\frac{\partial^2 TP}{\partial T \partial\, p}\right)\left(\frac{\partial^2 TP}{\partial \beta \partial\, p}\right)$$

The Hessian matrix is given as below:

$$TP(\xi, p, T) = \begin{bmatrix} \frac{\partial^2 TP(\xi,p,T)}{\partial \xi^2} & \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial T} & \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial p} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial T^2} & \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial p} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial T} & \frac{\partial^2 TP(\xi,p,T)}{\partial p^2} \end{bmatrix}$$

Step 4: Determine feasibility of optimum

If the second-order conditions confirm concavity (i.e., negative semi-definiteness of the Hessian), then optimum solution exists.

Step 5: Iterate for New Solution (if Step 4 fails)

Adjust the parameter values or re-evaluate the problem setup and repeat Step 3 with updated values until the second-order conditions are satisfied.

Step 6: Declare the Optimum Solution

Once the necessary and sufficient conditions are met:

- Report on the optimal values of β∗, p∗ and T∗
- Verify feasibility with original constraints:

$p > 0, T > 0, \beta > 0$ and $M \geq T$.

7. Sensitivity Analysis

To evaluate the robustness of the optimal solution, a sensitivity analysis was conducted on the key decision variables β, p and T.

Mathematical concavity of the profit function

Mathematical justification for case-1, $M < T$.

$H_{11} = -5209.8224438198 < 0$

$$H_{12} = \begin{vmatrix} \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial p} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial p^2} \end{vmatrix} = 6551.61568164 > 0$$

$$H_{13} = \begin{vmatrix} \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial T^2} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial T} \end{vmatrix} = -79499.822614056 < 0$$

$$H_{21} = \begin{vmatrix} \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial T} & \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial p} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial T} & \frac{\partial^2 TP(\xi,p,T)}{\partial p^2} \end{vmatrix} = -1386.45861804 < 0$$

$$H_{22} = \begin{vmatrix} \frac{\partial^2 TP(\xi,p,T)}{\partial \xi^2} & \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial p} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial p^2} \end{vmatrix} = 351.009977316 > 0$$

$$H_{23} = \begin{vmatrix} \frac{\partial^2 TP(\xi,p,T)}{\partial \xi^2} & \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial T} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial T} \end{vmatrix} = -19521.73291858 < 0$$

$$H_{31} = \begin{vmatrix} \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial T} & \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial p} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial T^2} & \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial p} \end{vmatrix} = -383771.80272594 < 0$$

$$H_{32} = \begin{vmatrix} \frac{\partial^2 TP(\xi,p,T)}{\partial \xi^2} & \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial p} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial p} \end{vmatrix} = 15911.3616468 > 0$$

$$H_{33} = \begin{vmatrix} \frac{\partial^2 TP(\xi ,p,T)}{\partial \xi^2} & \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial T} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial T^2} \end{vmatrix} = -1194058.3989745$$

Mathematical justification for case-2, $M \geq T$

$$H_{11} = 3677130283.3449 > 0$$

$$H_{12} = \begin{vmatrix} \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial p} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial p^2} \end{vmatrix} = -1473998.9795732 < 0$$

$$H_{13} = \begin{vmatrix} \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial T^2} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial T} \end{vmatrix} = 19651451518.04856 > 0$$

$$H_{21} = \begin{vmatrix} \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial T} & \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial p} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial T} & \frac{\partial^2 TP(\xi,p,T)}{\partial p^2} \end{vmatrix} = -1473998.97957320477 < 0$$

$$H_{22} = \begin{vmatrix} \frac{\partial^2 TP(\xi ,p,T)}{\partial \xi^2} & \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial p} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial p^2} \end{vmatrix} = 594.78594764816 > 0$$

$$H_{23} = \begin{vmatrix} \frac{\partial^2 TP(\xi ,p,T)}{\partial \xi^2} & \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial T} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial p \partial T} \end{vmatrix} = -1043038.11450185 < 0$$

$$H_{31} = \begin{vmatrix} \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial T} & \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial p} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial T^2} & \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial p} \end{vmatrix} = 19651451518.04855 > 0$$

$$H_{32} = \begin{vmatrix} \frac{\partial^2 TP(\xi ,p,T)}{\partial \xi^2} & \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial p} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial p} \end{vmatrix} = -1043038.11450185 < 0$$

$$H_{33} = \begin{vmatrix} \frac{\partial^2 TP(\xi ,p,T)}{\partial \xi^2} & \frac{\partial^2 TP(\xi,p,T)}{\partial \xi \partial T} \\ \frac{\partial^2 TP(\xi,p,T)}{\partial T \partial \xi} & \frac{\partial^2 TP(\xi,p,T)}{\partial T^2} \end{vmatrix} = 13894664009.22294969 > 0$$

Hence for case 1, mathematically proved that the Hessain is negative definite and gets it's the maximum at the points $(0.0350189,\ 442.921, 263.673)$. Similarly, for the case-2 mathematically proved and gets it's the maximum at the points $(0.0372134, 313.887, 219.175)$. Concavity of the total profit with respect to the decision variables for the case-1 and case-2 are shown in the **Figures 4** to **9**.

8. Results and Discussion

***For case* 1:**

In this section, the numerical illustration has been done for both case-1 $M < T$ and case-2 $M \geq T$. To develop the mathematical model, the appropriate values of the following parameters have been chosen to show the concavity of the model based on the pervious literature which are given as follows:

$r = 0.01, \gamma = 0.5, x_2 = 2\ (per\ unit\ ton), \tau = 1(per\ unit\ ton), M = 0.3(\$\ per\ unit\ time), I_e = 10(\$\ per\ time), f = 5(per\ unit\ per\ cycle), \mu_1 = 6(per\ unit\ time), \mu_2 = 0.6(per\ unit\ time), H = 0.8(\$\ per\ unit), b = 0.4, \theta = 0.02\ (per\ unit\ kg), y = 1.2(per\ unit\ ton), \alpha = 35, \beta = 15, e_H = 0.3(ton\ per\ unit), \sigma = 20(\$\ per\ kg), x_1 = 2(per\ unit\ ton), d_1 = 100(Kilometers), e_t = 0.35(ton\ per\ unit), A = 110(\$/order)$.

$T = 0.0350189, \quad \xi = 442.921, \quad p = 263.673, \quad TP = 641070$

***For case* 2:** To develop the mathematical model we have taken appropriate value of the following parameters to show the concavity of the model.

$r = 0.01, \gamma = 0.5, x_2 = 2\ (per\ unit\ ton), \tau = 1(per\ unit\ ton), M = 0.3(\$\ per\ unit\ time), I_e = 10(\$\ per\ time), f = 5(per\ unit\ per\ cycle), \mu_1 = 6(per\ unit\ time), \mu_2 = 0.6(per\ unit\ time), H = 0.8(\$\ per\ unit), b = 0.4, \theta = 0.02(per\ unit\ kg), y = 1.2(per\ unit\ ton), \alpha = 35, \beta = 15, e_H = 0.3(ton\ per\ unit), \sigma = 20(\$\ per\ kg), x_1 = 2(per\ unit\ ton), d_1 = 100(Kilometers), e_t = 0.35(ton\ per\ unit), A = 110(\$/order)$.

$T = 0.0372134, \quad \xi = 313.887, \quad p = 219.175, \quad TP = 307390$

The figures and tables have been provided for showing the impact of sensitive parameters such as *t, p* and ξ on cycle time and cost function. The **Figures 4** to **9** show the concavity of the total profit (*TP*) function on the decision variables *t, p* and ξ. The surface plot shows the variation of *TP* with these parameters. In both cases, the surface shows a peak, indicating the existence of a single optimal solution. The concavity confirms that the optimization model has a well-defined maximum, thus ensuring the stability of the solution. This visualization can be used to validate the behavior of the model under different scenarios, thus supporting the existence of an optimal EOQ configuration in an uncertain environment. **Figure 4** shows the concavity between total cycle length *T* and selling price of the items *p* with the total profit function *TP*. It is clear by above figure the total cycle length *T* increase with selling price then total profit highly increases. **Figure 5** shows the concavity between total cycle length *T* and preservation technology cost ξ with the total profit function *TP*. The total cycle length *increases* with preservation factor then total profit increases. In **Figure 6**, the graph depicts the selling price of items *p* and preservation technology cost ξ with the total profit function *TP*. It is clear by **Figure 6** the selling price of items *p* increases with preservation factor then total profit slightly changed.

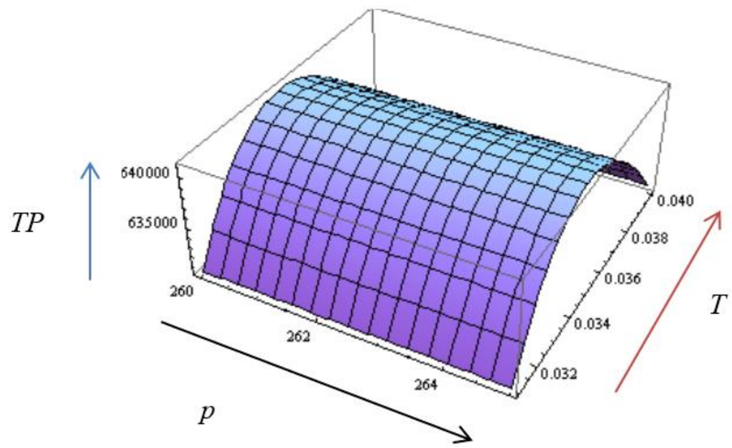

Figure 4. Concavity between *T* & *P* with *TP*.

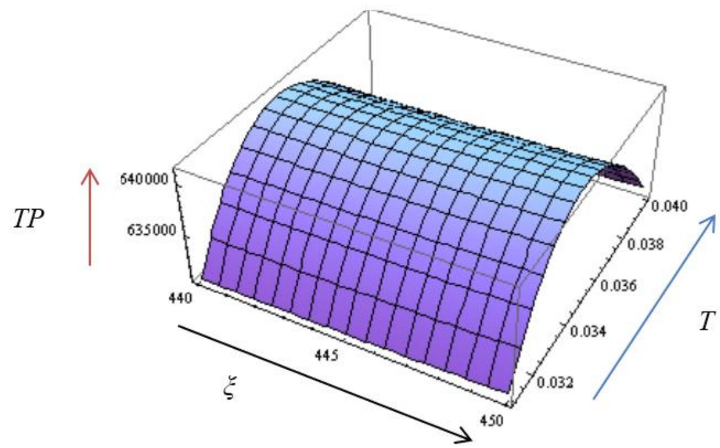

Figure 5. Concavity between *ξ* & *T* with *TP*.

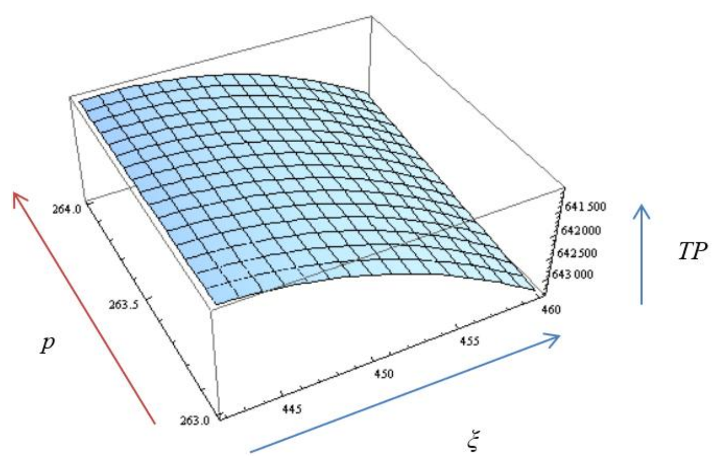

Figure 6. Graph between *p* & *ξ* with *TP*.

Figure 7 shows the concavity between total cycle length T and preservation technology cost ξ with the total profit function TP. The total cycle length T increase with preservation factor ξ then total profit sensitively increases. **Figure 8** shows the concavity between total cycle length T and selling price of the items p with the total profit function TP. It is clear by **Figure 8** the total cycle length *increases* with selling price then total profit sensitively increases.

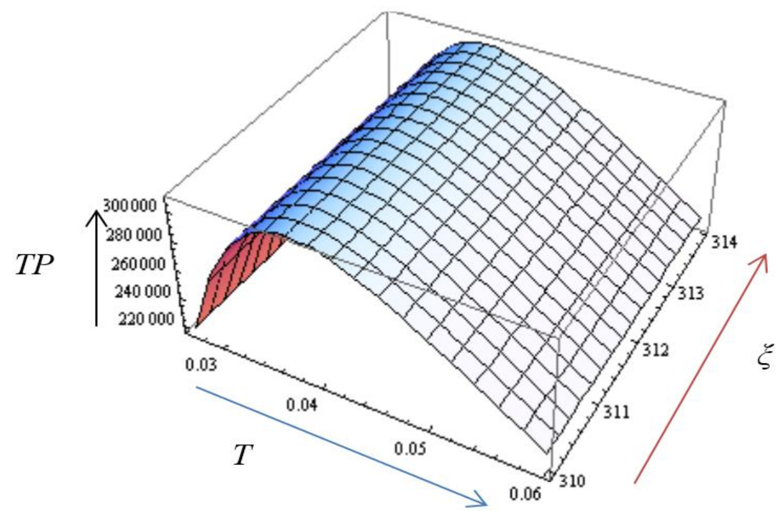

Figure 7. Concavity between T & ξ with TP.

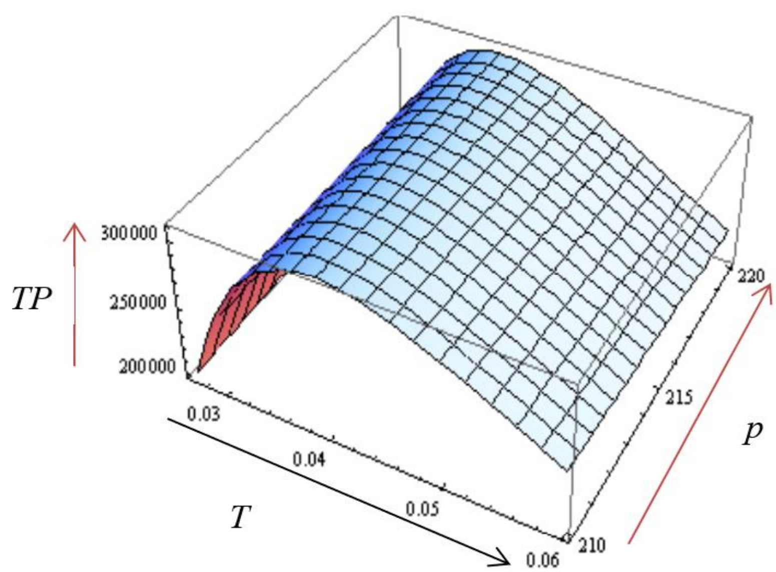

Figure 8. Concavity between T & p with TP.

Figure 9 illustrates the concave relationship between preservation technology cost (ξ), selling price (p), and the total profit function (TP). It is evident from the figure that as the preservation technology cost (ξ)

increases along with the selling price, the total profit increases significantly and shows high sensitivity to these changes.

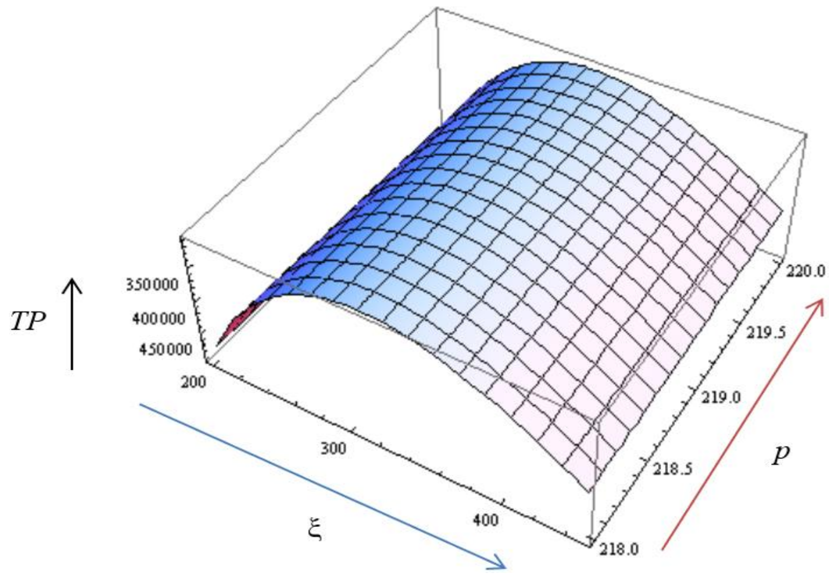

Figure 9. Graph between p & ξ with TP.

Table 1. Impact of parameter variations on cycle time $T$and total profit TP for case-1, $M < T$.

S. No.	Parameters	Changes	T	ξ	p	TP
1.	θ	0.011	0.0350168	442.949	263.773	641151
		0.020	0.0350189	442.921	263.673	641070
		0.031	0.0350298	442.826	263.571	640798
2.	R	0.009	0.0284505	492.378	281.209	972303
		0.010	0.0350189	442.921	263.673	641070
		0.011	0.0422320	402.434	249.562	440233
3.	γ	0.41	0.0350066	442.978	275.279	641198
		0.50	0.0350189	442.921	263.673	641070
		0.61	0.0350787	442.882	253.251	640957
4.	B	0.39	0.0427326	361.450	248.824	429949
		0.40	0.0350189	442.921	263.673	641070
		0.50	0.0435860	354.208	247.441	413216
5.	M	0.299	0.0347882	445.838	264.692	649506
		0.300	0.0350189	442.921	263.673	641070
		0.310	0.0373686	415.265	254.068	563829
6.	H	0.79	0.0354632	437.407	262.712	627736
		0.80	0.0350189	442.921	263.673	641070
		0.81	0.0345855	448.434	264.629	657079
7.	y	1.101	0.0350186	442.918	275.254	641186
		1.200	0.0350189	442.921	263.673	641070
		1.300	0.0350188	442.924	253.274	640956
8.	σ	19	0.0335003	442.938	263.725	669600
		20	0.0350189	442.921	263.673	641070
		21	0.0365345	442.903	263.625	614962

It is observed from **Table 1** increment in the parameter θ then T and TP both slightly increase and other parameters ξ and p show the decreasing trend. On the other hand, increasing the values of r, γ and M, total cycle length T highly affected and increases but p, ξ & TP are also highly affected and decreased. As per increasing the values of b, T increase but other parameters are highly affected and decreased. Moreover, increment in b shows the decrement in the values of T and reverse effect for other parameters. As per increment in H, T decreases and remaining parameters show an increasing trend. Minor changes have been observed with respect to y in all parameters. As σ approaches to the higher values, the values of ξ attains lower values and reverse pattern is followed by T, P and TP.

Table 2. Impact of parameter variations on cycle time T and total profit TP for case-2, $M \geq T$.

S. No.	Parameters	Changes	T	ξ	p	TP
1.	θ	0.01	0.0372108	313.919	219.177	307457
		0.02	0.0372134	313.887	219.175	307390
		0.03	0.0372160	313.856	219.173	307322
2.	r	0.009	0.0294682	371.448	238.170	538924
		0.010	0.0372134	313.887	219.175	307390
		0.011	0.0463332	266.202	204.195	179715
3.	B	0.3	0.0271163	454.778	245.634	657100
		0.4	0.0372134	313.887	219.175	307390
		0.5	0.0481410	231.093	201.899	163311
4.	M	0.29	0.0348686	335.372	226.165	349704
		0.30	0.0372134	313.887	219.175	307390
		0.31	0.0396282	294.417	212.962	271399
5.	H	0.7	0.0433007	262.324	208.528	212344
		0.8	0.0372134	313.887	219.175	307390
		0.9	0.0326574	366.011	229.410	421419
6.	σ	19	0.0353303	318.626	220.706	332767
		20	0.0372134	313.887	219.175	307390
		21	0.0391225	309.222	217.675	284531
7.	I_e	9	0.0374624	314.513	220.121	312863
		10	0.0372134	313.887	219.175	307390
		11	0.0385342	315.745	221.543	334562

Table 3. Sensitivity analysis of parameter variations using directional arrows for case-1 $M < T$.

S. No.	Parameters	Changes	T	ξ	p	TP
1.	θ	↓	↓	↑	↑	↑
		↑	↑	↓	↓	↓
2.	r	↓	↓	↑	↑	↑
		↑	↑	↓	↓	↓
3.	γ	↓	↓	↑	↑	↑
		↑	↑	↓	↓	↓
4.	b	↓	↑	↓	↓	↓
		↑	↑	↓	↓	↓
5.	M	↓	↓	↑	↑	↑
		↑	↑	↓	↓	↓
6.	H	↓	↑	↓	↓	↓
		↑	↑	↑	↑	↑
7.	y	↓	↓	↓	↑	↑
		↑	↓	↑	↓	↓
8.	σ	↓	↓	↑	↑	↑
		↑	↑	↓	↓	↓

Table 4. Sensitivity analysis of parameter variations using directional arrows for case-2 $M \geq T$.

S. No.	Parameters	Changes	T	ξ	p	TP
1.	θ	↓	↓	↑	↑	↑
		↑	↑	↓	↓	↓
2.	r	↓	↓	↑	↑	↑
		↑	↑	↓	↓	↓
3.	b	↓	↓	↑	↑	↑
		↑	↑	↓	↓	↓
4.	M	↓	↓	↑	↑	↑
		↑	↑	↓	↓	↓
5.	H	↓	↑	↓	↓	↓
		↑	↓	↑	↑	↑
6.	σ	↓	↓	↑	↑	↑
		↑	↑	↓	↓	↓
7.	I_e	↓	↑	↑	↑	↑
		↑	↑	↑	↑	↑

It is observed from **Table 2**, the increment in deterioration parameter θ then only T slightly increases but remaining parameters decreased. Also, on the other hand increment in the inflation rate r, M, σ & b then only T sensitively increases and remaining parameters p, ξ & TP sensitively decreases. As I_e, takes higher values then all the inventory parameters first decrease and then increase sharply. Additionally, the observations from the sensitivity analysis in **Tables 1** and **2** are visually represented in **Tables 3** and **4** respectively using an upward arrow indicate an increase, while a downward arrow denotes a decrease. This provides a systematic and intuitive view, allowing readers to easily interpret the changes in sensitive parameters and their impact on the model outcomes.

9. Managerial Insights

This section highlights subtle but critical observations that emerge from the detailed analysis of the model behavior under various parameter settings disused in previous section. Optimal green technology investment and preservation technology investment maximizes profit while lowering carbon emissions. Retailers should invest in *GTI* and *PTC* to make maximum profit.

- To increase the profits of this system, retailers should decrease the inventory costs. And from preceding research that higher values of holding cost, ordering cost, and purchasing cost, can be decrease the entire profit. Resultant we can say that retailers must keep the low cost of inventory parameters.
- The retailer may undoubtedly fix the optimum selling price of the items keeping in mind to profit. And maximum demand provides the maximum profit.
- The age of deteriorating items plays a vital role from a business point of view. The items shelf life is higher, then consequently it can be useful to get much profit because the retailer is getting more period for selling the items.
- Distance between suppler to retailer's is the key factor for retailers to get the maximum profit. Long distance reduces the profit because of carbon emission, consumption of fuel, delivery time and more other expenses. Here, minimum distance and permissible delay are beneficial to increase the retailer's profit.
- From a managerial perspective, the results suggest that maintaining $M < T$ yields better system performance in uncertain environments. Additionally, marginal changes in shelf-life control and replenishment timing can lead to noticeable improvements in profitability, provided the system operates near the identified optimal zones.

10. Conclusion

In the present study, an economic order quantity model for deteriorating items under the inflationary environment, preservation technology and *GTI* have been developed. It is assumed that the perishable items are deteriorating, and demand function is dependent on selling price and *GTI.* In the present study, optimal selling price, ordering quantity, preservation technology cost and *GTI* cost under the impact of inflation has been determined. The numerical examples are solved to validate our model. The sensitivity analysis is carried out to optimal strategies. One can conclude that the total profit, selling price, cycle length and preservation technology are highly affected by inflation and preservation technology constant in the trade credit case first. Also, in the second case all these parameters are highly affected by inflation, preservation technology constant, and trade credit period. Further noticed that the carbon emission and deterioration affected by *GTI* and preservation technology. Preservation technology reduces the deterioration of items. In the present study, the trade credit period is highly helpful to make maximum profit and short delivery distance are too beneficial for retailer profit. Graphical presentation shows the concavity of this model for both cases.

In the future this model may be extended with different demands and other parameters like time dependent demand, stock level dependent demand, and fuzzy based demand. Further this study may be beneficial with advance payment policy and other carbon emission policies. The present study can be further extended by analyzing the impact of investing in green technology on inventory management and carbon emissions in different industries.

Conflicts of Interest

The authors confirm that there is no conflict of interest to declare for this publication.

Acknowledgments

This research did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors. The author would like to thank the editor and anonymous reviewers for their comments that help improve the quality of this work.

AI Disclosure

During the preparation of this work the authors used generative AI to improve the language of the article. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

References

Ahmad, N., Sangal, I., Sharma, K., Jaysawal, M.K., Kumar, S., Pal, S.K., & Alam, K. (2023). A green realistic inventory model with preservation technology for deteriorating items under carbon emission. *Materials Today: Proceedings.* https://doi.org/10.1016/j.matpr.2023.03.017. (In press).

Bharti, D., Chaudhary, A., Singh, S.R., & Singhal, S. (2024). Green supply chain management model on reliability and demand dependent on time with carbon tax. *AIP Conference Proceedings*, *3081*(1), 090002. https://doi.org/10.1063/5.0196089.

Bhawaria, S., & Rathore, H. (2022). Production inventory model for deteriorating items with hybrid-type demand and partially backlogged shortages. In: Sahni, M., Merigó, J.M., Sahni, R., Verma, R. (eds) *Mathematical Modeling, Computational Intelligence Techniques and Renewable Energy*. Springer, Singapore, pp. 229-240. ISBN: 978-981-16-5952-2. https://doi.org/10.1007/978-981-16-5952-2_20.

Bhawaria, S., & Rathore, H. (2023). Economic production quantity model for deteriorating items with trade-credit policy and preservation technology under the effect of inflation. *AIP Conference, 2699*(1), 020026. https://doi.org/10.1063/5.0154109.

Bhawaria, S., Rathore, H., & Kumar, G. (2023). A reverse logistic inventory model with stock and selling price dependent demand under the impact of inflation and learning for non-instantaneous deteriorating products. *International Journal of Simulation and Process Modelling, 20*(3), 172-181. https://doi.org/10.1504/ijspm.2023.136930.

Bonney, M., & Jaber, M.Y. (2011). Environmentally responsible inventory models: non-classical models for a non-classical era. *International Journal of Production Economics, 133*(1), 43-53. https://doi.org/10.1016/j.ijpe.2009.10.033.

Chen, X., Benjaafar, S., & Elomri, A. (2013). The carbon-constrained EOQ. *Operations Research Letters, 41*(2), 172-179. https://doi.org/10.1016/j.orl.2012.12.003.

Dao, V., Langella, I., & Carbo, J. (2011). From green to sustainability: information technology and an integrated sustainability framework. *The Journal of Strategic Information Systems, 20*(1), 63-79. https://doi.org/10.1016/j.jsis.2011.01.002.

Esmaeilnezhad, E., Choi, H.J., Schaffie, M., Gholizadeh, M., & Ranjbar, M. (2017). Characteristics and applications of magnetized water as a green technology. *Journal of Cleaner Production, 161*, 908-921. https://doi.org/10.1016/j.jclepro.2017.05.166.

Gupta, A., & Khanna, A. (2024). A holistic approach to sustainable manufacturing: rework, green technology, and carbon policies. *Expert Systems with Applications, 244,* 122943. https://doi.org/10.1016/j.eswa.2023.122943.

Hasan, M.R., Roy, T.C., Daryanto, Y., & Wee, H.M. (2021). Optimizing inventory level and technology investment under a carbon tax, cap-and-trade and strict carbon limit regulations. *Sustainable Production and Consumption, 25,* 604-621. https://doi.org/10.1016/j.spc.2020.12.005.

Jeong, D.H., Kwon, O.J., & Kwon, Y.I. (2012). Network analysis of green technology using keyword of green field. *The Journal of the Korea Contents Association, 12*(11)*,* 511-518. https://doi.org/10.5392/jkca.2012.12.11.511.

Jiang, Y., Guo, Y., Bashir, M.F., & Shahbaz, M. (2024). Do renewable energy, environmental regulations and green innovation matter for China's zero carbon transition: evidence from green total factor productivity. *Journal of Environmental Management, 352,* 120030. https://doi.org/10.1016/j.jenvman/.2024.120030.

Kar, C., De, M., Maiti, M., & Das, P. (2024). Multi-objective perishable multi-item green inventory models with uncertain finite time horizons and constraints by neutrosophic optimisation approach. *International Journal of Mathematics in Operational Research, 27*(2), 167-198. https://doi.org/10.1504/ijmor.2024.137053.

Kumar, A., Yadav, A.S., & Yadav, D. (2024a). A two-storage production inventory model for deteriorating items with time and selling price dependent demand using flower pollination optimization. *Journal of Research Administration Society of Research Administrator's International, 6*(1), 2950-2966.

Kumar, N., Kumari, R., & Yadav, D. (2024b). Lot sizing model for multiple products over finite planning horizon under the effect of learning and time-value of money with cap-and-trade and carbon tax regulations: a fuzzy framework. *International Journal of Operational Research*, *49*(2), 231-264. https://doi.org/10.1504/ijor.2021.10041538.

Kumar, P., Gupta, M.M., Yadav, D., & Kumar, V. (2024c). Benefits of preservation technology, reworking, and waste management in sustainable production-inventory system in inflationary environment. *AIP Conference Proceedings*, *3081*(1), 080002. https://doi.org/10.1063/5.0196349.

Kumar, S., Sami, S., Agarwal, S., & Yadav, D. (2023a). Sustainable fuzzy inventory model for deteriorating item with partial backordering along with social and environmental responsibility under the effect of learning. *Alexandria Engineering Journal*, *69*, 221-241. https://doi.org/10.1016/j.aej.2022.11.023.

Kumar, S., Singh, S.R., Agarwal, S., & Yadav, D. (2023b). Joint effect of selling price and promotional efforts on retailer's inventory control policy with trade credit, time-dependent holding cost, and partial backlogging under inflation. *RAIRO-Operations Research*, *57*(3), 1491-1522. https://doi.org/10.1051/ro/2023066.

Lekaki, D., Kastori, M., Papadimitriou, G., Mellios, G., Guizzardi, D., Muntean, M., Crippa, M., Oreggioni, G., & Ntziachristos, L. (2024). Road transport emissions in EDGAR (Emissions Database for Global Atmospheric Research). *Atmospheric Environment*, *324*, 120422. https://doi.org/10.1016/j.atmosenv.2024.120422.

Li, L., Wang, Y., Wang, E., Zhang, H., Wang, C., & Li, Y. (2024). Towards a greener aging society: a dynamic and multilevel analysis of consumption carbon emissions among China's aging population. *Sustainable Cities and Society, 102,* 105217. https://doi.org/10.1016/j.scs.2024.105217.

Lin, P.C., & Bai, H.J. (2024). Emissions intensity comparisons and consumption-based CO_2 accounting of transportation services. *Maritime Economics & Logistics, 26*(1), 131-150. https://doi.org/10.1057/s41278-023-00259-9.

Liu, J.B., Liu, B.R., & Lee, C.C. (2024). Efficiency evaluation of China's transportation system considering carbon emissions: evidence from big data analytics methods. *Science of the Total Environment*, *922*, 171031. https://doi.org/10.1016/j.scitotenv.2024.171031.

Lu, H., Xiao, C., Jiao, L., Du, X., & Huang, A. (2024). Spatial-temporal evolution analysis of the impact of smart transportation policies on urban carbon emissions. *Sustainable Cities and Society, 101*, 105177. https://doi.org/10.1016/j.scs.2024.105177.

Mashud, A.H.M., Chakrabortty, R.K., Hussain, O.K., & Choi, T.M. (2024). Reducing emissions from production and distribution in three-echelon supply chains. *International Journal of Production Economics, 271,* 109181. https://doi.org/10.1016/j.ijpe.2024.109181.

Mendis, M.S., Abeyrathna, W., Halwatura, R.U., Amarasekara, H.S., Somadewa, R., & Jayasinghe, R. (2024). Accumulate and consolidate the traditional vernacular timber preservation technologies through a field survey. *Heliyon, 10*(1), e23907. https://doi.org/10.1016/j.heliyon.2023.e23907.

Muthusamy, P., Murugesan, V., & Selvaraj, V. (2024). Optimal production–inventory decision with shortage for deterioration item and effect of carbon emission policy combination with green technology. *Environment, Development and Sustainability*, *26*(9), 23701-23766. https://doi.org/10.1007/s10668-023-03621-2.

Padiyar, S.V.S., Kuraie, V.C., Makholia, D., Singh, S.R., Singh, V., & Joshi, N. (2024). An imperfect production inventory model for instantaneous deteriorating items with preservation investment under inflation on time value of money. *Contemporary Mathematics, 5*(2), 2271-2295. https://doi.org/10.37256/cm.5220243274.

Pal, D., Manna, A.K., Ali, I., Roy, P., & Shaikh, A.A. (2024). A two-warehouse inventory model with credit policy and inflation effect. *Decision Analytics Journal, 10,* 100406. https://doi.org/10.1016/j.dajour.2024.100406.

Peng, Y., Wang, Y., Chen, H., Wang, L., Luo, B., Tong, H., Zou, Y., Lei, Z., & Chen, S. (2024). Carbon reduction potential of a rain garden: a cradle-to-grave life cycle carbon footprint assessment. *Journal of Cleaner Production*, *434*, 139806. https://doi.org/10.1016/j.jclepro.2023.139806.

Pervin, M. (2024). A sustainable deteriorating inventory model with backorder and controllable carbon emission by using green technology. *Environment, Development and Sustainability,* 1-37. https://doi.org/10.1007/s10668-024-04717-z.

Priyan, S., Matahen, R., Priyanshu, D., & Mouqdadi, M. (2024). Environmental strategies for a healthcare system with green technology investment and pandemic effects. *Innovation and Green Development, 3*(1)*,* 100113. https://doi.org/10.1016/j.igd.2023.100113.

Rathore, H., Meedal, T., Bhawaria, S., & Sharma, R.S.A. (2024). An optimal inventory policy with ramp type demand rate and time varying holding cost in two-warehousing environment. *Proceedings of the Indian National Science Academy, 90*(4), 869-874. https://doi.org/10.1007/s43538-024-00242-9.

Roy, B., & Ghosh, N. (2024). Unequal shipment policy in a sustainable production inventory system considering defective items and multi-level price breaks*. International Journal of Systems Science: Operations & Logistics, 11*(1), 2310627. https://doi.org/10.1080/23302674.2024.2310627.

Roy, B., De, S.K., Rajput, N., & Bartwal, A. (2024). A carbon sensitive transport-based deteriorating supply chain model under type-2 fuzzy bi-matrix game. *International Journal of Management Science and Engineering Management, 19*(4), 333-349. https://doi.org/10.1080/17509653.2024.2336958.

San-José, L.A., Sicilia, J., Cárdenas-Barrón, L.E., & González-de-la-Rosa, M. (2024). A sustainable inventory model for deteriorating items with power demand and full backlogging under a carbon emission tax. *International Journal of Production Economics, 268*, 109098. https://doi.org/10.1016/j.ijpe.2023.109098.

Sebatjane, M. (2024). Three-echelon circular economic production–inventory model for deteriorating items with imperfect quality and carbon emissions considerations under various emissions policies. *Expert Systems with Applications, 252*(Part A), 124162. https://doi.org/10.1016/j.eswa.2024.124162.

Shah, N.H., & Jani, M.Y. (2016). Optimal ordering for deteriorating items of fixed-life with quadratic demand and two-level trade credit: optimal ordering. Two-level trade credits. In: Mittal, M., Shah, N. (eds) *Optimal Inventory Control and Management Techniques* (pp. 1-16). IGI Global Scientific Publishing. https://doi.org/10.4018/978-1-4666-9888-8.ch001.

Sharma, M.K., & Mandal, D. (2024). An inventory model with preservation technology investments and stock-varying demand under advanced payment scheme. *OPSEARCH,* 1-22. https://doi.org/10.1007/s12597-024-00743-7.

Sharma, R.S.A., & Rathore, H. (2024). An inventory model for deteriorating items with hybrid type demand and return in preservation technology investment. *Proceedings of the Indian National Science Academy*, *90*(4), 905-910. https://doi.org/10.1007/s43538-024-00252-7.

Singh, R., & Mishra, V.K. (2022). Sustainable integrated inventory model for substitutable deteriorating items considering both transport and industry carbon emissions. *Journal of Systems Science and Systems Engineering*, *31*(3), 267-287. https://doi.org/10.1007/s11518-022-5531-y.

Singh, S.R., & Chaudhary, R. (2021). Low carbon production inventory model for imperfect quality deteriorating items with the screening process. *IOP Conference Series: Materials Science and Engineering*, *1149*(1), 012010. https://doi.org/10.1088/1757-899x/1149/1/012010.

Song, X., Du, S., Deng, C., Shen, P., Xie, M., Zhao, C., Chen, C., & Liu, X. (2025). Carbon emissions in China's steel industry from a life cycle perspective: carbon footprint insights. *Journal of Environmental Sciences*, *148*, 650-664. https://doi.org/10.1016/j.jes.2023.04.027.

Soni, H., Shah, N.H., & Jaggi, C.K. (2010). Inventory models and trade credit: a review. *Control and Cybernetics, 39*(3), 867-882.

Xu, H., Chen, Y., Chen, S., & Luan, G. (2024). Detection of motor vehicle carbon emissions on urban road sections based on video sensing technology. In *Seventh International Conference on Traffic Engineering and Transportation System* (Vol. 13064, pp. 183-189). SPIE. Dalian, China. https://doi.org/10.1117/12.3015890.

Yadav, A.S., Kumar, A., Yadav, K.K., & Rathee, S. (2023). Optimization of an inventory model for deteriorating items with both selling price and time-sensitive demand and carbon emission under green technology investment. *International Journal on Interactive Design and Manufacturing, 19,* 1297-1313. https://doi.org/10.1007/s12008-023-01689-8.

Yadav, D., Kumari, R., Kumar, N., & Sarkar, B. (2021). Reduction of waste and carbon emission through the selection of items with cross-price elasticity of demand to form a sustainable supply chain with preservation technology. *Journal of Cleaner Production*, *297*, 126298. https://doi.org/10.1016/j.jclepro.2021.126298.

Yang, C.T., Gu, M., Lee, T.S., & Lu, C.J. (2024). Multistage global supply chain inventory model with the impact of carbon tariffs for deteriorating items. *Journal of Industrial and Management Optimization, 20*(3), 1271-1295. https://doi.org/10.3934/jimo.2023124.

Zehner, O. (2011). *Unintended consequences of green technologies*. Sage, London, https://doi.org/10.1007/978-1-4471-5532-4.

Zhang, L., Weng, D., Xu, Y., Hong, B., Wang, S., Hu, X., Zhang, Y., & Wang, Z. (2024). Spatio-temporal evolution characteristics of carbon emissions from road transportation in the mainland of China from 2006 to 2021. *Science of the Total Environment*, *917*, 170430. https://doi.org/10.1016/j.scitotenv.2024.170430.

Zhao, C., Tang, J., Gao, W., Zeng, Y., & Li, Z. (2024). Many-objective optimization of multi-mode public transportation 634 under carbon emission reduction. *Energy, 286*, 129627. https://doi.org/10.1016/j.energy.2023.129627.

Publisher's Note- Ram Arti Publishers remains neutral regarding jurisdictional claims in published maps and institutional affiliations.