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Inventory Management of Perishable Products under Inflation and Preservation Technology

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ABSTRACT: This study is on an inventory control model that shows how demand is related to both the selling price of the assumed commodities and the amount of stock on hand. There is also a temporal component to demand. Consequently, time, stock, and price are the three independent variables that drive demand. The model with partially backlogged data and an exponentially declining rate has also been used in this research to explore the shortage under the stated assumption. The effects of inflation are also considered. Our model's underlying premise is that there will always be degradation due to the impact of preservation techniques. The total average cost is calculated as a function of an independent variable that must be minimized in the inventory system for our model to work. In order to bolster our conclusions, sensitivity analysis using a perfect example was also presented when building the computation process to examine the influence of different factors.

Key Words: Inventory, preservation technology, inflation, stock dependent demand.

Contents

1. Introduction

Demand plays a very important role in managing the inventory. The selling of a product depends on various factors, which play a very crucial role in the demand for a product. Demand for items can depend on the price of the product; if the price is high, then the customer avoids such a product. If the price is lower, the customer will prefer this kind of product. If the stock is in less quantity, then demand increases, and an excess quantity of product leads to lower demand. So again, we can say stock availability plays a major role in the demand for products.

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2. Literature Review

Singh and Sharma presented an inventory strategy with a primary focus on trade and credit interactions between suppliers and customers [24]. This particular strategy is designed for scenarios in which the stock on hand affects the demand for perishable items. Aarya & Kumar [1] discussed the approach that assists companies in satisfying consumer demand effectively while maximizing revenue by optimizing production schedules, pricing policies, and inventory levels. Klein & Verdi *et al.* [22] provided a posteriori error estimates for a Penrose–Fife phase-field system, while Haque *et al.* [16] explored the generalized neutrosophic Laplace transform in an EOQ model with price- and deterioration-dependent demand. While Palanivel *et al.* [15] suggest a two-warehouse inventory model that incorporates non-degradable products, stock-dependent demand, shortages, and inflation. Khurana and Chaudhary [7] give a time-dependent demand model for stock degradation and shortages at the inventory order level. An inventory model with shortages and preservation technology investment with a controllable deterioration rate was presented by Priyamvada *et al.* [17]. An EOQ model was created by Shah and Naik [30] for deteriorating commodities with complete upfront payment and discount. Sarkar [31] concentrated on the imperfect production, stock-dependent demand, and EOQ model with payment delays. For supply chain and inventory management, Sharma & Jain [33] deployed AI and data analytics. Generally, Shortage cases were avoided by researchers in the initial stage of research. It was found that. But in real-life situations, a shortage occurs at a point in time. So, the shortage cannot be avoided when discussing the case of the model of inventory items of deteriorating items. Two types of situations or scenarios might arise during a stockout: a client backlog and a loss of sales. This was seen after a while. Sales lost indicate impatient consumers considering purchasing from another provider. Backlog cases involve customers returning to fulfil their needs. While demand arises amid shortages, it is generally believed that demand is entirely lost or fully backlogged. In stockout situations, some customers return, while others travel to other sellers to complete their purchases. Jaggi *et al.* [14] devised pricing and inventory methods with restricted capacity and a time-proportional backlog rate.

An inventory model that combined lost sales and back orders based on a real-world scenario was provided by Padmanabhan and Virat [32]. In which inflation is the key component in managing the inventory system, generally, researchers avoid the effect of inflation in calculating the total cost. But in a real-life situation, inflation can't be ignored. So, in the past couple of years, researchers have focused on inflation and developing various models of deteriorating items.

Kumar *et al.* [5] emphasize the supply chain of 3 echelon kinds of models with limited available storage capacity, with the lead time under the inflationary environment. Park [26] discusses how inflation affects the EOQ concept in the situation of trade credit between buyers and sellers regarding financing issues. Singh. Sharma [27] discussed a variable-based production of an inventory model, and also the demand rate under inflation, with the practical situation of the daily life of the inventory problem discussed. For unpreserved items with scarcity cases, in the face of inflation. A non-instantaneous degrading item inventory model with partial backlog, payment delays, inflation-dependent demand, and customer returns was created by Ghoreishi *et al.* [3]. In a stock-dependent consumption economy, Patra and Ratha [16] proposed an inventory replenishment policy for degrading items. In an inflationary context, Rizwanullah et al.'s [21] supply-chain two-warehouse inventory model for degrading items on an exponential time function with shortage and partial backlog is presented. A variable-based inventory model, as well as a demand rate under inflation and a real-world example of an inventory problem, were covered by Singh and Sharma [23]. In order to address the production model in the event of shortages related to inflationary conditions, Singh *et al.* [25] constructed a warehouse model without a perfect model using a fuzzy technique. Preservation technology has long been recognized as a crucial factor in optimizing inventory management, particularly for perishable goods. Historically, research in this area has focused on various methods to extend the shelf life and maintain the quality of products. Early studies examined basic techniques such as refrigeration and controlled atmospheres, which laid the groundwork for modern preservation strategies. Today, preservation technology encompasses advanced storage solutions, precise temperature regulation, and innovative packaging methods that significantly slow the deterioration process. These advancements have allowed businesses to minimize waste, improve product availability, and optimize inventory levels. The integration of these technologies not only results in substantial cost savings but also enhances customer satisfaction. Kumar *et al.* [6] developed the fuzzy lot-sizing model, which optimizes production quantities for goods within a set timeframe, considering setup costs, inventory holding costs, time-value of money, worker experience, and environmental regulations, providing a valuable tool for efficient manufacturing planning. Mahata & Debnath [11] worked on research with the aim of optimizing production planning for factories, addressing challenges like defective items and cost uncertainties. It explores R&D expenditures and screening impact on inventory management, aiming to minimize costs by reducing defects and improving screening. Mashud *et al.* [12] focused on the model, which helps and aids businesses in managing non-instantaneously deteriorating inventory by considering preservation technology costs, trade credit benefits, and partial back-ordering drawbacks, enabling informed decisions for optimal inventory management and profit maximization.

Research by Mohanty *et al.* [13] offers a valuable tool for businesses managing deteriorating inventory with unpredictable demand. By considering the benefits of trade credit, the impact of deterioration, and the effectiveness of preservation technology, the model helps companies develop optimal inventory strategies. This can lead to improved cash flow management, minimized losses from deterioration, and ultimately, maximized profits in a dynamic market environment. The research developed by Rahman & Rashid [21] encourages businesses to adopt a data-driven inventory management approach for perishable products, resulting in increased profits and consistent access to fresh products for consumers. Pervin *et al.* [20] made the assumption in their research paper, which focused on the integrated vendor-buyer model that optimizes supply chain management in dynamic market environments with quadratic demand, quality control, and preservation technology advancements. It minimizes overall costs, improves customer satisfaction by minimizing stockouts, and fosters stronger partnerships through collaboration and information sharing. This research offers valuable insights for businesses. Sindhuja & Arathi [23] developed research that provides a valuable tool for businesses dealing with perishable products, enabling data-driven decisions to optimize inventory strategies, maximize profits, and minimize waste. The research by Sebatjane [27] offers insights for optimizing a three-echelon food supply chain by considering preservation technology's impact on lot-sizing and shipment strategies. It helps businesses reduce waste, optimize production and shipping, and deliver fresher products. This data-driven decision promotes sustainability, efficiency, and fresher food delivery.

An inventory model for depreciating commodities was presented by Kumar *et al.* [8], taking trade credit and multivariate demand into account. Muriana [14] created an inventory management plan based on the Weibull deterioration, restricted recovery assumptions, and residual life of perishable commodities. Additionally, a scheme for environmentally responsible advance payments was suggested. Roy *et al.* [22] developed a 3D titanium aluminium carbide MXene network for fluorouracil detection, while Sundaresan *et al.* [28] discovered COVID-19's impact on inventory models and payment facilities. Whereas, De *et al.* [2] investigate the impact of inflation under COVID-19's supply chain challenge. Additionally, Haque *et al.* [4] discovered the model with price sensitivity demand environment. On the other hand, Khurana *et al.* [7] highlighted the issue related to the stock depended demand under shortage case with partial backlog situation. Kumar *et al.* [9] & [10] address the issue related to the carbon emission and sustainable development in inventory model respectively. Palanivel *et al.* [15] & [17] integrated the stock sensitivity demand with two warehouse system and preservation investment respectively. Also, Inventory model with Sustainable environment with carbon tax policy has been investigate by the Rani *et al.* [19]. Shaikh *et al.* [29] focused the advance payment situation in his model under preservation investment. Whereas, Sebatjane, [32] highlighted the carbon emission and sustainable development with imperfect inventory items in Three-echelon circular economic production–inventory model. Recent studies on inventory management have increasingly focused on deteriorating and perishable items by incorporating real-world factors such as inflation, pricing strategies, trade credit, and sustainability. Shekhar *et al.* [34] proposed a unified manufacturer–retailer model with two-tier trade credit and reverse logistics under inflation, highlighting the benefits of supply chain coordination. Verma *et al.* [35] & [36] developed EOQ-based models considering selling-price-dependent demand, variable holding costs, deterioration, and partial backlogging, demonstrating the strong influence of pricing and customer behaviour on inventory decisions. Verma *et al.* [37] analysed time-proportional deterioration with varying demand patterns, while Verma *et al.* [38] incorporated stock-dependent demand and trade credit to improve ordering policies. More recent work by Verma *et al.* [39] and [40] emphasized eco-friendly supply chains, preservation investment, carbon taxation, and inflationary effects in multi-level production systems. Collectively, these studies show a shift toward integrated, sustainable, and inflation-aware inventory models, forming the foundation for the present research.

In this paper, the impact of the inflationary environment, preservation technology, and partial backlogging on the inventory system of deteriorating items has been discussed. The multivariate demand, which depends on stock, time, and price, has been considered. To the best of our belief, no researcher has worked on the concept of customer returns with two different demands in shortage and no shortage period under inflation. In the shortage phase, time and price-dependent demand rates have been assumed, while in the shortage phase, the demand rate depends on the stock level as well as time and price.

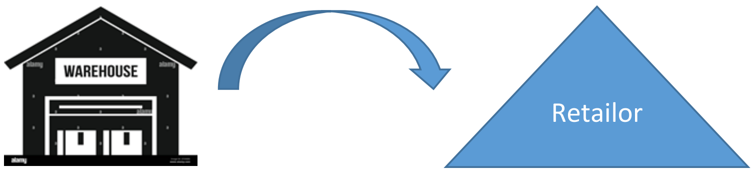

Figure 1: Supply chain process from the warehouse to the retailer.

All of the specified assumptions and notations used throughout the paper are contained in Section 2. The multivariate demands mathematical model has been created in Section 3. The problem-solving process and a numerical example are provided in Section 4. Section 5 contains the sensitivity analysis. Section 6 and 7 presents the findings and conclusion, respectively.

3. Assumptions and Notations

3.1. Assumptions

This model is developed based on the following assumptions.

(1) In a situation where there is no stock out, demand for the product is believed to be a function of price and stock $D_1(p, I(t)) = (a + bI(t))p^{-w}$; in a situation where there is a stock out, demand is thought to be solely reliant on price. $D_2(p) = ap^{-w}$.

(2) Shortages are permissible and partially backlogged with an exponentially decreasing rate given as $B(T-t) = e^{-\delta(T-t)}$, where $\delta > 0$.

(3) Storage capacity is unlimited.

(4) In nature, the products are degrading.

(5) Deteriorated items are not replaceable.

(6) To slow down the current rate of deterioration, preservation technology is employed.

(7) Reduce deterioration rate, $\theta_1(\xi) = \theta(1 - e^{-\xi x})$, $x > 0$, $\theta \in (0, 1)$, where x represent the coefficient, which is representing the efficiency of preservation technology.

(8) Resultant deterioration rate, $\theta_2(\xi) = (\theta - \theta_1(\xi))$.

3.2. Notations

The following notations are used in the development of this model.

Notation	*Description*	*Units*
C_0	Ordering Cost	Price/order
C_p	Purchasing Cost	Price/unit
C_h	Holding Cost	Price/unit/time unit

Notation	*Description*	*Units*
C_s	Cost of shortage	Price/unit
C_l	Cost of lost sale	Price/unit
p	Selling price	Price unit
R	Inflation rate	Constant
Q_1	Positive stock level at $t = 0$	Units
Q_2	Backordered quantity	Units
Q	Order quantity	Units
δ	Backlogging parameter	Units
D_1 and D_2	Demand during different time interval	Units
a, b, p, w	Demand Parameter	Constant
θ	Rate of deterioration	Constant
ξ	Preservation technology constant	Price/unit time
$\theta_1(\xi)$	Reduced deterioration rate	Per Unit
$\theta_2(\xi)$	Resultant deterioration rate	Per Unit
$X\ (> 0)$	Coefficient which is representing the efficiency of preservation technology	Constant
	Decision variable	
T^*	Replenishment Cycle time	Time Unit
t_1^*	The time at which inventory level becomes zero	Time unit

4. Mathematical Modelling

In the beginning of inventory model cycle, a lot size equals to Q_1 units are received at $t = 0$, that starts depleting due to demand and deterioration and drops to zero at $t = t_1$. After that, shortages accumulate during the time interval $[t_1, T]$ and moderately backlogged. At $t = T$, the level of negative inventory reached to Q_2 units as shown in Figure 2. The equation representing the inventory level during diverse stage of time interval is given as follows:

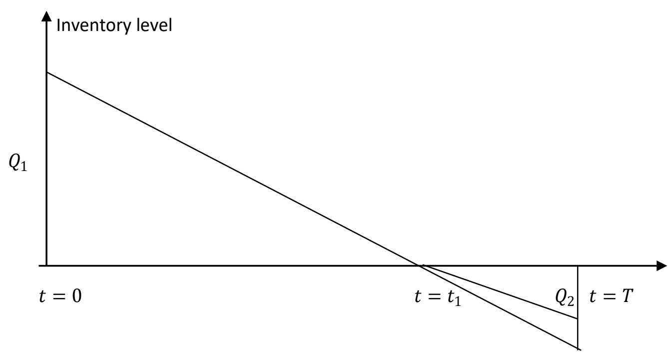

Figure 2: Visual depiction of inventories over time

Formulation of Problem:

$$\frac{dI_1(t)}{dt} + \theta I_1(t) = -D_1(p, I_1(t)), \quad 0 \le t \le t_1, \tag{4.1}$$

$$\frac{dI_2(t)}{dt} = -B(T - t)D_2(p), \quad t_1 \le t \le T. \tag{4.2}$$

With boundary conditions

$$I_1(t_1) = I_2(t_1) = 0.$$

The solution of (4.1) and (4.2), are as follows

$$I_1(t) = \frac{k_2}{k_1}(-1 + e^{-k_1(t-t_1)}), \quad 0 \le t \le t_1, \tag{4.3}$$

$$I_2(t) = -\frac{k_2}{\delta}(e^{-(T-t)\delta} - e^{-(T-t_1)\delta}), \quad t_1 \le t \le T, \tag{4.4}$$

where $k_1 = \left(\theta + \frac{b}{p^w}\right)$, $k_2 = \frac{a}{p^w}$.

The maximum positive inventory is

$$Q_1 = I_1(0) = \frac{k_2}{k_1}(-1 + e^{k_1 t_1}). \tag{4.5}$$

The maximum backorders are

$$Q_2 = -I_2(T) = \frac{k_2}{\delta}(1 - e^{-(T-t_1)\delta}). \tag{4.6}$$

Total ordering quantity

$$\begin{aligned} Q &= [Q_1 + Q_2] = \frac{k_2}{k_1}(-1 + e^{k_1 t_1}) + \frac{k_2}{\delta}(1 - e^{-(T-t_1)\delta}), \\ Q &= [Q_1 + Q_2] = (m_1 - m_2 - m_3 + m_4), \\ m_1 &= \frac{k_2}{k_1}e^{k_1 t_1}, \ m_2 = \frac{k_2}{k_1}, \ m_3 = \frac{k_2}{\delta}e^{-(T-t_1)\delta}, \ m_4 = \frac{k_2}{\delta}. \end{aligned} \tag{4.7}$$

Case 1. Neither the effect of inflation nor the effect of preservation technology involved, i.e., in this instance, we have assumed that there is no inflationary effect and no preservation technology effect used.

Cost calculations

1. *Ordering Cost* $OC = C_o$.
2. *Holding Cost*
$$HC = C_h \int_0^{t_1} I_1(t)dt = C_h \left[\frac{m_1}{k_1}(1 - e^{-k_1 t_1}) - m_2 t_1\right].$$
3. *Purchasing Cost*
$$PC = C_p[Q_1 + Q_2] = C_p[m_1 - m_2 - m_3 + m_4].$$
4. *Deterioration Cost*
$$DC = C_d\theta \left[\frac{m_1}{k_1}(1 - e^{-k_1 t_1}) - m_2 t_1\right].$$
5. *Shortage Cost*
$$\begin{aligned} SC &= C_s \int_{t_1}^{T} [-I_2(t)]dt \\ &= C_s \left(\frac{(1 - e^{-(T-t_1)\delta})m_4}{\delta} - m_3(T - t_1)\right). \end{aligned}$$
6. *Lost Sale Cost*
$$\begin{aligned} LSC &= C_l \int_{v}^{T} (1 - B(T - t))D_2(p)dt \\ &= C_l m_4(e^{-(T-t_1)\delta} - 1 + (T - t_1)\delta). \end{aligned}$$

The system's current total cost of worth is

$$\begin{aligned}
TAC(t_1, T) &= \frac{1}{T}[OC + HC + DC + BC + LSC + PC] \\
&= \frac{1}{T}\left[C_o + C_h\left[\frac{m_1}{k_1}(1 - e^{-k_1 t_1}) - m_2 t_1\right] + C_p\left[m_1 - m_2 - m_3 + m_4\right]\right. \\
&\quad + C_d\theta\left[\frac{m_1}{k_1}(1 - e^{-k_1 t_1}) - m_2 t_1\right] + C_s\left(\frac{(1 - e^{-(T-t_1)\delta})m_4}{\delta} - m_3(T - t_1)\right) \\
&\quad \left. + C_l m_4\left(e^{-(T-t_1)\delta} - 1 + (T - t_1)\delta\right)\right]. \qquad (4.8)
\end{aligned}$$

Case 2. We have assumed the Situation where effect of inflation involved

Cost calculations

1. *Ordering Cost*

$$OC = C_o$$

2. *Holding Cost*

$$\begin{aligned}
HC &= C_h \int_0^{t_1} I_1(t) e^{-Rt} dt \\
&= C_h\left(\frac{m_2}{R}(e^{-Rt_1} - 1) + \frac{m_1}{k_1 + R}(1 - e^{-(k_1+R)t_1})\right).
\end{aligned}$$

3. *Purchasing Cost*

$$\begin{aligned}
PC &= C_p[Q_1 + Q_2]e^{-RT} \\
&= C_p[(m_1 - m_2 - (m_3 - m_4)e^{-RT})]
\end{aligned}$$

4. *Deterioration Cost*

$$= C_d\left[\frac{1}{p^w}\left\{\frac{a}{R}(1 - e^{-(R)t_1}) + b\left\{\frac{m_1}{k_1 + R}(1 - e^{-(k_1+R)t_1}) + m_2(e^{-(\delta-R)t_1} - 1)\right\}\right\}\right].$$

5. *Shortage Cost*

$$\begin{aligned}
SC &= C_s \int_{t_1}^{T} [-I_2(t)] e^{-Rt} dt \\
&= C_s\left(\frac{m_3}{R}(e^{-RT} - e^{-Rt_1}) - \frac{m_4}{R - \delta}(e^{-RT} - e^{-Rt_1 \pm (T-t_1)\delta})\right).
\end{aligned}$$

6. *Lost Sale Cost*

$$\begin{aligned}
LSC &= C_l \int_{v}^{T} (1 - B(T - t)) D_2(p) e^{-Rt} dt \\
&= C_l\left(\frac{k_2}{R}(-e^{-RT} + e^{-Rt_1}) + \frac{k_2}{R - \delta}(e^{-RT} - e^{-Rt_1 + (-T+t_1)\delta})\right).
\end{aligned}$$

The present worth total cost of the system is

$$
\begin{aligned}
TC(t_1,T) &= \frac{1}{T}[OC+HC+DC+BC+LSC+PC+PRC] \\
&= \frac{1}{T}\Bigg[C_o + C_h\left(\frac{m_2}{R}(e^{-Rt_1}-1) + \frac{m_1}{k_1+R}(1-e^{-(k_1+R)t_1})\right) \qquad (4.9)\\
&\quad + C_p[(m_1-m_2-(m_3-m_4)e^{-RT})] \\
&\quad + C_d\left[\frac{1}{p^w}\left\{\frac{a}{R}(1-e^{-(R)t_1}) + b\left\{\frac{m_1}{k_1+R}(1-e^{-(k_1+R)t_1}) + m_2(e^{-(\delta-R)t_1}-1)\right\}\right\}\right] \\
&\quad + C_s\left(\frac{m_3}{R}(e^{-RT}-e^{-Rt_1}) - \frac{m_4}{R-\delta}(e^{-RT}-e^{-Rt_1\pm(T-t_1)\delta})\right) \\
&\quad + C_l\left(\frac{k_2}{R}(-e^{-RT}+e^{-Rt_1}) + \frac{k_2}{R-\delta}(e^{-RT}-e^{-Rt_1+(-T+t_1)\delta})\right)\Bigg]. \qquad (4.10)
\end{aligned}
$$

Case 3. In this case we have assumed the Situation where effect of inflation and preservation technology involved

$$\frac{dI_1(t)}{dt} + (\theta-\theta_2(\xi))I_1(t) = -D_1(p,I(t)), \quad 0 \le t \le t_1, \qquad (4.11)$$

$$\frac{dI_2(t)}{dt} = -B(T-t)D_2(p), \quad t_1 \le t \le T. \qquad (4.12)$$

With boundary conditions

$$I_1(t_1) = I_2(t_1) = 0.$$

The solution of (4.11) and (4.12), are as follows

$$
\begin{aligned}
I_1(t) &= \frac{k_2}{k_3}(e^{-(t-t_1)k_3}-1), \\
I_2(t) &= \frac{k_2}{\theta}(e^{-(T-t_1)\delta}-e^{-(T-t)\delta}), \\
k_3 &= (\theta e^{-\xi x} + \frac{b}{p^w}), \quad k_2 = \frac{a}{p^w}.
\end{aligned}
$$

The maximum positive inventory is

$$Q_1 = I_1(0) = m_5 - m_6.$$

The maximum backorders are

$$Q_2 = -I_2(0) = m_3 - m_4,$$

where $m_5 = \frac{k_2}{k_3}e^{k_3t_1}$, $m_6 = \frac{k_2}{k_3}$, $m_3 = \frac{k_2}{\delta}e^{-(T-t_1)\delta}$, $m_4 = \frac{k_2}{\delta}$.

Total ordering quantity

$$Q = [Q_1 + Q_2] = [m_5 - m_6 + m_3 - m_4].$$

Cost calculations

1. *Ordering Cost*

$$OC = C_o$$

2. *Holding Cost*

$$
\begin{aligned}
HC &= C_h\int_0^{t_1} I_1(t)dt \\
&= C_h\left(\frac{m_6}{k_3}e^{k_3t_1} - \frac{m_6}{k_3} - m_6t_1\right).
\end{aligned}
$$

3. *Deterioration Cost*

$$= C_d(\theta - \theta_2(\xi))[m_5 - m_6 + m_3 - m_4].$$

4. *Purchasing Cost*

$$\begin{aligned} PC &= C_p[Q_1 + Q_2] \\ &= C_p[m_5 - m_6 + m_3 - m_4]. \end{aligned}$$

5. *Shortage Cost*

$$\begin{aligned} SC &= C_s \int_{t_1}^{T} [-I_2(t)]dt \\ &= C_s \left(\frac{(1 - e^{-(T-t_1)\delta})m_4}{\delta} - m_3(T - t_1) \right). \end{aligned}$$

6. *Lost Sale Cost*

$$\begin{aligned} LSC &= C_l \int_{v}^{T} (1 - B(T - t))D_2(p)dt \\ &= C_l m_4(e^{-(T-t_1)\delta} - 1 + (T - t_1)\delta). \end{aligned}$$

7. *Preservation Cost*

$$PRC = \xi T.$$

The system's current total cost of worth is

$$\begin{aligned} TAC(t_1, T) &= \frac{1}{T}[OC + HC + DC + BC + LSC + PC] \\ &= \frac{1}{T}\Bigg[C_o + C_h\left(\frac{m_6}{k_3}e^{k_3 t_1} - \frac{m_6}{k_3} - m_6 t_1\right) \\ &\quad + C_d(\theta - \theta_2(\xi))[m_5 - m_6 + m_3 - m_4] \\ &\quad + C_p[m_5 - m_6 + m_3 - m_4] + C_s\left(\frac{(1 - e^{-(T-t_1)\delta})m_4}{\delta} - m_3(T - t_1)\right) \\ &\quad + C_l m_4(e^{-(T-t_1)\delta} - 1 + (T - t_1)\delta) + \xi T\Bigg]. \end{aligned}$$

5. Optimal Solution Procedure

The objective function has two variables, i.e., the length of time of the interval having no shortages, (t_1) and the Replenishment cycle length (T). In order to obtain the optimal values (t_1) and the Replenishment cycle length (T). Figure 3, shown the method used in paper for finding the optimal values.

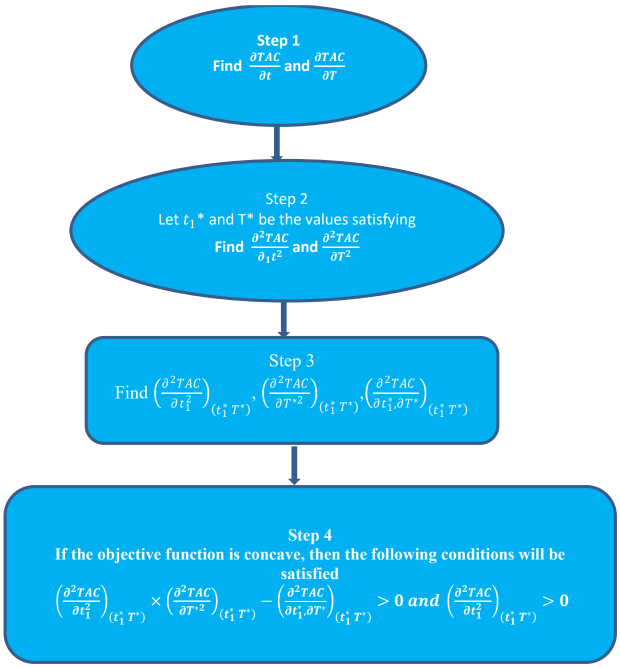

Figure 3: Depicts the method for Optimal solution procedure

5.1. Numerical Examples

The corresponding units make use of the following parameters. To calculate the total average cost (TAC^*) and choice variable as an output, we utilized the Mathematica-11 software program. Optimal values for the choice variables here, as shown by Examples 5.1, ??, and ??, which is followed by the Figure 4, 5 and 6 that represent the Convexity TAC^* with respect to t_1^* and T^* in each cases.

Example 5.1 *Case 1 (No Inflation, No preservation involved)*

$C_0 = 500$	$C_p = 4$	$w = 0.6$
$C_h = 7$	$C_l = 1.7$	$\theta = 0.030$
$C_s = 2$	$a = 30$	$\delta = 0.9$
$C_d = 1.5$	$b = 0.50$	$p = 19$
The optimal values of the decision variable are $t_1^* = 0.0366305$, $T^* = 7.690567$ *and* $TAC^* = 789.583$		

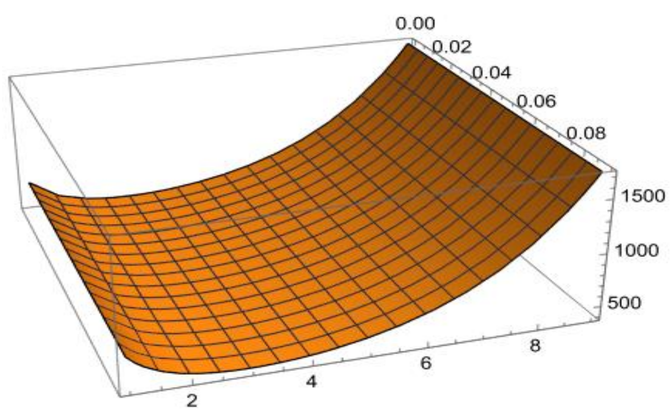

Figure 4: Depicts the convexity TAC^* with respect to t_1^*, T^*

Example 5.2 *Case 2. With Inflation (i.e. Inflation involved)*

$C_0 = 500$ $C_h = 7$ $C_s = 2$ $C_d = 1.5$ $R = 0.03$	$C_p = 4$ $C_l = 1.7$ $a = 30$ $b = 0.50$	$w = 0.6$ $\theta = 0.030$ $\delta = 0.9$ $p = 19$
The optimal values of the decision variable are $t_1^* = 0.047304$, $T^* = 9.0690569$ *and* $TAC^* = 510.111$		

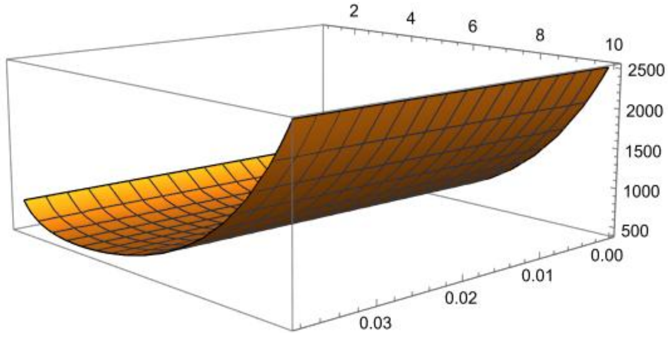

Figure 5: Depicts the Convexity TAC^* with respect to t_1^*, T^*

Example 5.3 *Case 3. With preservation (Effect of Preservation Involved)*

$C_0 = 500$ $C_h = 7$ $C_s = 2$ $C_d = 1.5$ $\xi = 0.03$	$C_p = 4$ $C_l = 1.7$ $a = 30$ $b = 0.50$	$w = 0.6$ $\theta = 0.030$ $\delta = 0.9$ $p = 19$
The optimal values of the decision variable are $t_1^* = 0.0266305$, $T = 4.69056$ *and* $TAC^* = 769.056$		

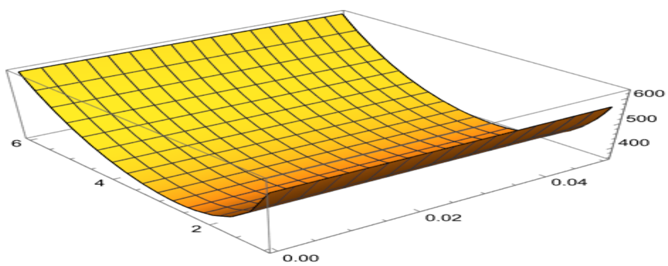

Figure 6: Depicts the Convexity TAC^* with respect to t_1^*, T^*

With the help of Mathematica-11 software tool, we received the three Dimension Figure which represent concavity of total average cost function in all 3 cases. Concavity represent the optimal (Minimum TAC^*), which shows the authenticity of our model.

6. Sensitivity Analysis

We have shown Sensitivity analysis which is crucial for validation of our mode and decision-making, and assessing risks. We used various parameter and cost coefficient on the basis of we develop conclusion and results.

6.1. Sensitivity analysis for Case 1 – No Inflation, No preservation involved

The sensitivity analysis of t_1^*, T^* and TAC^* is being formulated in this part by varying the input (-20% to 20%). This is displayed in Table 2 below.

Table 2:

Parameters	*Value*	% Change	t_1^*	T^*	TAC^*
C_h	5.6	−20%	0.0366308	7.69069	785.583
	6.3	−10%	0.0366309	7.69066	789.583
	7	0	0.0366305	7.69056	789.583
	7.7	10%	0.0366302	7.69036	789.683
	8.4	20%	0.0366301	7.690526	789.983
θ	0.027	−20%	0.039805	7.90156	782.523
	0.029	−10%	0.039730	7.90172	787.556
	0.030	0	0.036630	7.69056	789.598
	0.033	10%	0.036230	768056	792.589
	0.360	20%	0.036030	7.69059	796.557
C_d	1.2	−20%	0.056912	7.69956	789.501
	1.35	−10%	0.076983	7.69856	789.502
	1.5	0	0.036630	7.69056	789.583
	1.65	10%	0.036692	7.68056	789.692
	1.90	20%	0.016961	7.69001	789.992
a	27	−20%	0.036688	7.69001	789.500
	29	−10%	0.036680	7.69021	789.555
	30	0	0.036695	7.69059	789.583
	33	10%	0.036693	7.69092	789.587
	36	20%	0.036692	7.69091	789.585
b	0.70	−20%	0.056630	7.90056	789.5831
	0.75	−10%	0.076630	7.69090	789.5833
	0.50	0	0.036630	7.69056	789.5835
	0.55	10%	0.047330	7.68052	789.5838
	0.60	20%	0.047330	7.68001	789.5839
β	0.78	−20%	0.036311	7.690567	789.118
	0.57	−10%	0.036321	7.690565	789.203
	0.6	0	0.036632	7.690569	789.553
	0.66	10%	0.036672	7.690568	789.623
	0.92	20%	0.036653	7.690561	789.913
p	13.9	−20%	0.0366325	7.690169	789.593
	15.3	−10%	0.0366324	7.690289	788.5923
	19	0	0.0366320	7.690567	789.583
	18.9	10%	0.0366319	7.690667	790.583
	20.7	20%	0.0366318	7.690962	791.583

6.2. Sensitivity analysis for Case 2 – With Inflation (i.e. Inflation involved)

The sensitivity analysis of t_1^*, T^* and TAC^* is being formulated in this part by varying the input (−20% to 20%). This is displayed by the below Table 3.

Table 3:

Parameters	*Value*	% Change	t_1^*	T^*	TAC^*
C_h	3.7	−20%	0.0473391	9.0690562	510.101
	3.9	−10%	0.0473362	9.0690561	510.109
	7	0	0.0473305	9.0690561	510.111
	7.7	10%	0.0473300	9.0690561	510.112
	7.6	20%	0.0473289	9.0690561	510.113
θ	0.027	−20%	0.0268305	9.0690662	509.231
	0.029	−10%	0.0269305	9.0690612	509.111
	0.030	0	0.0473305	9.0690562	510.211
	0.033	10%	0.0265305	9.0690572	510.323
	0.360	20%	0.0267305	9.0690522	510.892
C_d	1.2	−20%	0.0473373	9.0693563	510.731
	1.35	−10%	0.0473372	9.0692563	510.700
	1.5	0	0.0473305	9.0690563	510.111
	1.65	10%	0.0473302	9.0690753	510.101
	1.90	20%	0.0473301	9.0690773	510.001
a	27	−20%	0.0473382	9.0690816	510.009
	29	−10%	0.0473380	9.0690826	510.010
	30	0	0.0473399	9.0690566	510.111
	33	10%	0.0473353	9.0690216	510.113
	36	20%	0.0473321	9.0690206	510.117
b	0.70	−20%	0.0473391	9.0691556	501.111
	0.75	−10%	0.0473390	9.0691576	509.111
	0.50	0	0.0473389	9.0690564	510.111
	0.55	10%	0.0473399	9.0690524	511.111
	0.60	20%	0.0473332	9.0690314	511.211
β	0.78	−20%	0.0473399	9.0680564	510.101
	0.57	−10%	0.0473399	9.0680564	510.102
	0.6	0	0.0473399	9.0690564	510.111
	0.66	10%	0.0473399	9.0691164	510.119
	0.92	20%	0.0473399	9.0692564	510.120
p	13.9	−20%	0.0473401	9.0690219	710.101
	15.3	−10%	0.0473400	9.0690239	792.111
	19	0	0.0473399	9.0690569	510.111
	18.9	10%	0.0473395	9.0690909	513.321
	20.7	20%	0.0473390	9.0690919	517.211
R	0.024	−20%	0.047102	9.0690123	509.101
	0.027	−10%	0.047203	9.0690221	509.211
	0.03	0	0.047304	9.0690569	510.001
	0.033	10%	0.047405	9.0690731	511.001
	0.036	20%	0.047501	9.0690921	511.821

6.3. Sensitivity analysis for Case 3 – With preservation (Effect of Preservation Involved)

The sensitivity analysis of t_1^*, T^* and TAC^* is being formulated in this part by varying the input (−20% to 20%).This is displayed by the below Table 4.

Table 4:

Parameters	*Value*	% Change	t_1^*	T^*	TAC^*
C_h	3.7	−20%	0.0269305	4.69059	769.000
	3.9	−10%	0.0268305	4.69058	769.010
	7	0	0.0266305	4.69560	769.056
	7.7	10%	0.0265305	4.69050	769.096
	7.6	20%	0.0267305	4.69050	769.086
θ	0.027	−20%	0.02666052	4.99056	761.056
	0.029	−10%	0.02667052	4.92056	762.056
	0.030	0	0.02663052	4.69056	769.056
	0.033	10%	0.02662053	4.68056	769.216
	0.360	20%	0.02661057	4.69211	769.331
C_d	1.2	−20%	0.0266300	4.690567	769.0561
	1.35	−10%	0.0266301	4.690563	769.0562
	1.5	0	0.0266305	4.690562	769.0565
	1.65	10%	0.0266306	4.690561	769.0569
	1.90	20%	0.0266306	4.690560	769.0569
a	27	−20%	0.0268905	4.69260	768.056
	29	−10%	0.0268905	4.69200	768.056
	30	0	0.0266305	4.69056	769.056
	33	10%	0.0265105	4.69055	790.056
	36	20%	0.0261005	4.69057	791.056
b	0.70	−20%	0.0266305	4.69236	769.005
	0.75	−10%	0.0266305	4.69023	769.053
	0.50	0	0.0266305	4.69056	769.056
	0.55	10%	0.0273305	4.68056	769.056
	0.60	20%	0.0266305	4.68006	769.059
w	0.78	−20%	0.0216300	4.62056	769.001
	0.57	−10%	0.0226300	4.63056	769.002
	0.6	0	0.0266305	4.69056	769.056
	0.66	10%	0.0296300	4.90056	769.056
	0.92	20%	0.0286300	4.91056	769.059
P	13.9	−20%	0.0273360	4.69006	719.056
	15.3	−10%	0.02663359	4.69016	729.056
	19	0	0.02663350	4.69056	769.056
	18.9	10%	0.0273349	4.69066	789.056
	20.7	20%	0.0266348	4.69096	789.057
C_ξ	0.8	−20%	0.0266101	4.69010	719.105
	0.9	−10%	0.0266201	4.69015	729.099
	1	0	0.0266305	4.69056	769.056
	1.1	10%	0.0266401	4.69057	799.056
	1.2	20%	0.0266402	4.69058	789.052

6.4. Observation for all 3 cases

By the Table 5, we have shown the observation from the sensitivity analysis from all three Cases (Case 1, Case 2, and Case 3)

Table 5:

Parameters	t_1^*		T^*		TAC^*	
	Increase	Decrease	Increase	Decrease	Increase	Decrease
C_o	✓		✓			✓
C_h		✓		✓	✓	
θ		✓		✓	✓	
C_d		✓		✓	✓	
a	✓			✓	✓	
b	✓		✓		✓	
w		✓		✓	✓	
p		✓		✓	✓	
R	✓		✓		✓	
ξ	✓		✓			✓

6.5. Graphical representation of Comparison between $TAC^*(1)$, $TAC^*(2)$ and $TAC^*(3)$

From the sensitivity analysis from the (Table 2, Table 3, Table 4 and observation Table 5) of all cases, Here we have shown the Compression between $TAC^*(1)$, $TAC^*(2)$ and $TAC^*(3)$ with respect to various parameter and cost coefficient used in paper.

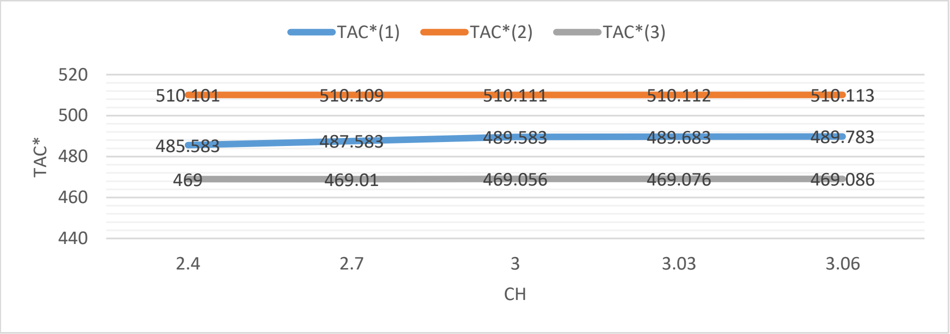

Figure 7: Depicts the variation in $TAC^*(1)$, $TAC^*(2)$ and $TAC^*(3)$ with respect to (C_h)

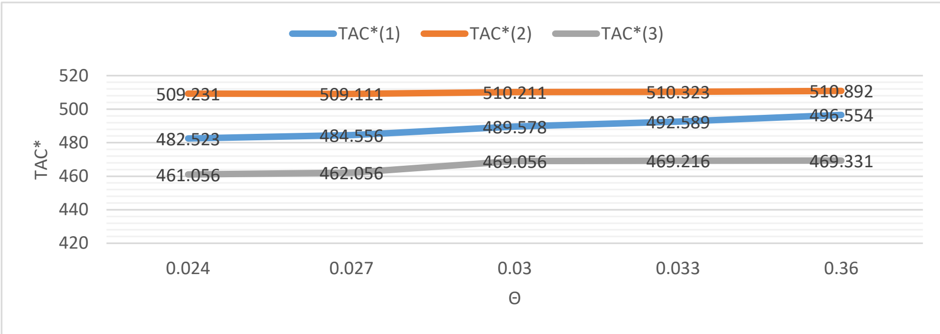

Figure 8: Depicts the variation in $TAC^*(1)$, $TAC^*(2)$ and $TAC^*(3)$ with respect to deterioration rate (θ)

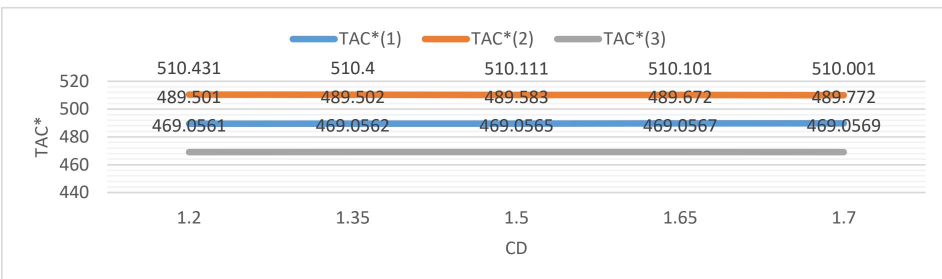

Figure 9: Depicts the variation in $TAC^*(1)$, $TAC^*(2)$ and $TAC^*(3)$ with respect to (C_d)

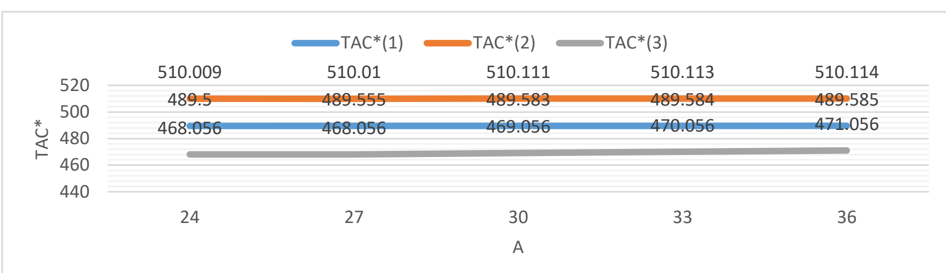

Figure 10: Depicts the variation in $TAC^*(1)$, $TAC^*(2)$ and $TAC^*(3)$ with research to (a)

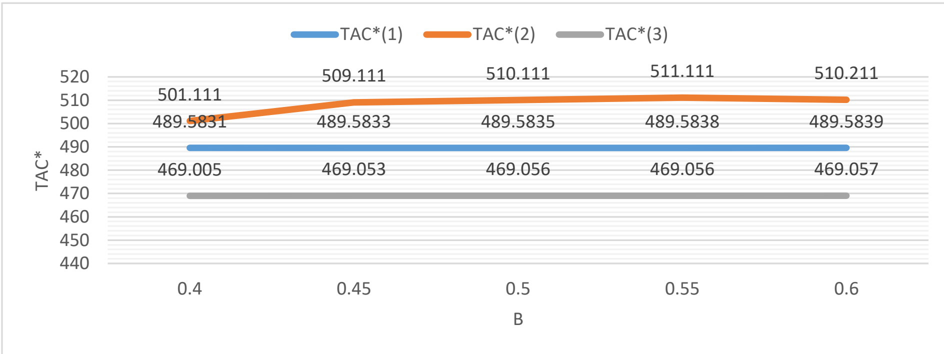

Figure 11: Depicts the variation in $TAC^*(1)$, $TAC^*(2)$ and $TAC^*(3)$ with respect to demand parameter (b)

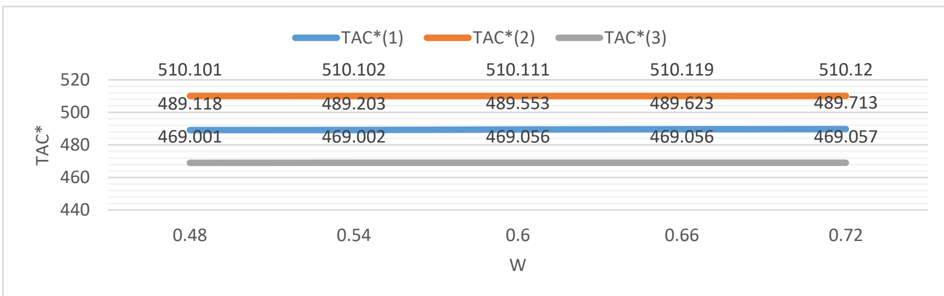

Figure 12: Depicts the variation in $TAC^*(1)$, $TAC^*(2)$ and $TAC^*(3)$ with respect to demand parameter (w)

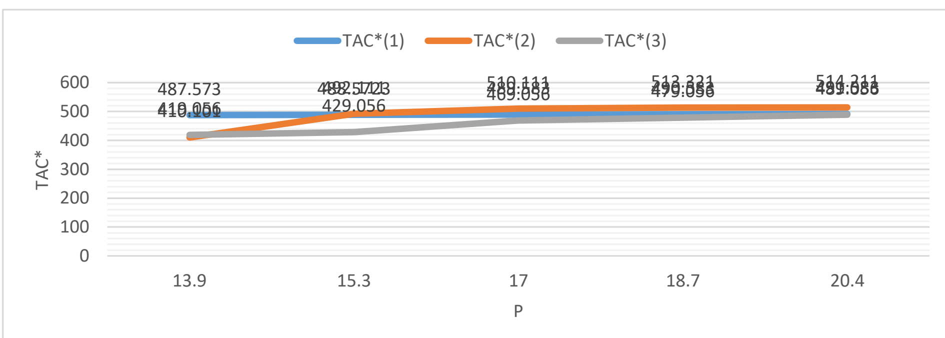

Figure 13: Depicts the variation in $TAC^*(1)$, $TAC^*(2)$ and $TAC^*(3)$ with respect to demand parameter to (p)

7. Results and Managerial implications

We have made the following results based on the observation Table 5.

- Increasing the ordering cost (Co) leads to a higher EOQ, which in turn *extends the no stock-out time interval* (t_1^*) and *Replenishment Cycle* (T^*) but Decrease in *Total Average Cost* (TAC^*). Managers should regularly monitor and assess changes in ordering costs (Co) for any fluctuations. Update EOQ and safety stock levels often. Utilize a variety of vendors and work out reasonable terms to manage cost swings, have a buffer supply on hand.

- In short, increasing holding cost (C_h) leads to *Decreased No Stock out Time Interval* (t_1^*), *Decreased Replenishment Cycle* (T^*) but Increase in *Total Average Cost* (TAC^*). In the case of of increasing holding costs, manager can make informed decisions about inventory management that can lead to improved efficiency, cost savings, and better cash flow. In short, increasing Deterioration costs (Cd) and *Deterioration rate* (θ) leads to *Decreased No Stock out Time Interval* (t_1^*), *Decreased Replenishment Cycle* (T^*) but Increase in *Total Average Cost* (TAC^*). By implementing regular monitoring of Deterioration costs and Deterioration rate, Managers can effectively manage Deterioration costs and Deterioration rate, minimize product spoilage, and optimize inventory management for a more efficient and profitable operation Regularly as needed to ensure continuous optimization.

- Increasing the *stock-dependent demand Parameter* (b) leads to an extends *the no stock-out time interval* (t_1^*) and *Replenishment Cycle* (T^*) but increase in *Total Average Cost* (TAC^*).

- Increasing *"a" (base demand)* leads to a longer no stock out time interval (t_1^*), and *shorter replenishment cycles* (T^*) But but Increase in *Total Average Cost* (TAC^*).

- *Price* (P) and price coefficient (w) can indirectly affect the no stockout interval and replenishment cycle through their impact on demand. i.e. Increasing the *stock-dependent demand Parameter* (p *and* w) leads to a *shrink the no stock-out time interval* (t_1^*) and *Replenishment Cycle* (T^*) but increase or in *Total Average Cost* (TAC^*).

- *Special Situation in Case 2 and Case 3.*
  From *Case 2*, We Observed by increase in the inflation rate (R) parameter by 10%, some notable changes in TAC^* are found. We see increase in *No Stock out Time Interval* (t_1^*), *Replenishment Cycle* (T^*) *and Total Average Cost* (TAC^*) by corresponding change in inflation rate (R).

In *Case 2*, the highest total cost was due to inflation driving the price up compared to the baseline (*Case 1*). This highlights the importance of considering different factors when evaluating TAC. Inflation can significantly increase overall costs. Inflation can also impact TAC, In such situations manager need to take proactive measures such as negotiating with suppliers, optimizing inventory levels, and adjusting product prices to reflect inflation while maintaining customer competitiveness. Supplier selection should consider the impact of preservation methods and inflation on TAC, forming strong relationships with reliable suppliers for better pricing and mitigation efforts. Regular data analysis can help refine strategies and identify cost-saving opportunities, improving supplier relationships and effective communication with customers in an inflationary environment

- *From Case 3*, we Observed, Decrement change (TAC^*) but *increment* change in No Stock out Time Interval (t_1^*) and Replenishment Cycle (T^*) are found by corresponding Increment change in preservation cost coefficient (C_ξ).

  However, in *Case 3*, preservation efforts resulted in a cost saving of 789.583-769.056, indicating that preservation might involve strategies that reduce overall acquisition costs. This suggests that preservation might involve strategies that reduce spoilage or damage during storage, leading to less waste and lower overall costs. Preservation may lead to cost savings depending on the specific preservation method and its impact on other factors. Retail managers can optimize costs by analysing high spoilage rates and frequent replacements. Preservation strategies can be implemented to reduce costs, especially for products with high spoilage or frequent replacements. Analysing which products benefit most from extended shelf life or reduced damage can help identify cost-saving opportunities.

- As seen in (Figure 14), the variation in TAC^* with regard to R is presented. After an initial very moderate rise in TAC^*, we find that when the inflation rate increases by 10%, there is a large incremental movement detected. Additionally, by examining (Figure 15), we noticed a quick decline in TAC^* with regard to a 10% increment change in preservation cost COEFFICENT (C_ξ).

  Here we have shown the graphically representation of comparisons between $TAC^*(1)$, $TAC^*(2)$ and $TAC^*(3)$ with respect to various parameter and cost coefficient used in paper Based on the (Table 2,

Table 3, Table 4). In the graphically representation, Figure 6, Figure 7, Figure 8, Figure 9, Figure 10, Figure 11, and Figure 12, depicts the variation in $TAC^*(1)$, $TAC^*(2)$ and $TAC^*(3)$ with respect to $(Ch_.)$, deterioration rate (θ), deterioration coefficient (C_d), demand parameter (a), demand parameter (b), demand parameter (w) and to selling price demand parameter (p) respectively.

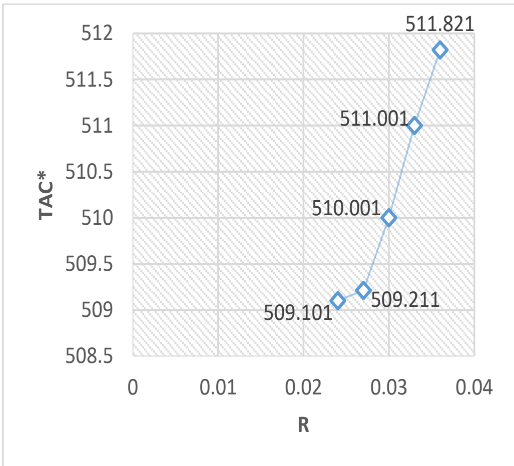

Figure 14: Represent variation in TAC^* on with respect to R

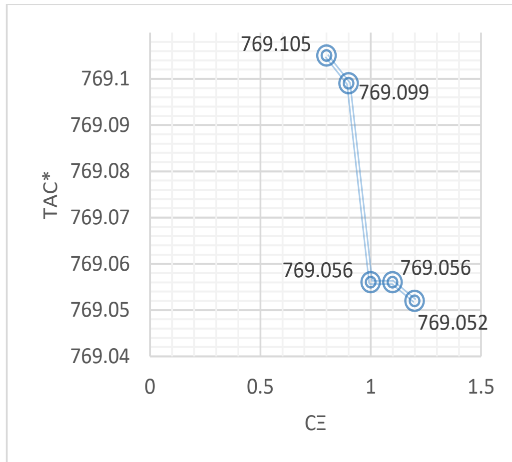

Figure 15: Represent variation in TAC^* on with respect to C_ξ

8. Conclusion

In this proposed model, an inventory problem with the effect of inflation and preservation technology has been discussed. A situation of shortage of inventory with a partial backlogging rate connected with the constant deterioration rate has been investigated. Price, time, and stock are the three independent variables that have been part of demand. Furthermore, the inflation and preservation technology effect is also used in this model, giving much flexibility to cover many real-life situations for this demand-related scenario.

Three-Dimensional Figures from Mathematica-11 indicate the concavity of the total average cost function in all three cases, which indicates the authenticity of the assumed models.

Case 1. No Inflation, *No preservation involved* $t_1^* = 0.0366305$ $T^* = 7.69056$ $TAC^* = 789.583$	*Case 2. With Inflation* (i.e., effect of Inflation involved) $t_1^* = 0.047304$ $T = 9.069056$ $TAC^* = 510.111$	*Case 3. With preservation* *(Effect of Preservation Involved)* $t_1^* = 0.0266305$ $T^* = 4.69056$ $TAC^* = 769.056$

Here we have shown the finding for TAC^* and their comparison between Total Average Cost in all 3 cases as a result of our paper. Additionally, Figure 16 depicts the comparison between Total Average Cost from all 3 cases.

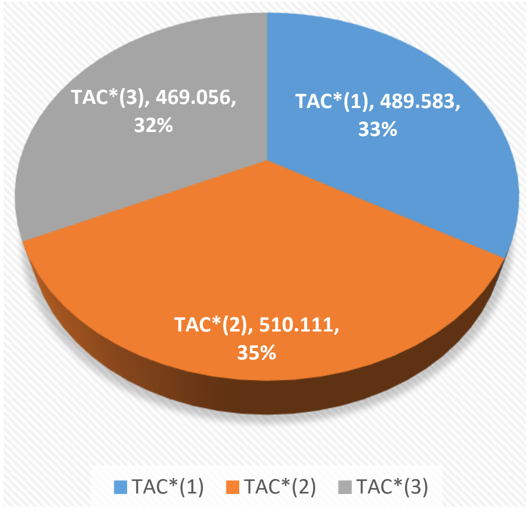

Figure 16: Depicts the comparison between Total Average Cost

We can extend the proposed model in several ways by taking different backlogging rates with different deterioration rates, like the Weibull distribution and time-dependent deterioration rates. Also, we can lead this model by taking permissible delay of payment under the trade Credit policy, Advance payment, and discounting policy.

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