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An Integrated Inventory Framework for Perishable Items under Age Dependent Deterioration and Demand under the Effect of Inflation

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Abstract

This study develops an inventory model for perishable items incorporating the effects of age dependent deterioration and age and time dependent demand under effect of inflation. Unlike conventional inventory models that assume a constant or time dependent deterioration rate, the proposed model integrates the influence of the item's age and the elapsed time since replenishment on the decay process. Demand is formulated as a function of time and age and deterioration as a function of product age to capture quality degradation in fruits and vegetables, pharmaceutical, and biological inventories. The proposed inventory model considers a finite planning horizon and assumes complete replenishment considering effect of inflation. Total cost components including holding cost, deterioration cost, ordering cost, purchasing cost and sales revenue are clearly formulated to determine the optimized replenishment model that minimizes the total inventory cost. The numerical results show that incorporating age dependent deterioration behavior significantly impacts optimal order quantity and cycle duration. The sensitivity analysis provides the impact of key parameters such as deterioration rate coefficients, demand pattern on the overall model. The model discussed in this paper provides a framework for the inventory management of perishable items and helps decision makers to design cost-effective and quality-sensitive replenishment strategies.

Keywords

Perishable Inventory, Deterioration, Time and Age Dependent Demand, Inflation

1. Introduction

Customers always show a strong favor towards the freshly stocked items like fruits and vegetables, pharmaceuticals, dairy items, fashionables, etc. and their purchasing likelihood declines as products' age increase within the inventory. These products' perceived value decreases with age, resulting in a gradual decline in demand. The drop in demand may be driven by seasonal changes, visible loss of quality, or the product nearing its expiry date. This behavioral response shifts over time and influences the way demand evolves during a cycle. Earlier research work on inventory models treated demand as constant and deterioration as instantaneous and subsequent studies modified these assumptions by incorporating time-dependent demand, age-related deterioration and inflationary effects.

The study of deteriorating inventory systems has become increasingly important as perishability, obsolescence and quality degradation affect different types of products, including food, pharmaceuticals and chemicals. Over the years, researchers have progressively enhanced traditional inventory assumptions to incorporate realistic operating situations such as variable deterioration rates, limited shelf-life, multi factor demand structures, time value of money, shortages and stockpiling, trade credit, inflation, sustainability concerns, and multi-echelon supply chains. Early survey papers Goyal and Giri [1] classified deterioration as a constant, time-dependent, age-dependent, and stock-dependent, which set the stage for further development into building active deterioration models to examine actual product behavior. An important development which took place in the literature is the concept of non-instantaneous deterioration, in which products remain usable for an initial period before the beginning of deterioration. Bakker *et al.* [2] laid the initial classification of deteriorating-inventory models and emphasized the need for integrated modelling. The following review organized three decades of research developments into thematic areas such as deterioration behavior, demand modelling, shortages, financial policies, preservation technology, sustainability, uncertainty modelling, and supply-chain coordination. Deterioration is one of the important characteristics of perishable inventory models, and significant research has been carried out to accurately build models for the same.

Aladwani *et al.* [3] explored finite horizon inventory policies for non-instantaneous deteriorating items with permissible delay in payment and Finite-horizon settings were examined, also incorporated permissible delay in payment with non-instantaneous deterioration. Palanivel and Uthayakumar [4] combined non-instantaneous deterioration into a finite horizon EOQ model with price and advertisement dependent demand under inflation. Controllable deterioration, in which, firms lower the deterioration rate using preservation technologies has started gaining importance in recent years. Their work demonstrated that the remaining cycle length has an impact on customer patience and replenishment timing.

Hsu *et al.* [5] were amongst the first to propose this idea of investment in preservation technology as a strategic decision variable. Their work established that investments in such technologies can drastically reduce losses and inventory holding costs. Subsequently, Palani and Maragatham [6] and Maheshwari *et al.* [7] extended the idea by combining preservation with marketing sensitive demand.

Mahato *et al.* [8] developed a multistage supply chain inventory model under carbon emission regulations to enable firms to invest in deterioration reducing technology. Advanced versions integrate deterioration control into supply chain models. Supply chain oriented environmental models were also studied.

Mahato and Mahata [9] studied multi-echelon structures with controllable deterioration, carbon emissions and production disruption also studied a two-echelon system integrating production disruption and controllable deterioration. Research in these areas highlights the shift toward modelling deterioration as a controllable and strategic variable rather than a passive parameter. The next important parameter is demand, which needs to be considered in the inventory systems models. The demand is generally variable for deteriorating items. Researchers have explored various forms of dynamic demand to capture market realities. Time dependent demand has been commonly used in deteriorating inventory research. However, Mishra *et al.* [10] studied time varying holding costs and partial backlogging as well.

Early research including Datta and Pal [11], other important parameters which have significant impact on inventory models are the time value of money and inflation. Some of the earlier works in which inflation was integrated in deteriorating-inventory models and Bose *et al.* [12] incorporated time dependent demand under inflation and analyzed how inflation and time discounting affect optimal inventory levels. Additionally, price plays an important role in perishable products' sales. Hasan and Mashud [13] carried out the study and developed a model for deteriorating products in which demand is dependent on selling price and frequency of advertisement. Advertising significantly impacts perishable goods demand and considered partial backlogging where customers wait for some fraction of time and then products become completely out of stock. Price driven demand in combination with preservation and trade credit were studied and analyzed by Kumar *et al.* [14] also incorporated advertisement and time dependent demand with preservation investment. Maheshwari *et al.* [7] On similar lines, Shah and Pandey [15] introduced demand dependent on advertisement and stock display. Ouyang *et al.* [16] extended inflation analysis to stock-dependent demand. Narang *et al.* [17] developed an EPQ model for three level production inventory model with seasonal demand considering advertisement impact on deteriorating items. These contributions marked that how the demand and seasonality affect the buying behavior of the customers in the changing market scenarios. Macías-López *et al.* [18] developed an inventory model which is explicitly useful for health-conscious customers, the model proposed for product freshness integrating price, stock and also captured deterioration for inventory management and also explicitly integrated shelf-life and non-linear holding costs into a perishable inventory model.

Shortages are very common in inventory management for perishable goods due to demand fluctuations and rapid spoilage. Shelf life is one of the important factors determining replenishment frequency. The review that follows outlines the major strands of research and shows how deterioration processes, demand specifications, shortage treatment, economic settings, and environmental considerations have shaped current modelling practices. Sicilia *et al.* [19] in their model, allowed shortages but assumed full backlogging by considering deterioration. Mohanty and Tripathy [20] established fuzzy model for constant deterioration in which shortages are allowed for inventory management models. Dey *et al.* [21] Patra [22] and Singh *et al.* [23] studied two warehouse systems with deterioration, shortages, and inflation. Similarly, Ogbonna *et al.* [24] demonstrated a two-storage model with salvage value under inflation and showed how storage configuration affects replenishment policy. Two warehouse systems demonstrated that storage type affects deterioration, salvage value, and replenishment timing. Barman *et al.* [25] analyzed pricing and scheduling for non-instantaneous deterioration in a two-layer supply chain.

Other important parameters which have significant impact on inventory models are the time value of money and inflation. Some of the earlier works in which inflation was integrated in deteriorating-inventory models including Gite [26], Sarker and Pan [27]. Their work showed that inflation significantly impacts holding, deterioration, and replenishment costs. Trade credit and payment delays add financial realism to the inventory models. Choudhury and Mahata [28] integrated trade credit with default risk in a dual channel supply chain with deteriorating products also analyzed dual channel coordination under dynamic demand and credit policy. Kumar [29] included fuzzy holding and ordering costs with shortages in active market conditions. Shaikh and Gite [30] combined fuzzy cost structures with inflation and price sensitive demand. Sustainability has emerged as a major direction in deteriorating inventory research in recent years. Lok *et al.* [31] introduced preservation technology investment under carbon emission considerations. Shah *et al.* [32] developed a sustainable production inventory model which included green technology investment, demonstrating how reduction in carbon emission can align with profit maximization.

However, no existing study integrates age dependent deterioration, time and age sensitive demand, and inflation within a unified analytical framework. As a result, current models are unable to fully capture realistic perishability dynamics where product age directly influences both deterioration and customer demand behavior.

In this paper, we formulate an integrated model for perishable items where demand varies with time and age considering effect of inflation. The customers prefer fresher items and demand drops with age and time, and overall drop in demand may be due to seasonality, while the inventory simultaneously deteriorates physically. Hence, model will be useful when customers prefer fresh items and demand drops with respect to age. The inventory level will decrease due to deterioration, which is governed by age of the product.

We have built a model where the new stock is preferred and older stock experience lesser demand due to the combined effects of time and shelf life.

2. Notations and Assumptions

2.1. Notations

For the formulation of the proposed inventory model notations and assumptions considered as follows:

$I(t)$: Inventory level at time ($0 < t \le T$)

$\theta(a)$: Age dependent deterioration or decay rate *i.e.* $\theta(a) = \lambda a$

a : Initial age of the item at the time of stocking

a_0 : Constant initial age parameter

D_0 : Base demand

α : Time dependent demand decay parameter

β : Age dependent demand sensitivity parameter

λ : Deterioration rate parameter

i : Discount rate

γ : Inflation sensitivity parameter

p : Selling price per unit

K : Cost per order

h : Holding cost

$TP(T)$: Total profit

c_p : Purchase cost

c_d : Deterioration cost

2.2. Assumptions

1) Single item is considered for the cycle.

2) No replacement or repair of deteriorating items is considered.

3) The demand is age and time dependent *i.e.* $D(t,a) = (1-\alpha t)(1-\beta a)$, Time effect: $(1-\alpha t)$ gives overall time and the overall demand drops may be due to seasonality age effect: $(1-\beta a)$ As item get closer to expiry customer interest reduces.

4) Lead time is zero.

5) No Shortages are allowed.

6) Planning horizon is finite.

7) The setup costs in inventory are constants.

8) The Linear age-dependent deterioration rate *i.e.* $\theta(a) = \lambda a$.

9) The Variable a and time t are treated as conceptually distinct. Time t denotes the elapsed duration within the inventory cycle, whereas age a represents the maturity level of the product at the moment it enters the inventory system.

10) Items are assumed to be stocked with a predetermined initial age. Such situations arise in practice when goods are received after partial aging, such as stored blood units, processed food products, dairy items, or pharmaceuticals.

11) Since the initial age is fixed at the time of replenishment, it does not evolve

dynamically with time.

Therefore, $a = a_0$ (constant throughout the cycle).

3. Model Formulation

In many inventory models, demand is generally assumed to remain constant throughout the planning horizon. However, this assumption becomes unrealistic in the case of perishable goods, where customer purchasing behavior is strongly influenced by product freshness and market timings. In practical situations, demand tends to decline due to seasonality, changing consumer preferences, and the gradual aging of products.

To reflect this realistic behavior the present model assumes that demand depends on both elapsed time and product age. Let "t" denote the elapsed time within the inventory cycle and "a" represent the age of the product. As time progresses and items grow older, customers exhibit reduced preference due to freshness considerations.

Accordingly, the demand rate is modelled function of time and age considering effect of inflation as:

$$D(t,a) = D_0(1-\alpha t)(1-\beta a_0)e^{-\gamma_i t}$$

This structure captures the joint influence of market time effects and product aging on demand decline. The model is particularly applicable for the products where freshness plays a vital role in customer purchasing decisions.

At the beginning of the replenishment cycle ($t = 0$), the inventory level is assumed to be maximum and equal to the order quantity Q. As time progresses, inventory decreases not only due to customer demand but also due to physical deterioration of items. The deterioration rate is assumed to be age-dependent and is defined as:

$$\theta(a) = \lambda a$$

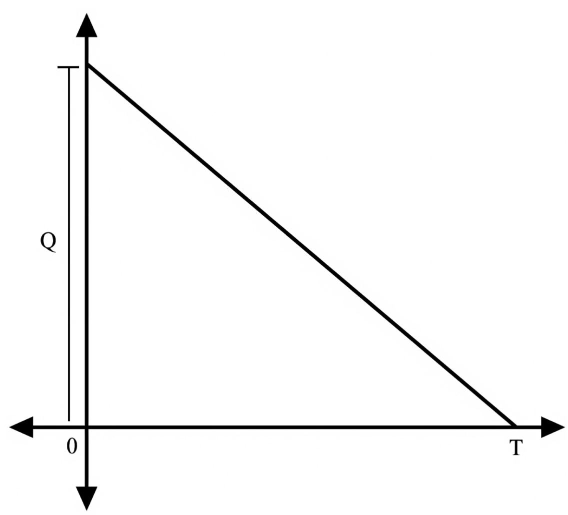

Figure 1. Graphical representation of inventory model.

Since the product age is considered constant within the cycle, *i.e.*, $a = a_0$, the deterioration rate reduces to:

$$\theta(a) = \lambda a_0$$

Thus, as shown in **Figure 1**, the inventory level declines simultaneously due to demand fulfilment and deterioration effects. By considering both mechanisms the inventory differential equation is formulated as follows:

$$\frac{\mathrm{d}I(t)}{\mathrm{d}t} + \lambda a_0 I(t) = -D_0(1-\alpha t)(1-\beta a_0)\mathrm{e}^{-\gamma_i t} \quad 0 \le t \le T \tag{1}$$

where $\theta(a) = \lambda a_0$, $D(t,a) = D_0(1-\alpha t)(1-\beta a_0)\mathrm{e}^{-\gamma_i t}$, $\gamma_i = \gamma - i$

The initial boundary conditions are

$$I(0) = I_0 = Q,\ I(T) = 0 \tag{2}$$

The solution for Equation (1) using the boundary conditions is

$$I(t) = \mathrm{e}^{-\lambda a_0 t}\left[I_0 + D_0(1-\beta a_0)\left(\left(\frac{1}{k} + \frac{\alpha}{k^2}\right)(1-\mathrm{e}^{kt}) - \frac{\alpha t}{k}\mathrm{e}^{kt}\right)\right] \tag{3}$$

where, $k = \lambda a_0 - \gamma_i$

Using the initial boundary conditions the Total Order Quantity Q is

$$Q = \int_0^T D(t,a)\,\mathrm{d}t$$

$$Q = D_0(1-\beta a_0)\left[\frac{1-\mathrm{e}^{-\gamma_i T}}{\gamma_i} - \alpha\left(\frac{1-\mathrm{e}^{-\gamma_i T}}{\gamma_i^2} - \frac{T\mathrm{e}^{-\gamma_i T}}{\gamma_i}\right)\right] \tag{4}$$

To calculate total profit per cycle the following sales revenue, purchase cost, holding cost, deterioration cost, ordering cost have been considered.

$$TP(T) = S_{Revenue} - C_{Purchase} - C_{holding} - C_{detorioration} - C_{ordering} \tag{5}$$

1) Ordering cost or setup cost

$$C_{ordering} = K \tag{6}$$

2) Purchase cost: The unit item purchase cost "c_p" and the Q units bought at $t = 0$ then

$$C_{Purchase} = c_p \int_0^T D(t,a)\,\mathrm{d}t$$

$$C_{Purchase} = c_p D_0(1-\beta a_0)\left[\frac{1-\mathrm{e}^{-\gamma_i T}}{\gamma_i} - \alpha\left(\frac{1-\mathrm{e}^{-\gamma_i T}}{\gamma_i^2} - \frac{T\mathrm{e}^{-\gamma_i T}}{\gamma_i}\right)\right] \tag{7}$$

3) Holding inventory cost or carrying cost

$$C_{holding} = h\int_0^T I(t)\,\mathrm{d}t$$

$$C_{holding} = hI_0\left(\frac{1-\mathrm{e}^{-\lambda a_0 T}}{\lambda a_0}\right) - hD_0(1-\beta a_0)\left[\frac{1}{k}\left(\frac{1-\mathrm{e}^{-\gamma_i T}}{\gamma_i} - \frac{1-\mathrm{e}^{-\lambda a_0 T}}{\lambda a_0}\right) - \frac{\alpha}{k}\left(\frac{1-\mathrm{e}^{-\gamma_i T}}{\gamma_i^2} - \frac{T\mathrm{e}^{-\gamma_i T}}{\gamma_i}\right)\right] \tag{8}$$

4) Deterioration cost

$$C_{deterioration} = c_d \int_0^T \lambda a_0 I(t)\,\mathrm{d}t$$

$$C_{deterioration} = c_d \left[I_0\left(1-\mathrm{e}^{-\lambda a_0 T}\right) - \lambda a_0 D_0\left(1-\beta a_0\right)\left(\frac{1}{k}\left(\frac{1-\mathrm{e}^{-\gamma_i T}}{\gamma_i} - \frac{1-\mathrm{e}^{-\lambda a_0 T}}{\lambda a_0}\right) - \frac{\alpha}{k}\left(\frac{1-\mathrm{e}^{-\gamma_i T}}{\gamma_i^2} - \frac{T\mathrm{e}^{-\gamma_i T}}{\gamma_i}\right)\right)\right] \tag{9}$$

5) Sales revenue

$$S_{Revenue} = p\int_0^T D(t,a)\,\mathrm{d}t$$

$$S_{Revenue} = pD_0\left(1-\beta a_0\right)\left[\frac{1-\mathrm{e}^{-\gamma_i T}}{\gamma_i} - \frac{\alpha\left(1-\mathrm{e}^{-\gamma_i T}\right)}{\gamma_i^2} + \frac{\alpha T\mathrm{e}^{-\gamma_i T}}{\gamma_i}\right] \tag{10}$$

where, $\gamma \neq 0$

Therefore, the total profit per cycle is

$$\begin{aligned} TP(T) = {} & \left(p-c_p\right)D_0\left(1-\beta a_0\right)\left[\frac{1-\mathrm{e}^{-\gamma_i T}}{\gamma_i} - \frac{\alpha\left(1-\mathrm{e}^{-\gamma_i T}\right)}{\gamma_i^2} + \frac{\alpha T\mathrm{e}^{-\gamma_i T}}{\gamma_i}\right] \\ & - hI_0\left(\frac{1-\mathrm{e}^{-\lambda a_0 T}}{\lambda a_0}\right) hD_0\left(1-\beta a_0\right)\left[\frac{1}{k}\left(\frac{1-\mathrm{e}^{-\gamma_i T}}{\gamma_i} - \frac{1-\mathrm{e}^{-\lambda a_0 T}}{\lambda a_0}\right) \right. \\ & \left. - \frac{\alpha}{k}\left(\frac{1-\mathrm{e}^{-\gamma_i T}}{\gamma_i^2} - \frac{T\mathrm{e}^{-\gamma_i T}}{\gamma_i}\right)\right] \\ & - c_d\left[I_0\left(1-\mathrm{e}^{-\lambda a_0 T}\right) - \lambda a_0 D_0\left(1-\beta a_0\right)\left(\frac{1}{k}\left(\frac{1-\mathrm{e}^{-\gamma_i T}}{\gamma_i} - \frac{1-\mathrm{e}^{-\lambda a_0 T}}{\lambda a_0}\right) \right.\right. \\ & \left.\left. - \frac{\alpha}{k}\left(\frac{1-\mathrm{e}^{-\gamma_i T}}{\gamma_i^2} - \frac{T\mathrm{e}^{-\gamma_i T}}{\gamma_i}\right)\right)\right] - K \end{aligned} \tag{11}$$

The optimal cycle length T^* is obtained by solving first order derivative $\frac{\mathrm{d}\left(TP(T)\right)}{\mathrm{d}T} = 0$ and the second order derivative $\frac{\mathrm{d}^2\left(TP(T)\right)}{\mathrm{d}T^2} < 0$ ensures the concavity of profit function and T^* gives maximum profit.

4. Numerical Example

Considering following parameter values

$p = \text{Rs.}40/\text{unit}, c_p = \text{Rs.}20/\text{unit}, h = \text{Rs.}0.5/\text{unit}, K = \text{Rs.}600/\text{order}$,
$c_d = \text{Rs.}5/\text{unit}, D_0 = 100$ units, $\alpha = 0.02, \beta = 0.01, a_0 = 1, \lambda = 0.1$,
$i = 0.05, \gamma = 0.8, I_0 = 200$ units.

The solution for the crisp model is $T^* = 1.2631$, $TP^* = 819.4970$, $AP^* = 648.7504$, $Q^* = 79.9549$.

5. Sensitivity Analysis

A sensitivity analysis is carried out to investigate the robustness of the proposed model with respect to changes in key parameters.

Table 1. Sensitivity analysis for various parameters.

Parameters		T	AP	Q
c_p	16	1.1016	909.1649	73.5162
	18	1.1746	777.2435	76.5277
	20	1.2631	648.7504	79.9549
	22	1.3732	524.2898	83.9036
	24	1.5150	404.6715	88.5208
h	0.4	1.2552	662.9820	79.6550
	0.45	1.2591	655.8628	79.8045
	0.5	1.2631	648.7504	79.9549
	0.55	1.2672	641.6447	80.1063
	0.6	1.2713	634.5459	80.2585
c_d	4	1.2552	662.9820	79.6550
	4.5	1.2591	655.8628	79.8045
	5	1.2631	662.7504	79.9549
	5.5	1.2672	662.6447	80.1063
	6	1.2713	662.5459	80.2585
λ	0.08	1.2527	661.2133	79.5613
	0.09	1.2578	654.9305	79.7552
	0.1	1.2631	648.7504	79.9549
	0.11	1.2686	642.6726	80.1604
	0.12	1.2743	636.6970	80.3717
D_0	80	1.4964	394.4226	118.5184
	90	1.3659	519.4666	121.7105
	100	1.2631	648.7504	125.0561
	110	1.1795	781.5973	128.4526
	120	1.1098	917.4966	131.8470
p	32	1.9866	185.0389	100.7066
	36	1.5150	404.6715	88.5208
	40	1.2631	648.7504	79.9549
	44	1.1016	909.1649	73.5162
	48	0.9871	1181.5272	68.4472
K	480	1.0823	751.2561	72.6946
	540	1.1730	698.0268	76.4640
	600	1.2631	648.7504	79.9549
	660	1.3531	602.8665	83.2069
	720	1.4434	559.9403	86.2507

The sensitivity analysis presented in Table 1 and as shown in Figures 2-4 provides impact of key system parameters on average profit, optimal cycle length and optimal order quantity.

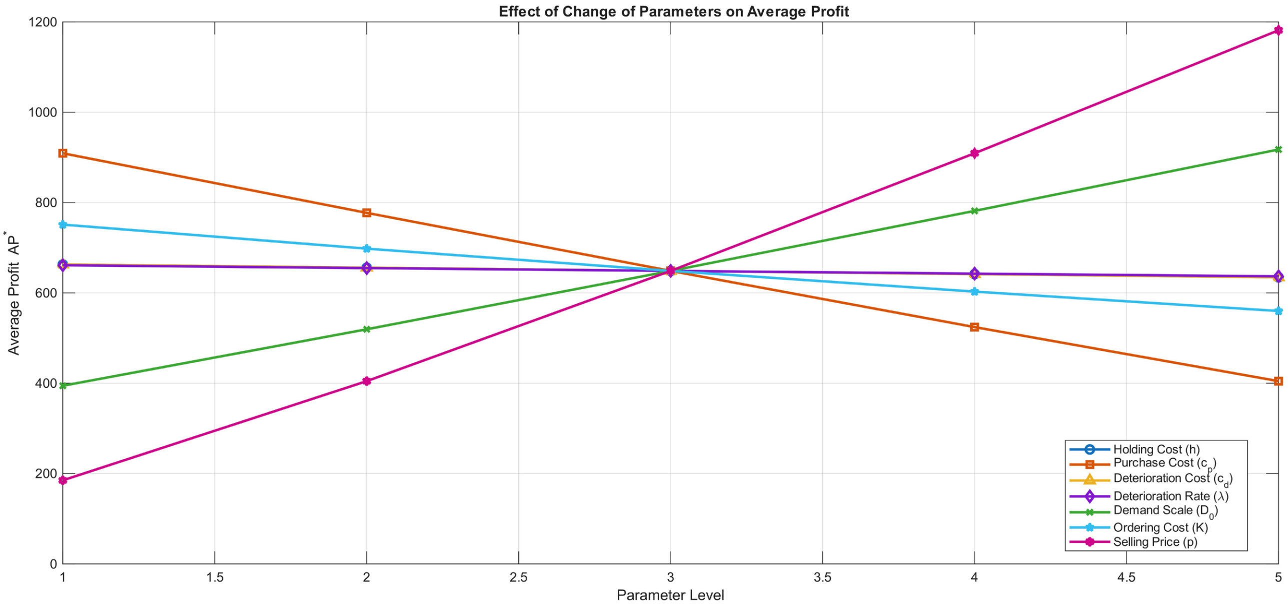

Figure 2. Effect of change of parameters on average profit.

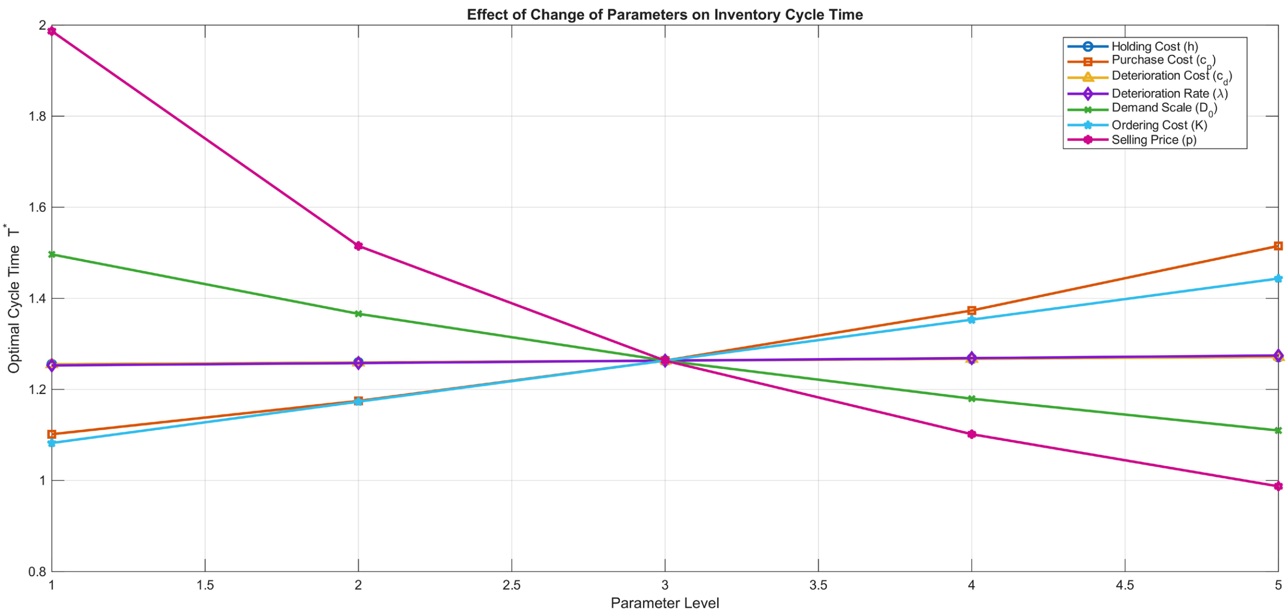

Figure 3. Effect of change of parameters on inventory cycle time.

As the purchase cost c_p increases, both the optimal cycle length T and order quantity Q increase. This behavior suggests that firms must reduce replenishment frequency as procurement costs increase.

An increase in holding cost h leads to a slightly increase in both optimal cycle length and order quantity. This reflects a strategy where firms adjust replenishment timing to offset higher storage expenses. At the same time the average profit decreases gradually, indicating moderate system sensitivity to holding cost.

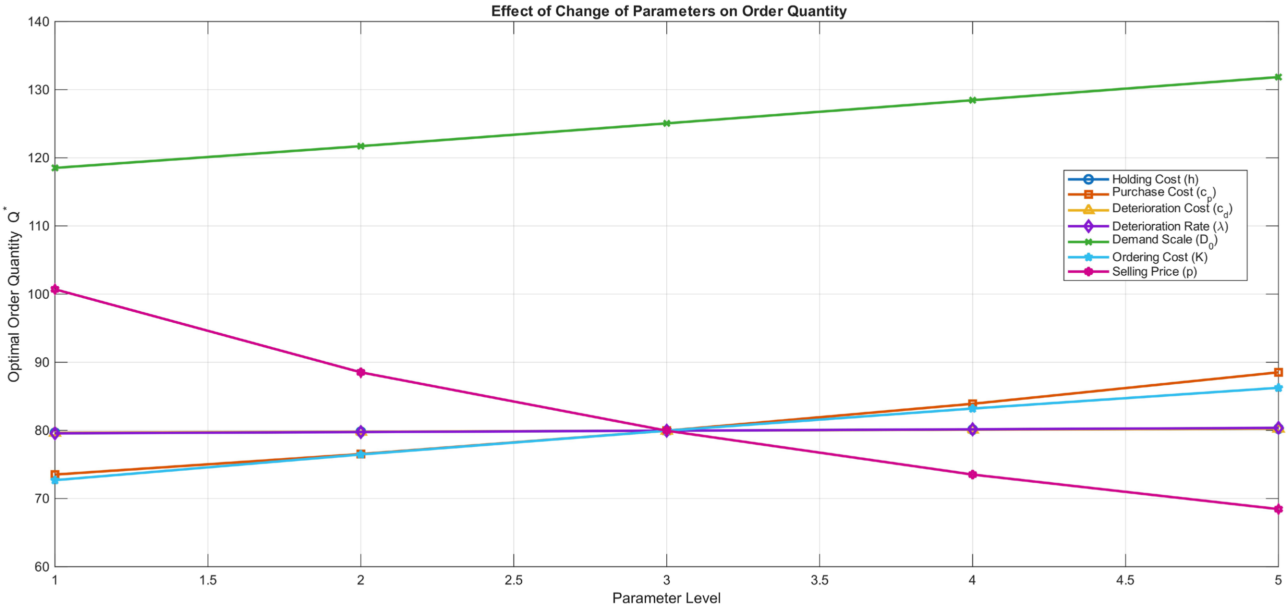

Figure 4. Effect of change of parameters on order quantity.

When deterioration cost c_d increases, the optimal cycle length and order quantity show only marginal increases. The average profit decreases steadily, indicating that deterioration cost exerts a weaker impact on system performance. The relatively flat curves confirm low sensitivity of profit to this parameter.

An increase in the deterioration rate λ results in higher cycle length and order quantity, while average profit decreases steadily. This suggests the adverse effect of faster spoilage on profitability, although the sensitivity remains moderate compared to economic parameters.

The demand scale parameter D_0 exerts a strong positive influence on the system. As demand increases, both average profit and order quantity rise significantly, whereas the optimal cycle length decreases due to faster inventory turnover.

Selling price p shows the highest sensitivity among all parameters. A rise in selling price leads to a high increase in average profit, while both optimal cycle length and order quantity decrease, it gives rapid replenishment strategies to capitalize on higher margins.

Finally, as ordering cost K increases system responds by increasing cycle length and order quantity to reduce ordering frequency. However, average profit declines due to higher fixed operational costs.

Sensitivity analysis of average profit with respect to major economic and deterioration parameters as shown in Figure 2. The comparative slopes illustrate the relative profitability impact of pricing, demand intensity and cost related factors within the proposed inventory framework.

Effect of parameter variations on optimal cycle length. As shown in Figure 3, it demonstrates replenishment timing adjustments under changing economic costs, deterioration dynamics, and demand conditions, highlighting key trade-offs in inventory planning.

Sensitivity of optimal order quantity to system parameters. As shown in **Figure 4**, it captures the responsiveness of replenishment size decisions to demand fluctuations, pricing policies, and cost deterioration interactions.

The uncovering of the proposed model extends several implications for inventory managers handling perishable products. Selling price and demand scale both stand out the critical factors as the most influential drivers of profitability indicating the importance of pricing strategies and demand forecasting, even small changes in pricing produces noticeable revenue. The higher deterioration rates substantially reduce profit and suggesting the need for improved technology-based systems. While holding and deterioration costs affect operational performance and their sensitivity is comparatively lower than economic parameters. Holding cost control, a profitability while its impact remains moderate compared to pricing factors. Additionally, increased ordering and procurement costs encourage longer replenishment cycles and bulk purchasing decisions. Therefore, the integrated consideration of age, time, and inflation effects enables managers to design more responsive and cost-efficient inventory policies.

6. Conclusion

This paper proposed an integrated inventory framework for perishable items in which demand is influenced by time, product age and inflationary effects. The deterioration increases linearly with age of parameter. The proposed model extends classical inventory formulations by incorporating age and time dependent demand under inflation and age dependent deterioration. The framework explicitly incorporates freshness related customer behaviour and economic dynamics in a unified analytical structure. The inventory system is modelled through a first order differential equation and closed form expressions for the inventory level, The results indicate that selling price and demand scale parameters have a significant influence on average profit, while holding cost, deterioration cost explained comparatively moderate effects. The optimal replenishment cycle length T^* is determined by maximizing the total profit function and the concavity of the profit function ensures the existence of a unique optimal solution. Numerical illustrations confirms that the model stability and economically interpretability for the range of parameter values. Sensitivity analysis is carried out to assess the robustness of key system parameters for the optimal decisions and profit performance. These findings provided important managerial insights for firms dealing with perishable products, highlighting the need for careful pricing and demand management in environments characterized by product aging and inflation. The study may be extended in future research by considering dynamic aging, shortages, uncertainty in demand, or sustainability related factors.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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