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Economic Order Quantity Model For Deteriorating Items With Time-Dependent Demand And Time-Varying Holding Cost Under Inflationary Environment

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Abstract
In this paper study develops an inventory model for deteriorating items under a realistic market environment characterized by time-dependent demand, time-varying holding cost, and inflation. Traditional Economic Order Quantity models assume constant demand and holding costs; however, such assumptions are often impractical in dynamic economic conditions. In this study, the demand rate is considered as a function of time, while holding cost varies over time due to inflationary effects. The rate of deterioration is assumed to be constant, and shortages are not allowed. The effect of inflation and the time value of money is incorporated using the discounted cash flow approach to determine the present value of total inventory cost. The total cost function, including ordering cost, purchasing cost, and holding cost, is formulated over a finite planning horizon. The findings demonstrate that inflation and time-dependent demand significantly affect optimal ordering decisions. The proposed model offers a practical decision-making framework for managing perishable and deteriorating goods in an inflationary economic environment.

Keywords: *Economic Order Quantity; Deteriorating Items; Time-Dependent Demand; Time-Varying Holding Cost; Inflation; Optimal Replenishment Policy*

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I. Introduction

Inventory management is a key function in production and supply chain systems, helping organizations maintain an optimal balance between supply and demand while minimizing costs. Among various inventory control approaches, the Economic Order Quantity (EOQ) model is widely used to determine the optimal order quantity that minimizes total inventory costs. However, the classical EOQ model assumes constant demand, constant holding cost, and no deterioration of items, which rarely holds in real-world scenarios. In practice, many products such as food, pharmaceuticals, chemicals, and electronic components deteriorate or lose value over time. The concept of deteriorating inventory was first introduced by Ghare and Schrader [5], which laid the foundation for more realistic inventory modeling. Demand often varies with time due to seasonal trends, market growth, and changing consumer preferences. To capture these effects, De and Chaudhuri [3] developed an EOQ model with time-dependent demand and shortages, while Chaudhuri highlighted its influence on inventory control. Further studies by Bhunia and Maiti [1] and Ghosh and Chaudhuri [6] analyzed deteriorating inventory systems with time-varying demand and shortages.Shortages and partial backlogging occur when demand exceeds stock availability. Wee [18] studied deteriorating inventory with partial backlogging, and Singh and Singh [12] extended the EOQ model by incorporating time-dependent demand and partial backlogging for deteriorating items. Inflation is another critical factor that impacts inventory costs, as it increases purchasing, ordering, and holding costs over time. Tripathi and Kumar[17] and Tripathi [16] incorporated inflation in EOQ models to better reflect economic realities. Holding cost may also vary over time due to changes in storage expenses, maintenance, and financial charges. To model realistic scenarios, Ouyang, Chen, and Teng [10] developed inventory systems with deterioration, time-dependent demand, and inflation. Recent research further extends these concepts by considering dynamic demand and economic factors, as shown by Mishra, Singh, and Pattnayak [9], Sarkar [11], Tiwari, Cárdenas-Barrón, and Goh [15], Mashud, Khan, and Uddin [8], and Dey, Giri, and Maiti [4]. Although extensive research exists on deteriorating inventory models, few studies simultaneously consider deterioration, time-dependent demand, time-varying holding cost, and inflation in a unified EOQ framework. Therefore, this study develops an EOQ model for deteriorating items with time-dependent demand and time-varying holding cost under an inflationary environment to determine the optimal replenishment policy that minimizes total inventory costs while reflecting realistic operational and economic conditions.

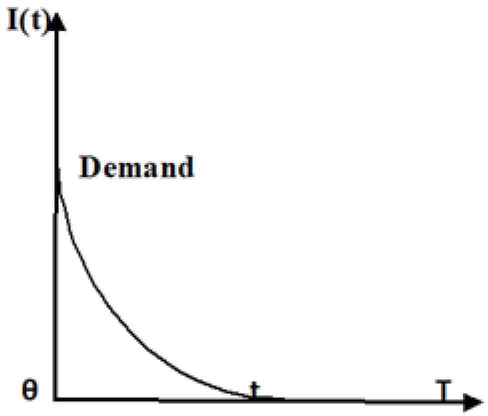
II. Assumptions

1. The demand rate is deterministic and time-dependent. It follows a quadratic function of time given by D(t)=a+bt+ ,a>0where a=is the initial demand rate, b= represents the linear change in demand over time, c= represents the acceleration (or deceleration) in demand growth.
2. Items deteriorate at a constant rate θ, where $0<\theta<1$
3. Holding cost is time-dependent due to inflation and is assumed to be of the form:
h(t)= $h_0 e^{kt}$
is the initial holding cost per unit per unit time, k is the inflation rate.
4. Inflation rate i is constant over the planning horizon.
5. Replenishment is instantaneous (lead time is zero). 6. Shortages are not allowed.
7. Inventory level reaches zero at the end of each cycle.
8. The planning horizon is finite and known in advance.
9. Ordering cost (fixed per order),
10. Purchasing cost (constant per unit),
11. Time-varying holding cost.

III. Notations

The following notations are used throughout the model:
D(t) = Demand rate at time t
a = Initial demand rate (a>0)
b = Linear demand coefficient
c =Quadratic demand coefficient
I(t) = Inventory level at time t
Q = Order quantity per cycle
T = Length of replenishment cycle
 = Exponential deterioration factor over cycle
H = Finite planning horizon
n = Number of replenishment cycles in planning horizon
Oc= Ordering cost per order
Cp = Purchasing cost per unit
h(t) = Holding cost per unit per unit time at time t
 = Initial holding cost per unit per unit time
k= Inflation rate affecting holding cost
θ = Constant deterioration rate ($0<\theta<1$)
i =Inflation rate
r = Discount rate (time value of money)
PV = Present value of total inventory cost

Mathematical Formulation



During the inventory period [0] the inventory diminishes due to the Combined effects of demand and deterioration, Consequently, it is described by the differential Equation ,

$\frac{dI(t)}{dt}$= -D(t) – θI(t) when I(t)>0 , 0≤t≤T,——(1)

with boundary condition I(0)=I_0 The solution of equation (1) is

$\frac{dI(t)}{dt}$+θI(t)= a+bt+ct^2

I(t)=$e^{\theta(T-t)}[\frac{a}{\theta}+b(\frac{T}{\theta}-\frac{1}{\theta^2})+c(\frac{T^2}{\theta}-\frac{2T}{\theta^2}+\frac{2}{\theta^3})]-[[\frac{a}{\theta}+b(\frac{t}{\theta}-\frac{1}{\theta^2})+c(\frac{t^2}{\theta}-\frac{2t}{\theta^2}+\frac{2}{\theta^3})]$, 0≤t≤T ——(2)

Therefore the total cost per cycle consists of the following components

Ordering cost

$Pv_{Oc}=O_c$

Purchasing costPv_{c_p}= c_pQ =$c_p e^{\theta T}\int_0^T(a+bt+ct^2)\,e^{-\theta T}$d =$e^{\theta T}[\frac{a(1-e^{-\theta T})}{\theta}+\frac{b(1-e^{-\theta T}(1+\theta T))}{\theta^2}+\frac{c(2-e^{-\theta T}(2+2\theta T+2\theta T)^2}{\theta^3}]$

Holding cost

$Pv_{Hc}=\int_0^T h(t)I(t)\,e^{-rt}$ dt

$Pv_{Hc}=h_0\int_0^T I(t)\,e^{(k-r)t}$ dt $=\frac{h_0e^{\theta T}}{k-r-\theta}\{[\frac{a(e^{(k-r-\theta)T}-1)}{k-r-\theta}+\frac{b(e^{k-r-\theta)T}-1)}{(k-r-\theta)^2}+\frac{c(e^{(k-r-\theta)T(k-r-\theta)^2T^2}-2(k-r-\theta)}{(k-r-\theta)^3}-[\frac{a(e^{-\theta T}-1)}{-\theta}+\frac{b((e^{-\theta T}(-\theta T-1)+1)}{-\theta^2}+\frac{c(e^{-\theta T}(\theta^2T^2+2\theta T+2)-2)}{-\theta^3}]\}$

Total cost per cycle

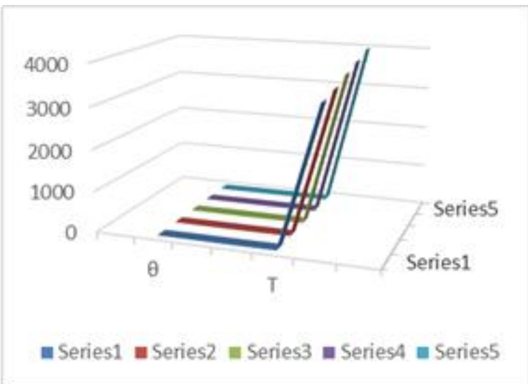
$p_v(T)=O_c+c_p$Q + Pv_{Hc}

$= O_c+c_pe^{\theta T}[\frac{a(1-e^{-\theta T})}{\theta}+\frac{b(1-e^{-\theta T}(1+\theta T))}{\theta^2}+\frac{c(2-e^{-\theta T}(2+2\theta T+2\theta T)^2}{\theta^3}]+\frac{h_0e^{\theta T}}{k-r-\theta}\{[\frac{a(e^{(k-r-\theta)T}-1)}{k-r-\theta}+\frac{b(e^{k-r-\theta)T}-1)}{(k-r-\theta)^2}+\frac{c(e^{(k-r-\theta)T(k-r-\theta)^2T^2}-2(k-r-\theta)}{(k-r-\theta)^3}-[\frac{a(e^{-\theta T}-1)}{-\theta}+\frac{b((e^{-\theta T}(-\theta T-1)+1)}{-\theta^2}+\frac{c(e^{-\theta T}(\theta^2T^2+2\theta T+2)-2)}{-\theta^3}]\}$

Numerical example : a=225,b=5,c=0.5,k=0.06,r=0.10, θ=0.04,h_0=2,Oc=700

Table-

θ	T_0	T_1	T	T_c
0.01	7.80	11.40	19.20	3420.50
0.02	7.95	11.60	19.55	3518.30
0.04	8.20	11.85	20.05	3685.70
0.06	8.45	12.10	20.55	3824.60
0.08	8.70	12.35	21.05	3976.40



IV. Parametric Analysis:

An increase in the deterioration rate (θ) reduces the optimal replenishment cycle length and increases total cost, implying more frequent ordering. Higher inflation and rising holding costs significantly influence optimal policy decisions by discouraging long holding periods growth in quadratic demand accelerates inventory depletion, there by shortening replenishment cycles. A higher discount rate reduces the present value of future holding costs, influencing cost trade-offs in long-term planning.

V. Conclusion

Study develops an integrated inventory model for deteriorating items under a realistic economic environment characterized by time-dependent demand, time-varying holding cost, and inflation. Unlike the classical Economic Order Quantity framework, which assumes constant demand and holding costs, the proposed model incorporates quadratic demand, constant deterioration, inflation-driven holding cost, and the time value of money using the discounted cash flow approach over a finite planning horizon. Incorporating inflation and discounting, the model determines the present value of total inventory cost, including ordering, purchasing, and holding costs. This approach provides a more accurate estimation of total cost in inflationary economic conditions. Overall, the model offers a comprehensive decision-making framework for businesses dealing with perishable and deteriorating goods such as food products, pharmaceuticals, and electronic components. It helps managers determine the optimal replenishment cycle under dynamic demand patterns and inflationary pressure. The proposed model can be further extended by incorporating shortages, trade credit policies, variable deterioration rates, stochastic demand, or multi-item inventory systems. These extensions would enhance its applicability in more complex and uncertain supply chain environments. The model extends traditional EOQ theory and is applicable to perishable goods industries operating in dynamic economic environments.

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