A INVENTORY MODEL FOR HEALTH SERVICE FIRMS IN QUADRATIC DEMAND OF PARABOLIC HOLDING COST WITH SHORTAGES

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Abstract:
During olden days, in the inventory models of Health service firms, the demand and cost of holding the things were fixed. Now in the modern world, the above cannot be considered as fixed. It is changing from time to time and place to place. So we have to formulate a model of demand in quadratic with time function. The cost of holding the things are considered as parabolic equations of time where changing of fixed deterioration is taken. The shortage of stocks is allowed. Using this inferences, a mathematical model have developed and find the solution and represented using graph. The scope is time should be optimal, order quantity is more of very least overall average cost. This result has more importance in Health service firms.

Key Words: Deterioration, Health service, Shortages, Time changeable demand and parabolic holding cost.

1. Introduction

As we enter the new globalised world, Health service sectors are facing different challenges, continuously improving their services and giving highest quality at optimal cost. Everyday Health service sectors deal with inventory complications, logistics of materials, and patient quarries regarding their health issues. Controlling the stock is not simple and it varies time to time, based on which the system will change the new domain to service their clients.

Decaying the referred as product decay, evaporation of spoilage and loss of usefulness. The inventories are realistic feature put into discussion. Often we discover Health service products, such as...
generic medicines, caplets, Ophthalmic, Creams, prescription painkillers, etc., that have a defined life expectancy, due to time it losses.

Vinod Kumar (et al) has proposed a model of Deteriorating inventory dependent demand and holding cost backlogging,[1]. S. K. Karuppasamy,. (et al) have developed a result of Coordination demand and order size dependent trade credit in healthcare industries a model for imperfect thing with time subordinate interest, holding cost and halfway accumulating and give logical arrangement of the model that limit the all out stock expense.[2]. Khanra S., (et al), has proposed a model of An EOQ model item quadratic demand delay in payment.[3]. Uthayakumar,. R (et al) has proposed a model of Pharmaceutical supply chain and Optimization for a pharmaceutical company and a hospital [4]. Khanra, S., (et al) have formulated  model of A note on order level inventory model [5]. Pavan Kumar., has presented a paper of deterministic inventory model for parabolic holding cost with no shortages is presented. Salvage value is also incorporated in the model. An expression for average total cost function is derived [6]. Vaithyasubramanian. (et al). A has proposed a model of Study on User Credentials Using Statistical Analysis [7] Vaithyasubramanian, (et al). have derived a paper of Multifactor authentication a study on user preference, remembering ability, error rate and time consumption [8]. Uthayakumar. R and et al has investigated non-constant deteriorating pharmaceutical things with healthcare Industries inventory model [9]. Pavan Kumar, (et al). has derived a paper of Inventory Control Model with Time-Linked Holding Cost, Salvage Value and Probabilistic Deterioration following Various Distribution it discussed an optimum inventory management issue with time-related cost of holding and salvage value. The decay of items after two distributions is a continuous random number uniform distribution and triangular distribution[10].

To develop a inventory of Health service firms model in quadratic time function, Parabolic holding cost and disintegration rate fixed. The rate of backlogging depends on the length of the next replenishment and allowing shortages. Our target is to find the least overall average cost with least time and largest quantity, leftover paper is constructed to arrange bellow as quoted. In the section (2), Symbols & Inferences is listed. Then section (3), we formulated a Math Optimizing model is recommended. In the next section (4), two level numerical problems is carried out and the section (5), Using table values sensitivity test is performed, graphical depiction are showed in section (6). Comments and reviews are submitted in section (7). In the last, completion and provide a few future investigate chance.

2. Symbols and Inferences

2.1. Symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>$S_F$</td>
<td>The Health service setup Cost/ordering cost per order;</td>
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<tr>
<td>$C_F$</td>
<td>The Health service purchase cost per unit;</td>
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<tr>
<td>$\theta_F$</td>
<td>The Health service defective rate;</td>
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<td>$K_F$</td>
<td>Health service Ordering cost</td>
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<td>$HC$</td>
<td>Health service holding Cost/Carrying Cost per unit per time unit;</td>
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<tr>
<td>$BC$</td>
<td>The Health service back ordered cost.</td>
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<tr>
<td>$L_F$</td>
<td>The Health service cost of lost sales per unit;</td>
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<tr>
<td>$t_{F1}$</td>
<td>The Health service time ,$t_{F1} \geq 0$</td>
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<tr>
<td>$T_{F1}$</td>
<td>($= t_{F1} + t_{F2}$) the length of cycle time;</td>
</tr>
<tr>
<td>$Q_{F1}$</td>
<td>The Health service inventory level during $[0,T_{F1}]$ ;</td>
</tr>
</tbody>
</table>
\( Q_{F2} \) The Health service inventory level during shortage period;
\( Q_F \) \((=Q_{F1}+Q_{F2})\) the Health service order quantity during a cycle of length \( T_{F1} \);
\( I_{F1}(t) \) The Health service level of positive inventory at time \( t \);
\( I_{F2}(t) \) The Health service level of negative inventory at time \( t \);
\( ATC(t_{F1},t_{F2}) \) The Health service Average total cost per time unit.

### 2.2 Inferences

- Allowing Health service Shortage & partially backlogged
- Health service Holding cost is parabolic of time \( h(t)=u+vrt^2 \), \( u \geq 0, v \geq 0 \) and the defective rate is constant.
  
  The Health service demand rate is time dependent \( f(t)=a_1+b_1t+c_1t^2 \), where \( a_1>0,b_1>0 \)

- The Health service lead time is zero, Infinite rate of replenishment is taken.
- \( B(t)=\frac{1}{1+\delta(T_{F1}-t)} \), \( \delta \) is backlogging parameter of health service and \((T_{F1}-t)\) is waiting time \((t_{F1} \leq t \leq T_{F1})\) where \( T_{F1}=t_{F1}+t_{F2} \).

![Graph of Inventory System](image)

**Figure 1: Graph of Inventory System**

### 3. The Mathematical Optimizing model generation
The rate of Health service inventory during positive stock period \([t_{F1}, t_{F1} + t_{F2}]\) is formed as follows

\[
\frac{dI(t)}{dt} + \theta F I(t) = -\left(a_1 + b_1 t + c_1 t^2\right), \quad 0 \leq t \leq t_{F1}
\]  

(1)

\[
\frac{dI(t)}{dt} = -\left(a_1 + b_1 t + c_1 t^2\right), \quad t_{F1} \leq t \leq t_{F1} + t_{F2}
\]  

(2)

with the boundary conditions \(I(t) = I(0) = 0\) at \(t = t_{F1}\), \(I(t) = Q(t)\) at \(t = 0\) and

\(Q(t) = -I_{F2}(t)\) The soln of eqn (1) and applying boundary conditions \(I(t) = 0\) we get

\[
I(t) = \left[\frac{-a_1 + b_1 (1 + \delta(t_{F1} + t_{F2})) + c_1 (1 + \delta(t_{F1} + t_{F2}))^2}{\delta^3}\right] \log\left[\frac{1 + \delta(t_{F1} + t_{F2} - t)}{1 + \delta(t_{F2})}\right]
\]

\[
+ \left[\frac{b_1}{\delta} + \frac{c_1 (1 + \delta(t_{F1} + t_{F2}))}{\delta^2}\right] (t - t_{F1}) + \frac{c_1}{2\delta} (t^2 - t_{F1}^2), \quad t_{F1} \leq t \leq t_{F1} + t_{F2}
\]

(3)

The solution of equation (2) and using the boundary conditions \(I(t) = 0\) we get

\[
I(t) = \left[\frac{-a_1 + b_1 (1 + \delta(t_{F1} + t_{F2})) + c_1 (1 + \delta(t_{F1} + t_{F2}))^2}{\delta^3}\right] \log\left[\frac{1 + \delta(t_{F1} + t_{F2} - t)}{1 + \delta(t_{F2})}\right]
\]

\[
+ \left[\frac{b_1}{\delta} + \frac{c_1 (1 + \delta(t_{F1} + t_{F2}))}{\delta^2}\right] (t - t_{F1}) + \frac{c_1}{2\delta} (t^2 - t_{F1}^2), \quad t_{F1} \leq t \leq t_{F1} + t_{F2}
\]

(4)

\[
Q(t) = I(t) + Q(t)
\]

(5)

\[
Q(t) = -I_{F2}(t)
\]

(6)

\[
Q(t) = Q(t) + Q(t)
\]

(7)
The Health service stock holding cost in $[0, t_{F1}]$ as follows

$$ HC = \int_{0}^{t_{r1}} H(t)I_{F1}(t) dt \Rightarrow HC = \int_{0}^{t_{r1}} \left( u + vt^2 \right) I_{F1}(t) dt $$

$$ HC = \left\{ t_{F1} \left( \frac{c_1v^2\theta_F}{84} \right) + t_{F1}^6 \left( \frac{b_1v\theta_F}{72} + \frac{c_1v}{18} \right) + t_{F1}^5 \left( \frac{a_1v\theta_F}{60} + \frac{b_1v}{15} + \frac{c_1u\theta_F}{10} \right) \right\} $$

$$ + t_{F1}^4 \left( \frac{a_1v}{12} + \frac{b_1u\theta_F}{8} + \frac{c_1u}{4} \right) + t_{F1}^3 \left( \frac{a_1u\theta_F}{6} + \frac{b_1u}{3} \right) + t_{F1}^2 \left( \frac{a_1u}{2} \right) $$. \hspace{1cm} (8)

Costs incurred in this period are the stock out cost for items that are back ordered

The stocks out costs are as follows

$$ BC = -S_F \int_{t_{r1}}^{t_{r1}+t_{r2}} I_{F2}(t) dt $$

$$ BC = S_F \left\{ -\frac{a_1}{\delta^2} - \frac{b_1}{\delta^3} \left( 1 + \delta(t_{F1} + t_{F2}) \right) - \frac{c_1}{\delta^4} \left( 1 + 2\delta(t_{F1} + t_{F2}) + \delta^2(t_{F1} + t_{F2}) \right) \log \left[ 1 + \delta t_{F2} \right] \right\} $$

$$ + S_F \left\{ \left( \frac{a_1}{\delta} + \frac{b_1}{\delta^2} + \frac{c_1}{\delta^3} \right) \left( 1 + \delta(t_{F1} + t_{F2}) \right) \right\} I_{F2} + \frac{1}{2\delta^2} \left( b_1\delta + c_1 \right) \left[ \left( t_{F1} + t_{F2} \right)^2 - t_{F1}^2 \right] $$

$$ + \frac{C_F}{3\delta} \left( t_{F1} + t_{F2} \right)^3 - \frac{t_{F1}^3}{3} \right\} $$. \hspace{1cm} (9)

Lost sales cost per cycle ($LS$)

$$ LS = L_F \int_{t_{r1}}^{t_{r1}+t_{r2}} \left[ 1 - \left( a_1 + b_1t + c_1t^2 \right) \left( \frac{1}{1 + \delta(t_{F1} + t_{F2} - t)} \right) \right] dt $$

$$ LS = L_F \left\{ \frac{a_1t_{F2} + b_1t_{F2}^2}{2} + b_1t_{F1}t_{F2} + \frac{c_1t_{F2}^2}{3} + c_1t_{F1}t_{F2} + c_1t_{F1}t_{F2}^2 - \frac{a_1 \log \left( 1 + \delta t_{F2} \right)}{\delta} \right\} $$

$$ + \frac{b_1t_{F2}^2}{\delta} - \frac{b_1 \left[ 1 + \delta(t_{F1} + t_{F2}) \right] \log \left( 1 + \delta t_{F2} \right)}{\delta^2} $$

$$ + \frac{c_1}{\delta^3} \left[ \delta t_{F2} + \frac{3\delta^2 t_{F2}^2}{2} + 2\delta^2 t_{F1}t_{F2} - \left[ 1 + \delta(t_{F1} + t_{F2}) \right]^2 \log \left( 1 + \delta t_{F2} \right) \right] $$

$$ + \frac{C_F}{3\delta^3} \left( 1 + t_{F2} \right)^3 - \frac{t_{F1}^3}{3} \right\} \hspace{1cm} (10)$$

Purchase cost per cycles ($PC$)

$$ PC = C_F \times Q_F $$


### Ordering cost \((OC) = K_F \) fixed cost

Thus the total average pharmaceutical inventory cost in the interval \([0, t_{F1} + t_{F2}]\) per unit time.

Average total cost = \(\frac{1}{t_{F1} + t_{F2}} [\text{Ordering cost} + \text{Purchase price} + \text{holding cost} + \text{shipping costs} + \text{stock out cost}]\)

\[(ie) \quad ATC = \frac{1}{t_{F1} + t_{F2}} [OC + PC + HC + BC + LS] \]

\[
PC = C_F \left[ \frac{a_1 t_{F1}}{2} + \frac{b_1 + a_1 \theta_F}{6} t_{F1}^2 + \frac{c_1 + b_1 \theta_F}{18} t_{F1}^3 + \frac{c_1 \theta_F}{10} t_{F1}^4 - \frac{b_1 \theta_F}{\delta} t_{F1} - \frac{c_1 (1 + \delta (t_{F1} + t_{F2}))}{\delta^2} \right] t_{F2}
\]

\[
= \left[ \frac{a_1}{\delta} + \frac{b_1 (1 + \delta (t_{F1} + t_{F2}))}{\delta^2} + \frac{c_1 [1 + \delta (t_{F1} + t_{F2})]^2}{\delta^3} \right] \log (1 + \delta t_{F2}) - \frac{c_1}{2 \delta} \left[ (t_{F1} + t_{F2})^2 - t_{F1}^2 \right]
\]

\[(11)\]

The necessary condition for least value of \(ATC(t_{F1}, t_{F2})\) are

\[
\frac{\partial (ATC(t_{F1}, t_{F2}))}{\partial t_{F1}} = 0 \quad \text{&} \quad \frac{\partial (ATC(t_{F1}, t_{F2}))}{\partial t_{F2}} = 0.
\]

The sufficient condition for least of \(ATC(t_{F1}, t_{F2}), t_{F1} > 0, t_{F2} > 0.\)
To solve using the any technique of computer based software and obtain optimal order cycle time \((t_{F_1}, t_{F_2})\) is \((t_{F_1}^*, t_{F_2}^*)\). The II order derivative of \(ATC(t_{F_1}, t_{F_2})\), is very complicated. That is also using computer based software verified and with the help of a graph the progress can be identified and tabulated.

4. Numerical problems

**Example 1:** The Health service input data are 
\[a_t = 25 \text{ units}, b_t = 40 \text{ units}, c_t = 50 \text{ units}, \theta_F = 0.005 \text{ units}, \]
\[u = 0.05 \text{ units}, v = 0.001 \text{ units}, \delta = 4.2 \text{ units}, S_F = Rs.12, L_F = Rs.15, C_F = Rs.50, K_F = Rs.5000.\]

We have the optimum solution as \(t_{F_1}^* = 1.125, t_{F_2}^* = 0.1702, ATC = 7943.745\) and quantity \(Q_F = 59.0405\).

**Example 2:** The Health service input data are 
\[a_t = 50 \text{ units}, b_t = 80 \text{ units}, c_t = 70 \text{ units}, \theta_F = 0.05 \text{ units}, \]
\[u = 5 \text{ units}, v = 2 \text{ units}, \delta = 5 \text{ units}, S_F = Rs.20, L_F = Rs.20, C_F = Rs.90, K_F = Rs.6000.\]

We have the optimum solution as \(t_{F_1}^* = 0.7882, t_{F_2}^* = 0.0823, ATC = 16786.668\) and quantity \(Q_F = 111.3272\).

5. Sensitivity analysis and representations using graphs

5.1. To demonstrate the modifications in the parameters are shown in Table

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<tr>
<th>Parameter</th>
<th>Variation</th>
<th>(t_{F_1})</th>
<th>(t_{F_2})</th>
<th>(Q_F)</th>
<th>(ATC(t_{F_1}, t_{F_2}))</th>
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5.2. Graph of parameters with average total cost
6. Observations using table value

Here the investigation are using tabular values we can observe the following progress

(1). The raising in a results in time \( t_{f_1} \) raising and Time \( t_{f_2} \) also decline, there by the order amount \( Q_f \) has also raising and Average tot cost \( ATC \) has also been raising.

(2). The raising in b results in time \( t_{f_1} \) decline and Time \( t_{f_2} \) also raising, there by the order amount \( Q_f \) has also decline and Average tot cost \( ATC \) has also been raising.

(3). The raising in c results in time \( t_{f_1} \) decline and Time \( t_{f_2} \) raising, there by the order

(4). Amount \( Q_f \) has also raising and Average tot cost \( ATC \) has also been raising.

(5). The raising in \( \theta_f \) results in time \( t_{f_1} \) raising and Time \( t_{f_2} \) also decline, there by the order amount \( Q_f \) has also raising and Average tot cost \( ATC \) has also been raising.

(6). The raising holding cost coefficient \( u \) in a results in time \( t_{f_1} \) raising and Time \( t_{f_2} \) also decline, there by the order amount \( Q_f \) has also raising and Average tot cost \( ATC \) has also been raising.

(7). The raising holding cost coefficient \( v \) in a results in time \( t_{f_1} \) raising and Time \( t_{f_2} \) also raising, there by the order amount \( Q_f \) has also raising and Average tot cost \( ATC \) has also been raising.

(8). The raising in setup cost \( s \) a results in time \( t_{f_1} \) decline and Time \( t_{f_2} \) raising, there by the order amount \( Q_f \) has also raising and Average tot cost \( ATC \) has also been decline.

(9). The raising in \( \delta \) a results in time \( t_{f_1} \) raising and Time \( t_{f_2} \) also decline, there by the order amount \( Q_f \) has also raising and Average tot cost \( ATC \) has also been raising.

(10). The raising in lost sales \( L_f \) results in time \( t_{f_1} \) decline and Time \( t_{f_2} \) also raising, there by the order amount \( Q_f \) decline and Average tot cost \( ATC \) has also been raising.

(11). The raising in purchase cost \( C_f \) results in time \( t_{f_1} \) decline and Time \( t_{f_2} \) also decline, there by the order amount \( Q_f \) has also decline and Average tot cost \( ATC \) has also been raising.

(12). The raising in ordering cost \( K_f \) results in time \( t_{f_1} \) raising and Time \( t_{f_2} \) also decline, there by the order amount \( Q_f \) has also raising and Average tot cost \( ATC \) has also been raising.

7. Conclusions

In this work the inventory model of Health service firms formulated using the demand in quadratic with time function, cost of holding the things as considered as parabolic equations of time changing of fixed deterioration is found. This established using shortages, by using this ideas a mathematical model framed and solved with the help of computation table & Graph, The impact of parameters vs optimal time and quantity and average overall cost showing see the progress, from the table, found greatest time period more quantity of very least overall average cost. This result has more application in Health service firms. This model can be further developed using Parabolistic demand and deterioration, the inflation, quadratic time function of holding cost etc.

REFERENCES


[9]. Pavan Kumar, P.S.Keerthika.,(2019). Inventory Control Model with Time-Linked Holding Cost, Salvage Value and Probabilistic Deterioration following Various Distributions., ISSN: 2278-3075,