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A Study of Inventory Model for Pharmaceutical Items Associated in Healthcare Industries

Ashutosh Pandey
Department of Mathematics,
Chandigarh University, Chandigarh, Punjab, India
Himanshu Pandey
Department of Mathematics and Statistics
DDU Gorakhpur University, Gorakhpur, India
Reeta Bhardwaj
Department of Mathematics
Amity University Haryana, Pachgaon, Haryana, India

Corresponding Author: **Himanshu Pandey**

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Abstract
In the current paper, defective item for pharmaceutical inventory model have been taken into consideration with demand as stock dependent and holding cost is linear. The objective of this paper is to propose an inventory model which optimizes the total cost associated with the model. In prior studies, the models having desire and holding cost been considered a fixed value, which is not always true in real life-situations. An illustration and sensitivity analysis have been done by taking a numerical example of the model.

Keywords: *1 Pharmaceutical, 2 Inventory Model,3 HealthCare, 4 Sensitivity.*

1. Introduction

Inventory control is having much concentration on the stock of some business. It is very important to handle a business successfully that where is stock, when it is going out or when it became excess. Therefore, to run a business smoothly it is very important to control inventory. Inventory control maintains the right balance of stock in the warehouses. To control the inventory, we need inventory models. In pharmacies inventory control plays a very significant role, because the global spending on medicines is in million and trillion U.S. dollars. Every year only 68% of expenditure costs of medicines are sold out in an average pharmacy and rest of the drugs get expired or we can say deteriorate. Deterioration means a stage of goods where it is no more in the condition of using it because it get spoiled, decay or evaporate etc.

Kumar and Kumar [2014] have developed an inventory model by taking deterministic deteriorating. Giri et al. [1996] have developed a more widespread EOQ model for decaying items by considering rate of demand, decaying rate, ordering or setup cost, holding cost as linearly intensifying functions of time. Lin et al. [2000] have developed the recoupment policies for the time dependent demand model by considering decaying rate as linearly intensifying. Aggarwal and Jaggi[1995] have presented a paper in which EOQ model is considered and it is often assumed that the payment of an order is done after receiving the order. However such a condition is not practical in real life.

Parvathi and Gajalakshmi [2013] present a completely backlogged inventory model with allowable shortage. Goyal [1985] developed a paper in which the discussion is about EOQ under condition of permissible delay in payments. P. K. Chenniappan et al. [2014] developed a predetermined inventory model for decaying products in which the shortages are allowed and moderately backlogged. R. Venkateswarlu et al.[2013] present a paper in which a predetermined inventory model has been carried out for decaying product when the demand rate is assumed to stock-dependent.

2. Model Formulation and Solution

2.1 Notation and Assumption

1. The demand rate is considered as linear and continual on time.
2. The holding cost is considered as linear and continual on time.
3. The recoupment rate is infinite having zero lead time.
4. The insufficiency of goods is not allowed.
5. The time frame is taken limitless.
6. The decaying rate is considered fixed on the on hand stock per unit/ time and there is no overhaul of the decaying goods in the cycle.

$D(t) = m + n.I(t), a, b > 0$, the stock dependent demand;

$H(t) = \alpha + \beta t$, $\alpha, \beta > 0,$ the time dependent holding/carrying cost per unit per time unit;

S = The setup cost or cost per order

C = The per unit purchase cost;

γ = The defective rate; $(0 < \gamma < 1)$ a fraction of the on hand pharmaceutical inventory;

DC = The total deterioration cost per cycle;

Q = The economic order quantity ordered at the time at $t = 0$

$y(t)$ = The inventory level at time t;

T = Replenishment cycle time.

2.2 Mathematical formulation

The differential equation governed the inventory level $I(t)$ at any time t during the cycle is given by:

$$\frac{dI(t)}{dt} + \gamma.I(t) = -(m + n.I(t)),\ \ m, n > 0,\ 0 \le t \le T \tag{1}$$

With boundary condition $I(0) = Q$ and $I(T) = 0$ .Solution of differential equation is computed as

$$I(t) = -\frac{m}{n+\gamma} + \frac{me^{(-t(n+\gamma)+T(n+\gamma))}}{n+\gamma} \tag{2}$$

We get the initial level of order quantity by putting $t = 0$ in equation (2) then we get:

$$Q = I(0) = -\frac{m}{n+\gamma} + \frac{me^{T(n+\gamma)}}{n+\gamma} \tag{3}$$

Demand in the whole cycle time [0, T] is computed as

$$\int_0^T D(t)dt = -\frac{mn}{(n+\gamma)^2} + \frac{mbe^{T(n+\gamma)}}{(n+\gamma)^2} + \frac{mnT\gamma}{(n+\gamma)^2} + \frac{mT\gamma^2}{(n+\gamma)^2}$$

$$\text{No. of decaying units } = Q - \left(-\frac{mn}{(n+\gamma)^2} + \frac{mne^{T(b+\gamma)}}{(n+\gamma)^2} + \frac{mnT\gamma}{(n+\gamma)^2} + \frac{mT\gamma^2}{(n+\gamma)^2} \right)$$

Decaying cost in period [0, T] is computed as

$$DC = C\left[-\frac{m}{n+\gamma} + \frac{me^{T(n+\gamma)}}{n+\gamma} - \left(-\frac{mn}{(n+\gamma)^2} + \frac{mne^{T(n+\gamma)}}{(n+\gamma)^2} + \frac{mnT\gamma}{(n+\gamma)^2} + \frac{mT\gamma^2}{(n+\gamma)^2} \right) \right]$$

Holding cost in cycle [0, T] is

$$HC = \int_0^T H(t)I(t)dt = \int_0^T (\alpha + \beta t)I(t)dt$$

$$TC=\frac{1}{T}\left[S+C\left[\begin{array}{l}-\frac{m}{n+\gamma}+\frac{me^{T(n+\gamma)}}{n+\gamma}-\\ \left(-\frac{mn}{(n+\gamma)^2}+\frac{mne^{T(n+\gamma)}}{(n+\gamma)^2}+\frac{mnT\gamma}{(n+\gamma)^2}+\frac{mT\gamma^2}{(n+\gamma)^2}\right)\\ +\\ \left(\begin{array}{l}-\frac{mn\alpha}{(n+\gamma)^3}+\frac{mn\alpha e^{T(n+\gamma)}}{(n+\gamma)^3}-\frac{mn^2T\alpha}{(n+\gamma)^3}-\frac{\alpha\beta}{(n+\gamma)^3}\\ -\frac{mnT\beta}{(n+\gamma)^3}+\frac{m\beta e^{T(n+\gamma)}}{(n+\gamma)^3}-\frac{mn^2T^2\beta}{2(n+\gamma)^3}-\frac{m\alpha\gamma}{(n+\gamma)^2}\\ -\frac{2mnT\alpha\gamma}{(n+\gamma)^3}+\frac{m\alpha\gamma e^{T(n+\gamma)}}{(n+\gamma)^3}-\frac{mT\gamma\beta}{(n+\gamma)^3}-\frac{mnT^2\gamma\beta}{(n+\gamma)^2}\\ -\frac{mT\alpha\gamma^2}{(n+\gamma)^2}-\frac{mT^2\beta\gamma^2}{2(n+\gamma)^3}\end{array}\right)\end{array}\right]\right]$$

The objective is to minimize the total cost associated with inventory model. The necessary and sufficient conditions for a given value T are respective $\frac{\partial TC}{\partial T}$ and $\frac{\partial^2 TC}{\partial T^2}>0$.

Now $\frac{\partial TC}{\partial T}=0$ gives the following non-linear equation in T :

$$-\frac{S}{T^2}+\frac{mCe^{T(n+\gamma)}}{T}+\frac{mn\alpha}{T^2(n+\gamma)^3}-\frac{mn\alpha e^{T(b+\gamma)}}{T^2(n+\gamma)^3}-\frac{mn^2\beta}{2(n+\gamma)^3}+\frac{\alpha\beta}{T^2(n+\gamma)^3}-\frac{\alpha\beta e^{T(n+\gamma)}}{T^2(n+\gamma)^3}$$
$$+\frac{m\alpha\gamma}{T^2(n+\gamma)^3}-\frac{m\alpha\gamma e^{T(n+\gamma)}}{T^2(n+\gamma)^3}-\frac{mn\gamma\beta}{(n+\gamma)^3}-\frac{m\gamma^2\beta}{2(n+\gamma)^3}-\frac{mnC}{T^2(n+\gamma)^2}+\frac{mnCe^{T(n+\gamma)}}{T^2(n+\gamma)^2}$$
$$+\frac{mn\alpha e^{T(n+\gamma)}}{T(n+\gamma)^2}+\frac{m\beta e^{T(n+\gamma)}}{T(n+\gamma)^2}+\frac{m\alpha\gamma e^{T(m+\gamma)}}{T(n+\gamma)^2}+\frac{mC}{T^2(n+\gamma)}-\frac{mCe^{T(b+\gamma)}}{T^2(n+\gamma)^2}-\frac{mnCe^{T(n+\gamma)}}{T(n+\gamma)}$$

and $\frac{\partial^2 TC}{\partial T^2}>0.$

Hence, the TC is minimum.

Numerical Illustration:

Consider a pharmaceutical inventory system with the following parameter: a = 25 units, α = 4 units, b = 40 units, β = 5 units, S = 500 per order, C = 40 per unit, γ = 0.05. The output is carried out by using **wolfram Mathematica**, we have T = 0.1699 year and the minimum average cost is TC = 3444.65 and from equation (3) we get the EOQ, Q = 561.958 (approx.).

Sensitivity analysis:

Table 1**: Effect of change in the parameter (m)**

m	T	TC	Q
24	0.17080	3424.26	559.299
25	0.1699	3444.65	561.958
26	0.1691	3464.45	565.989

Table 2**: Effect of change in the parameter (n)**

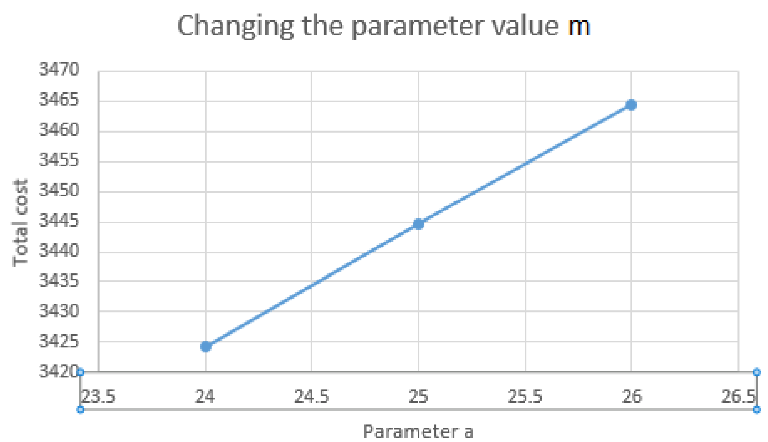
n	T	TC	Q
39	0.1732	3403.70	553.153
40	0.1699	3444.65	561.958
41	0.1670	3525.65	576.900

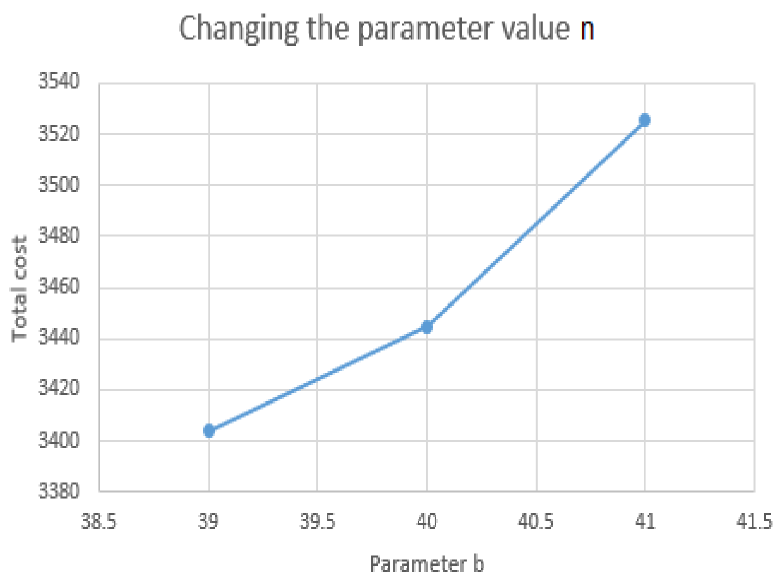
Table 3**: Effect of change in the parameter** α

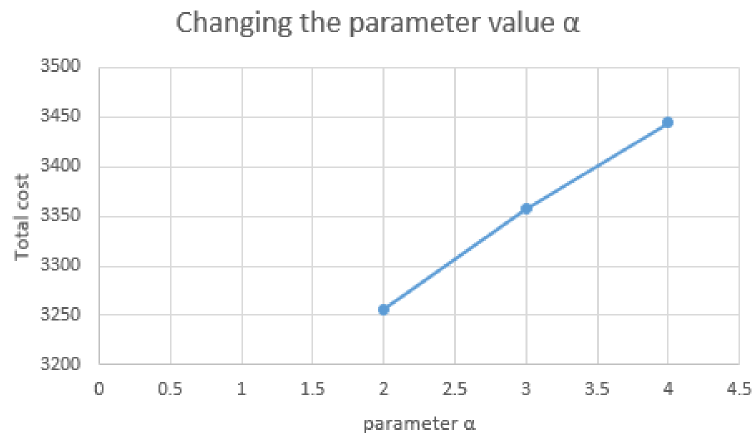
α	T	TC	Q
4	0.1699	3444.65	561.958
3	0.1738	3357.16	657.054
2	0.1784	3255.96	790.082

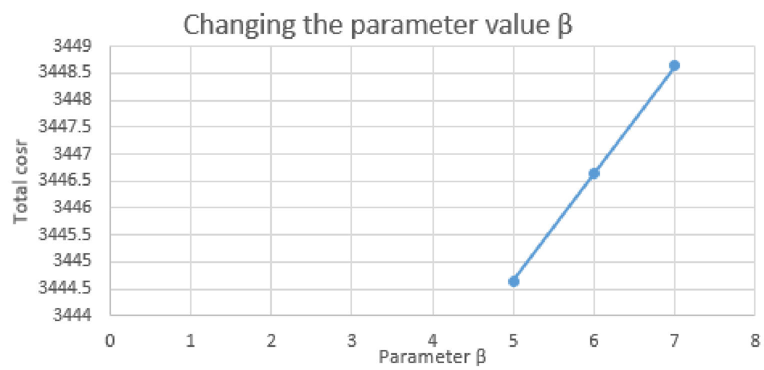
Table 4: **Effect of change in the parameter** β

β	T	TC	Q
5	0.1699	3444.65	561.958
6	0.1698	3446.64	559.709
7	0.1697	3448.63	557.470


Changing the parameter value m
Total cost
3470
3465
3460
3455
3450
3445
3440
3435
3430
3425
3420
23.5
24
24.5
25
25.5
26
26.5
Parameter a


Changing the parameter value n
Total cost
3540
3520
3500
3480
3460
3440
3420
3400
3380
38.5
39
39.5
40
40.5
41
41.5
Parameter b





On changing the parameter of the model there is corresponding change in TC, T and Q We perceive that the parameters involved in the current model m, n, α and β is more sensitive than the other parameters of the model. By changing the parameter values we are getting the optimum production quantity by the pharmaceutical company. Fig 1 - 4 shows the different quantity and associated

3.Conclusion:

In the present paper a pharmaceutical model is discussed in which we have taken demand as stock dependent and holding cost as linear function and the model is solved in such a way that the total cost is get minimized. We have also shown the sensitivity of the model that how the total cost and other quantities get change on changing the parameters of the model.

References

1. Yadav R. K. and Vats A. K. (2014),A deteriorating inventory model for quadratic demand and constant holding cost with partial backlogging and inflation, Journal of Mathematics, Vol 10(3), 47-52.
2. Giri B. C., VA. and VK. S. (1996) An EOQ model for deteriorating items with time varying demand and costs, Journal of Operational Research Society, Vol 47(11), 1398-1405.
3. Lin C., Tan B. and Lee W. (2000), An EOQ model for deteriorating items with time varying demand and shortages, International Journal of Systems Science, Vol 31(3)391-400
4. Aggarwal S. P. and Jaggi C. K.(1995),Ordering policies of deteriorating items under

permissible delay in payments},Journal of Operations Research Society, 36, 658-662

5. Parvathi P. and Gajalakshmi S. (2013), A Fuzzy Inventory Model with Lot Size Dependent Carrying Cost/ Holding Cost},Journal of Mathematics,Vol 7(6), 106-110.
6. GoyaS. K. l (1985), Economic Order Quantity under conditions of permissible delay in payments}, Journal of Operational Research Society, Vol 36(4), 335-338.
7. Jagadeeswari and Chenniappan P. K. (2014) An Order Level Inventory Model for Deteriorating Items with Time Quadratic Demand and Partial Backlogging}, Journal of Business and Management Sciences, vol 2, 79-82.
8. Venkateswarlu R. and Mohan R. (2013), An Inventory Model for Time Varying Deterioration and Price Dependent Quadratic Demand with Salvage Value,Indian Journal of Computational and Applied Mathematics, Vol. 1, 21-27.
9. Pandey A.; (2017), A Study of EPQ Inventory Model for Deteriorating Items Considering Stock Dependent Demand and Time Varying Holding Cost. Journal of Computer and Mathematical Sciences, Vol.8(7), 323-331
10. Pandey H., Pandey A. (2014) An Optimum Inventory Policy for Exponentially deteriorating Items, Considering Multi Variate Consumption Rate with Partial Backlogging. Mathematical Journal of Interdisciplinary Sciences Vol. 2, No. 2, pp. 143–158
11. Min J., Zhou Y., Liu G. and Wang S. (2012), An EPQ model for deteriorating items with inventory-level-dependent demand and permissible delay in payments},International Journal of Systems Science, 43, 1039-1053.
12. Uthayakumar R. and Karuppasamy S. K. (2016), A Fuzzy inventory model with lot size dependent ordering cost in healthcare industries},Operations Research and Applications: An International Journal (ORAJ), , 3, 17 - 29.
13. Mishra V. K. and Singh L. S. (2010), Deteriorating Inventory Model with Time Dependent Demand and Partial Back logging},Applied Mathematical Sciences, 4, 3611-3619.
14. Teng J. T. and Chang C. T. (2005), Economic production quantity models for deteriorating items with price- and stock-dependent demand, Computers and Operations Research, 32, 297-308.
15. Chang H. J., Hung C. H. and Dye C. Y. (2001), An inventory model for a deteriorating items with linear trend in demand under conditions of permissible delay in payments, Production Planning and Control, 12, 272-282.