International Journal of Computer Sciences and Engineering
Vol.**11**, Special Issue.**1**, pp.**197-200**, November **2023**
ISSN: 2347-2693 (Online)
Available online at: www.ijcseonline.org
ISSN: 2347-2693 (E)

Research Paper

Exponential Time-Dependent Demand (EOQ) Model for Decaying Goods with Shortages

Ayan Chakraborty[1]

[1]Dept. of Mathematics, Techno India University, Kolkata, India

Author's Mail Id: chakrabortyayan3@gmail.com.

Abstract: In this model, over a predetermined planning period, we study the inventory replenishment strategy for a depreciating good with an exponential time demand function. To reduce the average system cost, the amount of reorders, the gap between reorders, and the gaps between shortages within a given time frame are all estimated. How the approach works is demonstrated by one numerical example. Considering its sensitivity, the significance of the various variables in this model is assessed.

Keywords: Deterioration, Exponential Demand ,Shortages

1. Introduction

Researcher gave attention on inventory issues including time-variable demand patterns in recent times. A rough solution method was devised by Silver and Meal[1] for a deterministic time-varying demand pattern in general.Donaldson[2] used a linear demand trend over a constrained time horizon to analytically answer the classic no-shortage inventory problem. Donaldson's solution method was computationally challenging, nevertheless. In order to solve the Donaldson problem, For the unique circumstance of a positive, linear trend in demand, Silver[3] created a heuristic.Ritchie[4] was able to solve Donaldson's problem of linearly growing demand with a precise answer that embodied the EOQ formula's simplicity. Mitra et al. [5] described a straightforward process for changing the EOQ model for the instances of linearly rising and decreasing demand. The likelihood of a shortage and inventory degradation were not taken into account in any of the papers.

In our paper exponential demand is considered in place of linear trend of demand. Paper shortages are acceptable in this. Time proportional inventory model of deteriorating items was developed by Dave and Patel[6]. Sachan[7] has created this model to account for the backlogging option.

Assumptions & Notations

The following notations and presumptions have been used to create a deterministic inventory model.

i) a e^{bt} is the rate of demand.
ii) Fixed ordering value per order is A
iii) Inventory keeping cost per unit with respect to time is r.
iv) Cost of the inventory per unit is p.
v) cost of shortage per unit is s.
vi) H is the time horizon.
vii) θ is the rate of deterioration which deteriorates with respect to time

We divide total time interval into n slots so that T= $\frac{H}{n}$.Timing for giving the order is jT where j belongs from 0 to (n-1). Initial and terminal stock of goods is taken as empty. We can imagine that there is shortage between the time zone (jT,(j+1)T) and equal to KT(0<K<1). When (k+j)T is less than (j+1)T and greater than jT ,j= 0,1,2———n-2, shortages happen at the time (K+j)T(j=0,1,2,—————n-2). A shortage is not permitted during the final period ((n-1)T,H) and the final replenishment takes place at time (n-1)T.

Our aim is to mark the values of n that will reduce the overall cost across the time horizon by deriving the ideal reorder and shortage points (0,H).

2. Related Work

Mathematical Model Development:

The order quantities at every point of order are amounts required to fulfil the demand requirements for the appropriate time, apart from the shortage period, as well as the amounts was necessary to account for the decay in the no-shortage part of the afore mentioned time. Now if Q_j units ordered in time (j-1)T we have

$$Q_j = \int_{(j-1)T}^{(k+j-1)T} a e^{bt} e^{\theta t}\, dt$$
$$= \frac{a}{(b+\theta)}[e^{(k+j-1)(b+\theta)T} - e^{(j-1)(b+\theta)T}] \text{ ----------(1)}$$

We got

$$Q_n = \int_{(n-1)T}^{H} a e^{bt} e^{\theta t}\, dt$$

$= \frac{a}{(b+\theta)}[\, e^{(b+\theta)H} - e^{(b+\theta)(n-1)T} \,]$ --------------------(2)

Number of units Q_j which is needed for the interval (jT,(j+1)T) (where j is 1 to (n-1)),when there has no deterioration . Then

$Q_{j1} = \int_{(j-1)T}^{(k+j-1)T} ae^{bt}\, dt$

$= \frac{a}{b}[e^{(k+j-1)bT} - e^{(j-1)bT}]$ --------------------------(3)

And

$Q_{n1} = \int_{(n-1)T}^{H} ae^{bt}\, dt$

$= \frac{a}{b}[e^{Hb} - e^{b(n-1)T}]$ ----------------------------------(4)

The number of decay items in(jT,(k+j)T),j varies from 0 to (-1+n),is represented by

$D_j = Q_j - Q_{j1}$

$= \frac{a}{(b+\theta)}[\, e^{(b+\theta)(k-1+j)T} - e^{(b+\theta)(j-1)T} \,] - \frac{a}{b}[e^{b(k+j-1)T} - e^{b(j-1)T}]$ -----(5) j= 1,2,------(n-1)

And similarly

$D_n = Q_n - Q_{n1}$

$= \frac{a}{(b+\theta)}[\, e^{(b+\theta)H} - e^{(b+\theta)(-1+n)T} \,] - \frac{a}{b}[e^{Hb} - e^{b(-1+n)T}]$ --(6)

Cost for holding the inventory R_j through the period (jT,(j+i)T) ,j= 0,1,2,---------------(n-1) is given by

$R_j = \int_{(j-1)T}^{(k+j-1)T} (t-(j-1)T)ae^{bt} e^{\theta t}\, dt$

$= \frac{at}{(b+\theta)}(kTe^{(b+\theta)(k+j-1)T} - e^{(b+\theta)(j-1)T}) - \frac{a}{(b+\theta)2}(e^{(b+\theta)(k+j-1)T} - e^{(b+\theta)(j-1)T}) - \frac{a(j-1)T}{(b+\theta)}(e^{(b+\theta)(k+j-1)T} - e^{(b+\theta)(j-1)T})$ ---------------------- (7)

& $R_n = a((\frac{H}{(b+\theta)} e^{(b+\theta)H} - \frac{1}{(b+\theta)2} e^{H(b+\theta)}) - (\frac{(n-1)T}{(b+\theta)} e^{(b+\theta)(-1+n)T} - \frac{1}{(b+\theta)2} e^{(b+\theta)(n-1)T})) - a(n-1)T(\frac{1}{(b+\theta)} e^{(b+\theta)H} - \frac{1}{(b+\theta)} e^{(b+\theta)(n-1)T})$ ---------(8)

nA provides the setup cost over the horizon.

Let S_j be the shortage products through the period ((k+j-1)T,jT) ,j=(1,2,-------------(n-1))

Then $S_j = \int_{(k+j-1)T}^{jT} (jT-t)ae^{bt} dt$

$= \frac{ajT}{b}(e^{bjT} - e^{b(k+j-1)T}) - (a(\frac{t}{b} e^{bjT} - \frac{1}{b^2} e^{bjT})) - a(\frac{(k+j-1)T}{b} e^{b(k+j-1)T} - \frac{1}{b^2} e^{b(k+j-1)T})$ -----------------(9)

Where j varies from 1 to (n-1)

The entire cost over horizon C is therefore given by.

$C = nA + r\sum_{j=1}^{n-1} Rj + p\sum_{j=1}^{n-1} Dj + r\, Rn + p\, Dn + s\sum_{j=1}^{n-1} Sj$

$= nA + r\sum_{j=1}^{n-1} \frac{at}{(b+\theta)}(kTe^{(b+\theta)(k-1+j)T} - e^{(b+\theta)(j-1)T}) - \frac{a}{(b+\theta)2}(e^{(b+\theta)(k+j-1)T} - e^{(b+\theta)(j-1)T}) - \frac{a(j-1)T}{(b+\theta)}(e^{(b+\theta)(k+j-1)T} - e^{(b+\theta)(j-1)T})$
$+ p\sum_{j=1}^{n-1} \frac{a}{(b+\theta)}[\, e^{(b+\theta)(k+j-1)T} - e^{(b+\theta)(j-1)T} \,] - \frac{a}{b}[e^{b(k+j-1)T} - e^{b(j-1)T}]$
$+ r\, a((\frac{H}{(b+\theta)} e^{(b+\theta)H} - \frac{1}{(b+\theta)2} e^{(b+\theta)H}) - (\frac{(n-1)T}{(b+\theta)} e^{(n-1)T(b+\theta)} - \frac{1}{(b+\theta)2} e^{(b+\theta)(n-1)T})) - a(n-1)T(\frac{1}{(b+\theta)} e^{(b+\theta)H} - \frac{1}{(b+\theta)} e^{(n-1)T(b+\theta)}) + p\frac{a}{(b+\theta)}[\, e^{(b+\theta)H} - e^{(b+\theta)(n-1)T} \,] - \frac{a}{b}[\, e^{Hb} - e^{b(n-1)T} \,] + s\sum_{j=1}^{n-1} \frac{ajT}{b}(e^{bjT} - e^{b(k+j-1)T}) - (a(\frac{t}{b} e^{bjT} - \frac{1}{b^2} e^{bjT})) - a(\frac{(k+j-1)T}{b} e^{b(k+j-1)T} - \frac{1}{b^2} e^{b(k+j-1)T})$

3. Theory/Calculation

I have used the general concept of EOQ model and frame my model according to the condition and constraints involved in my model. As we have considered arbitrary time dependent demand so we are using integration method to calculate the different cost of the model. Then we got the total cost of the model. For calculation part we have used LINGO Techniques to calculate the global solution of the model. We draw the graphs of the model based on the deta by using the application of excel.

4. Experimental Method/Procedure/Design

My work is basically to derive the cost function of the model. So I have to formulate the cost function of the model first .Then deta are selected for the model. Using LINGO software we have tried to find out the global solution of my model. It is my experimental method that I have followed.

5. Results and Discussion

Numerical Analysis: Using the LINGO software, I calculated the total variable cost by entering the values of the following parameters taken from the model[8]: n=1, A=95, r=5, a=20,k=2,T=1,b=1,p=5,θ,=0.01,s=1.5,H=4,t=1,j=1.

The total cost equals 20188.76.

Here, I use lingo software to find the overall best option.

The following is the overall cost with respect to the various values of n that we obtained.

C = 20188.76 for n=1, C = 22087.83 for n=2, C = 22182.79 for n=3, and so on.

Sensitivity Analysis: We took the values of n=1, n=2 and so on and trying to see the changes of total cost of this model. The total cost vary depending on the value of n. We are attempting to compare changes in n to changes in total cost. Graphical presentation is also given as following.

Figures and Tables

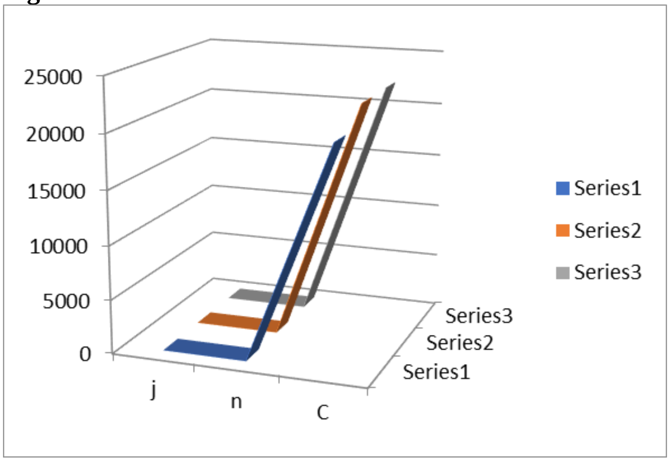

Fig-1.19 represents the relationship between n and Total Cost.

We took the values of K=2, k=3 and so on and trying to see the changes of total cost of this model. The total cost vary depending on the value of K. We are attempting to compare changes in K to changes in total cost. Graphical presentation is also given as following.

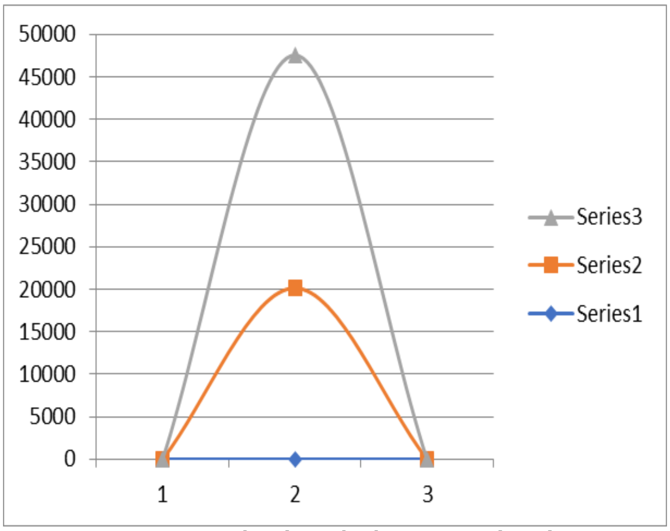

Fig-1.20 represents the relationship between K and Total Cost.

There has no tables in my model as such. Whatever deta I have considered that are written in numerical part.

6. Conclusion and Future Scope

We are dealing with a model where we are trying to see the different cost of the model in arbitrary time frame. As we all know that product's demand may arises in any time. So in our model we considered arbitrary time based demand ,deterioration cost, holding cost etc. It is also very much practical in the sense. We can improve this model by considering fuzzy or Neutrosophic environment. This will enrich the model. This can be considered as a future scope of my study.

Data Availability (Size 10 Bold)

The deta which has been taken in our model that are completely hypothetical and deta are taken to find out a global solution of our model.

Conflict of Interest

We wholeheartedly declare that we do not have any kind of Conflict of Interest.

Funding Source

I do not have any kind of funding sources in any manner.

Authors' Contributions

Author-1 developed the paper under the changed circumstances.Author-2 monitored the calculation and data selection. Author-3 supervises as a whole. All the authors reviewed and edited the manuscript and approved the final manuscript.

Acknowledgements

I want to acknowledge the contribution of Dr. Tripti Chakraborty, and Dr Nirmal Kumar Duari for their wholehearted contribution. Apart from them I want to acknowledge the contribution of Associate Prof Dr Dharampal Singh for the organization of such kind of National Seminar.

References

[1]. E.A.Silver ,A heuristic for selecting lot size quantities for the case of a deterministic time varying demand rate and discrete opportunities for replenishment, "Prod. Invent. Mgmt", Vol-**14**, Issue.**2**, pp.**64-74,1973.**

[2]. W.A.Donaldson , Inventory replenishment policy for a linear trend in demand –an analytical solution. J. Opl. Res. Soc.Vol.28, Issue.2, pp.**663-670, 1977.**

[3]. E.A.Silver A simple inventory decision rule for a linear trend in demand "J. Opl. Res. Soc." Vol.**30**, pp.**71-75,1979.**

[4]. 4.E.Ritchie, The EOQ for linear increasing demand: a simple optimal solution."J.Opl.Res.Soc"Vol.30, pp.71-75, 1984.

[5]. Amitava Mitra,James , A note on deterministic order quantities with a linear trend in demand."J.Opl.Res.Soc."Vol.**35**, pp.**141-144, 1984.**

[6]. U.Dave plicy inventory model for deteriorating items with time proportional demand .J.Opl.Res.Soc.32, 137-142.

[7]. R.S.Sachan, on inventory policy model for deteriorating items with time proportional demand "J. Opl. Res Soc".Vol.35, pp.1013-1019, 1984.

[8]. Goswami.A , An EOQ Model for Deteriorating Items with shortages and linear trend in demand, "Journal of Operational Research Society",Vol.42, No-12.

[9]. Kundu.S , Impact of carbon emission policies on manufacturing ,remanufacturing and collection of used item decisions with price dependent return,"OPSEARCH," Vol-55, Issue.2, pp.532-555, 2018.

[10]. Kundu.S , A Fuzzy rough integrated multi stage supply chain inventory model with carbon emissions under inflation and time value of money. "International Journal of Mathematics in operation research",Inderscience, Vol.14, Issue.1, pp.123-145, 2019.

AUTHORS PROFILE

Ayan Chakraborty earned his B.Sc, MA, B.Ed, M.Ed from Burdwan University, Rabindra Bharati University, Vidyasagar University and Calcutta University in the year 2009, 2011, 2013, 2015 respectively.I cleared UGC-NTA NET exam in the year 2019. I am now persuing my Ph.D in Mathematics from Techno India University. At the same time I am working as an Assistant Professor in Education Department at JIS UNIVERSITY.