AN EOQ MODEL FOR HEALTHCARE INDUSTRIES WITH EXPONENTIAL DEMAND PATTERN AND TIME DEPENDENT DELAYED DETERIORATION UNDER FUZZY AND NEUTROSOPHIC FUZZY ENVIRONMENT.

James Dipankar Sen[1], Tripti Chakrabarti[2]

1. Research Scholar, Department of Mathematics, Techno India University, West Bengal.
Email: sen011190@gmail.com
2. Faculty, Department of Mathematics, Techno India University, West Bengal

ABSTRACT

It is obvious that in health care industries, medicines and drugs i.e., the pharmaceutical items are the major inventory. The demand of this items may be fixed or vary with respect to time. Here we are dealing with several demand functions and time dependent deterioration which will come into effect after a certain period of time. Comparing the crisp model with fuzzy and neutrosophic fuzzy, we may find that neutrosophic model is more optimal and gives us better result. The main purpose of this work is to get optimal total cost for healthcare industries under exponential demand functions and time dependent deterioration rates with fuzzy and neutrosophic fuzzy parameters. At the end, numerical are given to illustrate the solution mechanism under different conditions in order to get optimum and best solution for this model.

KEYWORDS: -Fuzzy, Neutrosophic Fuzzy and Inventory.

DOI Number: 10.48047/NQ.2022.20.12.NQ77733 **NeuroQuantology2022;20(12): 4080-4086**

INTRODUCTION

Since the development of healthcare industries, daily new challenges are come into sight regarding to keeping the stock of such products in hospital for pharmaceutical product like drugs, tablets, capsules, blood, surgical kits etc. In inventory models, demand is a main river. Generally, the demand is of four type like demand depending on stock, demand of constant nature, demand of probabilistic nature and demand depending on time. In recent research work, inventory models with time dependent demand is an important factor in healthcare industries. In past research work, the EOQ models has constant demand. But in healthcare industries, there are many critical situations, when hospital needs a lot of pharmaceutical items for treatment. So that the demand rate of pharmaceutical items is vary, and it varies with time. So, in this research proposal, we examine the different demands for the healthcare industries. In future, holding the pharmaceutical product like tablets, drugs, capsules, blood, surgical kits are very useful in hospitals. The drugs and related product rate of demand is not steady and it varies with time. So, in that circumstances, demand of such products is always uncertain like drugs, inject able items, tablets, blood requirement should have a stock on hand in hospital because medicines play a vital responsibility in the care of patients. Also, we cannot ignore deterioration issue. Deterioration stock is defined as evaporation, defective, damage, loss of marginal value of product, spoilage the result in falling effectiveness from the original one due to which healthcare industry faces the trouble of pharmaceutical shortages, loss of revenue as well as their reputation, which occurs after a certain period of time. Controlling the spoilage or damages to the items of pharmaceutical industries. So, in the proposed work we develop an EOQ model for the different type of demand pattern in crisp, fuzzy and neutrosophic fuzzy environment by taken trapezoidal fuzzy number and triangular neutrosophic fuzzy number and defuzzification by signed distance method and by triangular single valued neutrosophic number respectively, we may find that neutrosophic may yield to more feasible and accurate result rather than crisp and fuzzy environment.

LITERATURE REVIEW

Inventory models of deteriorating items have been considered by numerous researchers in recent decades. In 1915, Harris first explained the first EOQ model [1]. In 1963, an Economic Order Quantity (EOQ) model have developed by Ghare and Schrader assuming an unvarying rate of deterioration [2]. In 2004, an inventory model with fuzzy demand and fuzzy random lead time has been introduced by Chang et al [3]. A comprehensive review done by numerous researches like Bakker et al. [4] extended by Janssen et al. [5] in which various characteristic of deteriorating products had been discussed. Chang et al [6]. Chung and Liao [7], Chauhan et al [8], Sharma et al [9] all discussed stock models in which demand treated as constant. Goyal et al [10] developed a finite time-horizon deterministic economic order quantity inventory model with shortages, where the demand is stock dependent and a comprehensive review on stock dependent demand by Urban [11]. Several researchers like Singh [12] are discussed an inventory model with linear demand. Chauhan and Singh [13] observed that the demand depends on time as well as several parameters. Khanna et al. [14]proposed an inventory model for imperfect production process with inspection error. Chang and Dye [15] measured an exponential demand rate is time-continuous function with partial backlogging. With the expansion of fuzzy set theory, the fuzzy approach has also been in use widely in inventory problems. The first publication by Zadeh [16] in fuzzy set theory and introduced the concept of uncertainty in the non-stochastic sense rather than the presence of random variables. Chaube et al. [17] introduced fuzzy reliability theory with the help of membership functions. In the last two decade, several researchers began to develop models for inventory problems under fuzzy environment variables to improve better result. Aarya et al. [18] introduced their inventory model with weibull deterioration and time dependent demand. Vujosevic et al. [19] explain the total cost of inventory is fuzzify by trapezoidal fuzzy number with backorder and to estimate the total cost through centroid to defuzzify. Roy and Maiti [20] described fuzzy EOQ model for limited shortage capacity. Chiang [21] used singed distance method to defuzzify inventory model with backorder. Yao et. al [22] applied the extension principle to obtain the fuzzy total cost, and then they defuzzify the fuzzy total cost by centroid method. Park [23] was the first mathematician who introduced fuzzy EOQ model. To examine "the effect of different approaches to obtain the EOQ", Vujosevic et al. [24] proposed an Fuzzy EOQ model. Hojati [25] finding some shortcomings in their study. Kumar et al. [26] done their research work with generalized trapezoidal intuitionistic fuzzy number on a fuzzy model. Yao et al. [27] shows his work with a numerical to get the fuzzy total cost with the help of mathematical tools. Yao and Chiang [28] compared the solution with different defuzzification methods like signed distance and centroid defuzzification method in an fuzzy EOQ model and explained some facts to choose the suitable defuzzification method for optimization. Moreover, Chakrabarti and Chaudhuri [29] suggested an EOQ model for deteriorating items with linear trend in demand and shortages in all cycles. Kundu and Chakrabarti [30] proposed impact of carbon emission policies on manufacturing remanufacturing and collection of used item decisions with price dependent return rates. Various researchers done their research in the field of inventory models with fuzzy parameters. In [31] Sen and Chakrabarti proposed an industrial production inventory model wih deterioration under neutrosophic Fuzzy Optimization

ASSUMPTIONS AND NOTATIONS:

The inventory model with three different demands for pharmaceutical items in healthcare industries under following assumption and notations:

(1) Demand, which is dependent of time, is exponential, i.e., $D(t) = -ae^{kt}$

(2) The deterioration is time dependent.

(3) The replenishment rate and the time horizon are infinite, and without replenishment of deteriorating items in a cycle.

(4) The demand and the cost are in fuzzy sense and in neutrosophic sense.

(5) M= Ordering cost per order.

(6) O= Holding cost of inventory model.

(7) I(t)=The level of inventory of items at any time t.

(8) N= The purchase cost of items per unit.

(9) θ = Rate of deterioration; ($0 < \theta < 1$).

(10) T= Length of each replenishment cycle.

(11) Q_2= Initial economic order quantity.

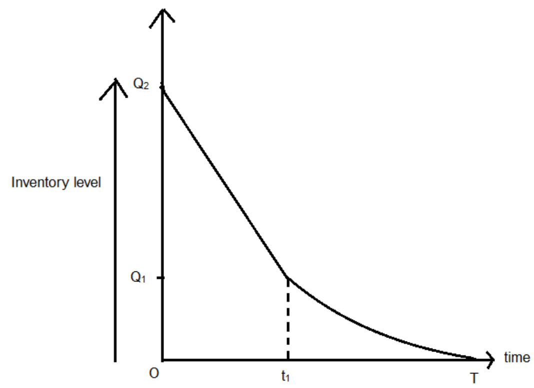
(12) TAC= Average total cost per unit time.

(13) TAC^{+} = The average total fuzzy cost per unit time.

(14) TAC^{++} = The average total neutrosophic cost per unit time.

Mathematical Model:

Here we introduce an EOQ model with deteriorating pharmaceutical items with exponential demand for healthcare industries under crisp, fuzzy environment and neutrosophic fuzzy environment.



The differential equation for the inventory levels for the healthcare industries under time dependent delayed deterioration and during the interval [0,T] is given as

$I'(t) = -ae^{kt} \qquad 0 < t < t_1$

$I'(t) + \theta t I = -ae^{kt} \quad t_1 < t < T$

With the condition $I(0) = Q_2$, $I(t_1) = Q_1$, $I(T) = 0$

The solution of the given equation is:

$$I = \frac{-a}{k}\left[e^{kt} - 1\right] + Q_2, \qquad 0 \le t \le t_1$$

$$I = a\left[(T-t) - \frac{\theta T t^2}{2} + \frac{\theta t^3}{2} + \frac{k}{2}\left((T^2 - t^2) - \frac{\theta T^2 t^2}{2} + \frac{\theta t^2}{2}\right) + \frac{\theta}{6}(T^3 - t^3)\right], \quad t_1 \le t \le T$$

Now, Total demand in [0,T]

$$= \int_0^T D(t) = \frac{-a}{k}\left[e^{kT} - 1\right]$$

Total number of deteriorating units in [0,T]

$$= Q_2 - \frac{-a}{k}\left[e^{kT} - 1\right] \qquad = Q_2 + \frac{a}{k}\left[e^{kT} - 1\right]$$

Deteriorating cost (DC) in [0,T]

$$= N \times \int_{t_1}^{T} \theta t I \, dt$$

$$= Na\left[\left[\frac{T^3}{6} + \frac{kT^4}{8}\right] - \left[\frac{T t_1^2}{2} - \frac{t_1^3}{3} + \frac{k}{2}\left(\frac{T^2 t_1^2}{2} - \frac{t_1^4}{2}\right)\right]\right]$$

Holding cost (HC) in [0,T]

$$= O \times \int_0^T I \, dt$$

$$= \frac{-aO}{k}\left[\frac{e^{kt_1}}{k} - t_1 - \frac{1}{k}\right] - OQ_2 t_1 + Oa\Big[T(T - t_1) - \frac{1}{2}(T^2 - t_1^2) - \frac{\theta T}{6}(T^4 - t_1^4) + \frac{\theta}{8}(T^4 - t_1^4) + \frac{k}{2}\Big[\Big(T^2(T - t_1) -$$

$$\frac{1}{3}(T^3 - t_1^3)\Big) - \frac{\theta T^2}{6}(T^3 - t_1^5) + \frac{\theta}{10}(T^5 - t_1^5)\Big]\Big]$$

Total average cost (TAC)

$$= \frac{1}{T}[M + DC + HC]$$

$$= \frac{1}{T}\Bigg[M + Na\Big[\Big[\frac{T^3}{6} + \frac{kT^4}{8}\Big] - \Big[\frac{Tt_1^2}{2} - \frac{t_1^3}{3} + \frac{k}{2}\Big(\frac{T^2t_1^2}{2} - \frac{t_1^4}{2}\Big)\Big]\Big] + \Big[\frac{-aO}{k}\Big[\frac{e^{kt_1}}{k} - t_1 - \frac{1}{k}\Big] - OQ_2t_1 + Oa\Big[T(T - t_1) - \frac{1}{2}(T^2 - t_1^2) - \frac{\theta T}{6}(T^4 - t_1^4) + \frac{\theta}{8}(T^4 - t_1^4) + \frac{k}{2}\Big[\Big(T^2(T - t_1) - \frac{1}{3}(T^3 - t_1^3)\Big) - \frac{\theta T^2}{6}(T^3 - t_1^5) + \frac{\theta}{10}(T^5 - t_1^5)\Big]\Big]\Big]\Bigg]$$

Now, we minimize TAC by the Lingo Software i.e., $\frac{dTAC}{dT} = 0$, $\frac{d^2TAC}{dT^2} > 0$ at $T = T^*$

Case – 2: When Demand is Fuzzy, i.e., $\tilde{D}(t) = -\tilde{a}e^{\tilde{k}t}$

The differential equation for the inventory levels for the healthcare industries under time dependent delayed deterioration and during the interval [0,T] is given as

$I'(t) = -\tilde{a}e^{\tilde{k}t}$ $\quad 0 < t < t_1$

$I'(t) + \theta tI = -\tilde{a}e^{\tilde{k}t}$, $t_1 < t < T$

With the condition $I(0) = 0$, $I(t_1) = Q_1$, $I(T) = Q_2$

The solution of the given equation is:

$$I = \frac{-\tilde{a}}{\tilde{k}}\big[e^{\tilde{k}t} - 1\big] + Q_2, \quad 0 \le t \le t_1$$

$$I = \tilde{a}\Big[(T - t) - \frac{\theta Tt^2}{2} + \frac{\theta t^3}{2} + \frac{\tilde{k}}{2}\Big((T^2 - t^2) - \frac{\theta T^2t^2}{2} + \frac{\theta t^2}{2}\Big) + \frac{\theta}{6}(T^3 - t^3)\Big], \quad t_1 \le t \le T$$

Now, Total demand in [0,T] = $\int_0^T D(t)$

$$= \frac{-\tilde{a}}{\tilde{k}}\big[e^{\tilde{k}T} - 1\big]$$

Total number of deteriorating units in [0,T] = $Q_2 - \frac{-\tilde{a}}{\tilde{k}}\big[e^{\tilde{k}T} - 1\big]$ $\quad = Q_2 + \frac{\tilde{a}}{\tilde{k}}\big[e^{\tilde{k}T} - 1\big]$

Deteriorating cost (DC) in [0,T] =N× $\int_{t_1}^T \theta tI\, dt$

$$= N\tilde{a}\Big[\Big[\frac{T^3}{6} + \frac{\tilde{k}T^4}{8}\Big] - \Big[\frac{Tt_1^2}{2} - \frac{t_1^3}{3} + \frac{\tilde{k}}{2}\Big(\frac{T^2t_1^2}{2} - \frac{t_1^4}{2}\Big)\Big]\Big]$$

Holding cost (HC) in [0,T]= O × $\int_0^T I\, dt$

$$= \frac{-\tilde{a}O}{\tilde{k}}\Big[\frac{e^{\tilde{k}t_1}}{\tilde{k}} - t_1 - \frac{1}{\tilde{k}}\Big] - OQ_2t_1 + Oa\Big[T(T - t_1) - \frac{1}{2}(T^2 - t_1^2) - \frac{\theta T}{6}(T^4 - t_1^4) + \frac{\theta}{8}(T^4 - t_1^4) + \frac{\tilde{k}}{2}\Big[\Big(T^2(T - t_1) - \frac{1}{3}(T^3 - t_1^3)\Big) - \frac{\theta T^2}{6}(T^3 - t_1^5) + \frac{\theta}{10}(T^5 - t_1^5)\Big]\Big]$$

Total average cost (TAC^+)= $\frac{1}{T}$ [M + DC + HC]

$$= \frac{1}{T}\Bigg[M + N\tilde{a}\Big[\Big[\frac{T^3}{6} + \frac{\tilde{k}T^4}{8}\Big] - \Big[\frac{Tt_1^2}{2} - \frac{t_1^3}{3} + \frac{\tilde{k}}{2}\Big(\frac{T^2t_1^2}{2} - \frac{t_1^4}{2}\Big)\Big]\Big] + \Big[\frac{-\tilde{a}O}{\tilde{k}}\Big[\frac{e^{kt_1}}{\tilde{k}} - t_1 - \frac{1}{\tilde{k}}\Big] - OQ_2t_1 + O\tilde{a}\Big[T(T - t_1) - \frac{1}{2}(T^2 - t_1^2) - \frac{\theta T}{6}(T^4 - t_1^4) + \frac{\theta}{8}(T^4 - t_1^4) + \frac{\tilde{k}}{2}\Big[\Big(T^2(T - t_1) - \frac{1}{3}(T^3 - t_1^3)\Big) - \frac{\theta T^2}{6}(T^3 - t_1^5) + \frac{\theta}{10}(T^5 - t_1^5)\Big]\Big]\Big]\Bigg]$$

Case – 3: When Demand is Neutrosophic Fuzzy, i.e., $\tilde{D}(t) = -\tilde{a}e^{\tilde{k}t}$

The differential equation for the inventory levels for the healthcare industries under time dependent delayed deterioration and during the interval [0,T] is given as

$I'(t) = -\tilde{a}e^{\tilde{k}t}$ $\quad 0 < t < t_1$

$I'(t) + \theta tI = -\tilde{a}e^{\tilde{k}t}$ $t_1 < t < T$

With the condition $I(0) = 0$, $I(t_1) = Q_1$, $I(T) = Q_2$

The solution of the given equation is:

$$I = \frac{-\tilde{a}}{\tilde{k}}\big[e^{\tilde{k}t} - 1\big] + Q_2, \quad 0 \le t \le t_1$$

$$I = \tilde{a}\left[(T-t) - \frac{\theta T t^2}{2} + \frac{\theta t^3}{2} + \frac{\tilde{k}}{2}\left((T^2 - t^2) - \frac{\theta T^2 t^2}{2} + \frac{\theta t^2}{2}\right) + \frac{\theta}{6}(T^3 - t^3)\right], \quad t_1 \le t \le T$$

Now, Total demand in [0,T] = $\int_0^T D(t)$

$= \frac{-\tilde{a}}{\tilde{k}}\left[e^{\tilde{k}T} - 1\right]$

Total number of deteriorating units in [0,T] = $Q_2 - \frac{-\tilde{a}}{\tilde{k}}\left[e^{\tilde{k}T} - 1\right] = Q_2 + \frac{\tilde{a}}{\tilde{k}}\left[e^{\tilde{k}T} - 1\right]$

Deteriorating cost (DC) in [0,T] $= N \times \int_{t_1}^{T} \theta t I \, dt = N\tilde{a}\left[\left[\frac{T^3}{6} + \frac{\tilde{k}T^4}{8}\right] - \left[\frac{Tt_1^2}{2} - \frac{t_1^3}{3} + \frac{\tilde{k}}{2}\left(\frac{T^2 t_1^2}{2} - \frac{t_1^4}{2}\right)\right]\right]$

Holding cost (HC) in [0,T]= $O \times \int_0^T I \, dt$

$$= \frac{-\tilde{a}O}{\tilde{k}}\left[\frac{e^{\tilde{k}t_1}}{\tilde{k}} - t_1 - \frac{1}{\tilde{k}}\right] - OQ_2 t_1 + Oa\left[T(T-t_1) - \frac{1}{2}(T^2 - t_1^2) - \frac{\theta T}{6}(T^4 - t_1^4) + \frac{\theta}{8}(T^4 - t_1^4) + \frac{\tilde{k}}{2}\left[\left(T^2(T - t_1) - \frac{1}{3}(T^3 - t_1^3)\right) - \frac{\theta T^2}{6}(T^3 - t_1^5) + \frac{\theta}{10}(T^5 - t_1^5)\right]\right]$$

Total average cost (TAC^{++})= $\frac{1}{T}$ [M + DC + HC]

$$= \frac{1}{T}\left[M + N\tilde{a}\left[\left[\frac{T^3}{6} + \frac{\tilde{k}T^4}{8}\right] - \left[\frac{Tt_1^2}{2} - \frac{t_1^3}{3} + \frac{\tilde{k}}{2}\left(\frac{T^2 t_1^2}{2} - \frac{t_1^4}{2}\right)\right]\right] + \left[\frac{-\tilde{a}O}{\tilde{k}}\left[\frac{e^{kt_1}}{\tilde{k}} - t_1 - \frac{1}{\tilde{k}}\right] - OQ_2 t_1 + O\tilde{a}\left[T(T-t_1) - \frac{1}{2}(T^2 - t_1^2) - \frac{\theta T}{6}(T^4 - t_1^4) + \frac{\theta}{8}(T^4 - t_1^4) + \frac{\tilde{k}}{2}\left[\left(T^2(T - t_1) - \frac{1}{3}(T^3 - t_1^3)\right) - \frac{\theta T^2}{6}(T^3 - t_1^5) + \frac{\theta}{10}(T^5 - t_1^5)\right]\right]\right]\right]$$

Illustrative example

For Crisp model,

θ = 0.3, m = 600, n = 50, a = 15, k = 50, O = 500, Q_1 = 500, Q_2 = 1000,

For Fuzzy model,

θ = 0.3, m = 600, n = 50, $\tilde{a}$ = (12, 14, 17, 19), $\tilde{k}$ = (47, 49, 51, 53), O = 500, Q_1 = 500, Q_2 = 1000,

For Neutrosophic Fuzzy Model,

θ = 0.3, m = 600, n = 50, $\tilde{a}$ = < (12, 14, 17: ε), (13, 15, 16: δ), (16, 17, 19: γ) >, $\tilde{k}$ = < (47, 49, 51: ε), (46, 48, 50: δ), (47, 49, 50: γ) >, O = 500, Q_1 = 500, Q_2 = 1000,

COMPARISON OF MODELS:

TAC = 68332.74 at t_1 = 0.1484 and T = 1.1488

TAC^{+} = 67251.11 at t_1 = 0.1477 and T = 1.1301

TAC^{++} = 66283.06 at t_1 = 0.1516 and T = 1.1495

CONCLUSION

We have developed a model of the pharmaceutical industry having perishable products. These products have time varying demand rate. Here we have considered demand to be exponential function of time under crisp, fuzzy and neutrosophic fuzzy environment. With the help of neutrosophic fuzzy number and defuzzification by triangular single valued neutrosophic number, we obtain the minimum cost for the health care industry under neutrosophic fuzzy environment. Also, we have compared the same by considering it in general fuzzy environment. The comparative study of the health care industry is done and checked by using different parameters. We obtained that the result for this EOQ model is different in crisp, fuzzy and neutrosophic fuzzy environment. We can see that the result is quite impressive with neutrosophic fuzzy parameters, and is much less in neutrosophic fuzzy parameters. From the study we find that the result is better for the neutrosophic fuzzy system compare to fuzzy and crisp. The scope of this research work can include optimization for multi-items, fuzzy deterioration rate, probabilistic fuzzy demand, partial backlogging under learning effect, with shortage / with-out shortage, variable lead-time, variable production rate, multi-echelon system, deterioration during shortage period, permissible delay, and fuzzy inflation rate etc.

References

[1] F.Harris, "Operation and Cost," *A.W.Shaw Co, Chicago,* 1915.

[2] P. M. G. a. G. F. Schrader, "A model for exponentially decaying inventory," *Journal of Industrial Engineering,* vol. 14(5), pp. 238-243, 1963.

[3] J. L. H.C.Chang, "Fuzzy mixture inventory model involving fuzzy random variable demand and fuzzy total demand," *European Journal of Operational Research,* vol. 169(1), pp. 65-80, 2006.

[4] J. R. M.Bakker, "Review of Inventory system with deterioration since 2001.," *European Journal of Operational Research,* vol. 221(2), pp. 275-284, 2012.

[5] T. C. a. J. L. Janssen, "Literature riview of deteriorating inventory models by key topics from 2012 to 2015," *Int. J. Production Economics,* vol. 182, pp. 86-112, 2016.

[6] C.T.Chang, "Optimal ordering policies for deteriorating items using a discounted cash flow analysis when a trade credit linked to order quantity," *Computers and Industrial Engineering,* vol. 24(1), pp. 43-54, 2010.

[7] J. K.J.Chung, "The optimal ordering policy in a DCF analysis for deteriorating items when trade credit depends on the order quantity.," *International Jpurnal of Production Economics,* vol. 100(1), pp. 116-130, 2006.

[8] A.Chauhan, "Volume flexible inventory model for unsystematic rate of deterioration with lost sales," *International Journal of Operation Research and Optimization (IJORO),* vol. 1(2), pp. 441-454, 2010.

[9] V.Sharma, "An Imperfect Production Model with Preservation Technology, Fuzzy and variable holding cost under two storage capacity," *International Journal of Agricultural and Statistical Sciences,* vol. 11(1), pp. 225-231, 2015.

[10] A.K.Goyal, "An EPQ model with stock dependent demand and time varying deteriorating with shortages under inflationary environment.," *Industrial Journal of Agricultural and Statistical Sciences,* vol. 9(1), pp. 173-182, 2013.

[11] T.L.Urban, "Inventory models with inventory level dependent demand: A comprehensive review and unifying theory," *European Journal of Operational Research,* vol. 162(3), pp. 792-804, 2005.

[12] S.Singh, "An EOQ model for items having linear demand under inflation and permissible delay," *International Journal of Computer Application,* vol. 33(9), pp. 48-55, 2011.

[13] A. Chauhan, "A note on the inventory models for deteriorating items with Verhulst's model type demand," *Int. J. Operational Research,* vol. 22(2), pp. 243-261, 2015.

[14] A.Khanna, "Inventory Modeling for Imperfect Production Process with Inspection Error, Sales Return and Imperfect Rework Process," *International Journal of Mathematical, Engineering and Management,* vol. 2(4), pp. 242-258, 2017.

[15] H.J.Chang, "An EOQ model for deteriorating items with exponential time-varying demand and partial backlogging," *Information and Management Sciences,* vol. 10(1), pp. 1-11, 1999.

[16] A.Zadeh, "Fuzzy Set," *Information and Control,* vol. 8, pp. 338-358, 1965.

[17] S.Chaube, "Fuzzy Reliability Theory Based on Membership Function," *International Journal of Mathematical, Engineering and Management Sciences,* vol. 1(1), pp. 34-40, 2016.

[18] D.D.Aarya, "Inventory model with time dependent demand, weibull deterioration and permissible delay in payment," *Non linear studies,* vol. 24(1), pp. 43-54, 2017.

[19] M.Vujosevic, "EOQ formula when inventory cost is fuzzy," *Int. J. Production Economics,* Vols. 45(1-3), pp. 499-504, 1996.

[20] T.K.Roy and M.Maity, "A fuzzy EOQ model with demand dependent unit cost under limited shortage capacity," *European Journal of Operation Research,* vol. 99(2), pp. 425-432, 1997.

[21] J. Chiang, J. S. Yao and H. M. Lee, "Fuzzy inventory with backorder defuzzification by signed distance method," *Journal of Information Science and Engineering,* vol. 21(4), pp. 673-694, 2005.

[22] J.S.Yao, S. C. Chang and J. S. Su, "Fuzzy inventory without backorder for fuzzy order quantity and fuzzy total demand quantity," *Computer and Operation Research,* vol. 27, no. 10, pp. 935-962, 2000.

[23] K.S.Park, "Fuzzy-set theoretic interpretation of economic order quantity, Systems, Man and Cybernetics," *IEEE Transactions,* vol. 17(6), pp. 1082-1084, 1987.

[24] M. Vujosevic, D. Petrovic and R. Petrovic, "EOQ formula when inventory cost is fuzzy," *Int. J. Production Economics,* vol. 105(1), pp. 499-504, 1996.

[25] M.Sojati, "Bridging the gap between probabilistic and fuzzy-parameter EOQ models," *International Journal of Production Economics,* vol. 91(3), pp. 215-221, 2014.

[26] P. Kumar and S. B. Singh, "Fuzzy system reliability using generalized trapezoidal intuitionistic fuzzy number with some arithmetic operation," *Nonlinear studies,* vol. 24(1), pp. 915-922, 2017.

[27] J. S. Yao, S. C. Chang and J. S. Su, "Fuzzy inventory without backorder for fuzzy order quantity and fuzzy total demand quantity," *Computer and 'Operation Research,* vol. 27(10), pp. 935-962, 2000.

[28] J. S. Yao and J. Chiang, "Inventory without backorder with fuzzy total cost and fuzzy storing cost defuzzified by centroid and signed distance," *European Journal of Operational Research,* vol. 148(2), pp. 401-409, 2003.

[29] T.Chakrabarti and K.S.Chaudhuri, "An eoq model for deteriorating items with a linear trend in demand and shortages in all cycles," *International Journal of Production Economics,* vol. 49(3), pp. 205-213, 1997.

[30] S.Kundu and T.Chakrabarti, "Impact of carbon emission policies on manufacturing, remanufacturing and collection of used item decisions with price dependent return rate," *Opsearch,* vol. 55(2), pp. 532-555, 2018.

[31] J. D. Sen and T. Chakrabarti, "An Industrial Production Inventory model with deterioration under neutrosophic fuzzy optimization," *Neuroquantology,* vol. 20, no. 19, pp. 4399-4406, 2022.