EOQ model for instantaneous deterioration products with power demand pattern over a finite time horizon

[1]V.LAKSHMI, [2]A.SURIYA

[1]Department of Mathematics, PERI Institute of technology , Chennai, Tamil Nadu, India
[2] SRI CHAITANYA TECHNO SCHOOL , SELAIYUR , Chennai, Tamil Nadu, India

Abstract

This paper deals with EOQ model for instantaneous deterioration products with power demand pattern over a finite time horizon. Demand is assumed to be three different models such as(a) increasing demand (b) linear demand (c) decreasing demand.The main objective of the mathematical model is provided to optimize the cycle time by minimizing the total cost. A numerical example is studied in both crisp environment and neutrosophic environment and a comparative analysis is performed here. It is observed that, the model performs of the model is better in a triangular neutrosophic area than in a crisp domain.

Keywords: Inventory,power demand, shortages, deterioration,increasing demand, decreasing demand, linear demand, neutronsophic number.

1. Introduction

In EOQ inventory models, researchers have considered the demand of the items as a power demand pattern system. Most of the situation demand for goods is constant, but the demand can vary with time. So, demonstrating the behaviours andthe evolution of the inventorymodel with a power demand pattern. There are 3 stages occurring for the cooked goods or the prepared goods (a) Increasing demand (m >1) always for food products where the sales varies depending on the expiry date,(b) Decreasing demand (m <1) the daily need products like petrol or diesel oil, water, milk and gas. Always there is a demand everyday so, effect on "m" is high. (c) Decreasing demand (m =1) is kept more or less at a uniform rate along the scheduling period, products like electrical goods, cleaning products, kitchen utensils etc.These products do not depend on specific time period with regard to customer demand.

Abdel-Basset et al. [1] introduced neutrosophic multi criteria decision making framework for the professional selection.Chakraborty et al.[13] focus on pentagonal neutrosophic numbers and their distinct properties. Smarandache[17] introduced a neutrosophic set and a neutrosophic logic by considering the non-standard analysis. Also, neutrosophic inventory model without shortages is introduced by Mullaiet al. [11]. Chakraborty et al. [4] explained different Forms of triangular neutrosophic Numbers, De-neutrosophication Techniques, and their applications. Adaraniwonet al.[2], ignited the concept ofan inventory model for delayed deteriorating items with power demand considering shortages and lost sales.Sicilia et al.[18] developed the conception of deterministic inventory systems with power demand pattern.

Uthayakumar[20] introduced the continuous review inventory model with controllable backorder rate and investments. Karaaslan[6]formulated and analytically solved the Gaussian single-valued neutrosophic numbers and its application in multi-attribute decision making. Smarandache[17]argued that unifying field in logics neutrosophy, neutrosophic probability, set and logic. Murugappan[15]discussed the single valued neutrosophic Inventory model with neutrosophic random variable. Sarkar[16]showed that the inventory model with variable demand, component cost and selling price for deteriorating items.

2. ASSUMPTIONS AND NOTATIONS

(i) $D(t) = \frac{\delta t^{\frac{1}{m}-1}}{mT^{\frac{1}{m}}}$ where δ is positive constant, 0 <m< 1 , T is the planning horizon.

(ii) Shortages are allowed
(iii) The lead time is negligible.
(iv) The deterioration rate θ is constant and, 0 <θ< 1.
(v) The inventory system is assumed for a finite time horizon.
(vi) The inventory system deals with a single item only.

The following notations are used throughout the paper

$\mathfrak{I}_1(t)$:Inventory level at time t, $0 < t < t_1$
$\mathfrak{I}_2(t)$: Inventory level at time t, $t_1 < t < t_2$
$\mathfrak{I}_3(t)$: Shortage inventory level at time t, $t_2 < t < T$
A : Ordering cost per order per year.
T : Cycle of length.
t_2 : Time at which the inventory level is vanish
C_S : Shortage cost per unitper unit time
C_h : Holding cost per unit per unit time
C_d : Deterioration cost per unit per unit time
δ : Demand size during the fixed cycle time T
m : Demand pattern index
S : Highest stock level at the beginning of the cycle.
Q : Total order Quantity per cycle.
TC (t_2, T) : Total cost per unit.

3. MATHEMATICAL FORMULATION:

The inventory system is developed as follows: S units of items arrived at the inventory system at the beginning of each cycle. The inventory Sdecreases during $[o, t_1]$, due to demand only, during $[t_1, t_2]$, the inventory is depleted due to both demand and deterioration and the inventory level is dropping to zero at t_2.Deterioration rate is (θ). Finally, a shortage occurs due to demand during the time Interval $[t_2, T]$.

3.1Definition: Neutrosophic Set: Smarandache[17]

A set $\widetilde{Ns}$ in the universal discourse X, symbolically denoted by x, it is called a neutrosophic set if $\widetilde{Ns} = \{\langle x;[\rho_{\widetilde{Ns}}(x), \sigma_{\widetilde{Ns}}(x), \tau_{\widetilde{Ns}}(x)]\rangle : x \in X\}$, where $\rho_{\widetilde{Ns}}(x)$: $X \to [0,1]$ is said to be the truth membership function, which represents the degree of assurance, $\sigma_{\widetilde{Ns}}(x)$: $X \to [0,1]$ is said to be the indeterminacy membership, which denotes the degree of vagueness, and $\tau_{\widetilde{Ns}}(x)$: $X \to [0,1]$ is said to be the falsity membership, which indicates the degree of scepticism on the decision taken by the decision maker $\rho_{\widetilde{SVNs}}(x)$, $\sigma_{\widetilde{SVNs}}(x)$, $\tau_{\widetilde{SVNs}}(x)$exhibits the following relation: $0 \le \rho_{\widetilde{SVNs}}(x) + \sigma_{\widetilde{SVNs}}(x) + \tau_{\widetilde{SVNs}}(x) \le 3$

3.2 Definition:Single-Valued Neutrosophic Set:Chakraborty [4]

A neutrosophic set $\widetilde{Ns}$ in the definition 3.1. is said to be a single-Valued neutrosophic Set ($\widetilde{SVNs}$) if x is a single-valued independent variable. $\widetilde{SVNs} = \{\langle x;[\rho_{\widetilde{SVNs}}(x), \sigma_{\widetilde{SVNs}}(x), \tau_{\widetilde{SVNs}}(x)]\rangle : x \in X\}$, where $\rho_{\widetilde{SVNs}}(x)$, $\sigma_{\widetilde{SVNs}}(x)$, $\tau_{\widetilde{SVNs}}(x)$ denoted the concept of accuracy, indeterminacy and falsity memberships function respectively.

Definition 3.2.1: (Neutro-normal)

If there exist three pointsφ_0, χ_0& ψ_0 , for which $\rho_{\widetilde{SVNs}}$ $(\varphi_0) = 1$, $\rho_{\widetilde{SVNs}}$ $(\chi_0) = 1$ &$\tau_{\widetilde{SVNs}}$ $(\psi_0) = 1$, then the $\widetilde{SVNs}$ is called neut-normal.

Definition 3.2.2: (Neutro-convex)

$\widetilde{SVNs}$is called neut-convex, which implies that $\widetilde{SVNs}$ is a subset of a real line by satisfying the following conditions:

i. $\rho_{\widetilde{SVNs}}\langle\vartheta\,\varphi_1 + (1-\vartheta)\varphi_2\rangle \geq min\langle\ \rho_{\widetilde{SVNs}}\ (\varphi_1),\ \ \rho_{\widetilde{SVNs}}\ (\varphi_2)\rangle$

ii.$\sigma_{\widetilde{SVNs}}\langle\vartheta\varphi + (1-\vartheta)\varphi_2\rangle \leq max\langle\sigma_{\widetilde{SVNs}}\ (\varphi_1), \sigma_{\widetilde{SVNs}}\ (\varphi_2)\rangle$

iii.$\tau_{\widetilde{SVNs}}(\langle\vartheta\varphi_1 + (1-\vartheta)\varphi_2\rangle \leq max\langle\tau_{\widetilde{SVNs}}(\ (\varphi_1),\tau_{\widetilde{SVNs}}(\ (\varphi_2)\rangle$

where φ_1&$\in\mathbb{R}and$ $\vartheta\in[0,1]$

Definition 3.3 (Triangular Single Valued Neutrosophic Number)

A triangular Single Valued neutrosophicnumber $(\widetilde{\Omega})$ is defined a $\widetilde{\Omega}=<(r_1, r_2, r_3: \Upsilon),), (u_1, u_2, u_3: \lambda), (q_1, q_2, q_3: \eta)\ >,\ where\mu,\ \vartheta,\ \zeta\in$ [0,1]. Here the truth membership function $\rho_{\widetilde{\Omega}}$: R → [0, ϒ], the hesitation membership function $\sigma_{\widetilde{\Omega}}$: R → [$\lambda$, 1] and the falsity membership function $\tau_{\widetilde{\Omega}}$: : R → [$\eta$, 1] are defined as follows:

$$\pi_{\widetilde{\Omega}} = \begin{cases} \vartheta_{\widetilde{\Omega}l}(x), & r_1 \leq x < r_2 \\ \Upsilon, & x = r_2 \\ \vartheta_{\widetilde{\Omega}r}(x), & r_2 < x \leq r_3 \\ 0, & otherwise \end{cases}$$

$$\theta_{\widetilde{\Omega}} = \begin{cases} \varepsilon_{\widetilde{\Omega}l}(x), & u_1 \leq x < u_2 \\ \lambda, & x = u_2 \\ \varepsilon_{\widetilde{\Omega}r}(x), & u_2 < x \leq u_3 \\ 1, & otherwise \end{cases}$$

$$\eta_{\widetilde{\Omega}} = \begin{cases} \ell_{\widetilde{\Omega}l}(x), & q_1 \leq x < q_2 \\ \eta, & x = q_2 \\ \ell_{\widetilde{\Omega}r}(x), & q_2 < x \leq q_3 \\ 1, & otherwise \end{cases}$$

3.4 De-neutrosophication of triangular single valued neutrosophic number:

In this model removal area technique has been applied to evaluate the de-neutrosophication value of triangular single valued neutrosophic number,

$\widetilde{\Omega}\ =<\ (r_1, r_2, r_3: \Upsilon), (u_1, u_2, u_3: \lambda), (q_1, q_2, q_3: \eta)\ >$as done by (Chakraborty, et. al.).

The de-neutrosophic form of $\tilde{S}$ is given as $neuD_{\widetilde{\Omega}} = \left(\frac{r_1+2\,r_2+\,r_3+u_1+2\,u_2+\,u_3+\,q_1+2\,q_2+\,q_3}{12}\right)$

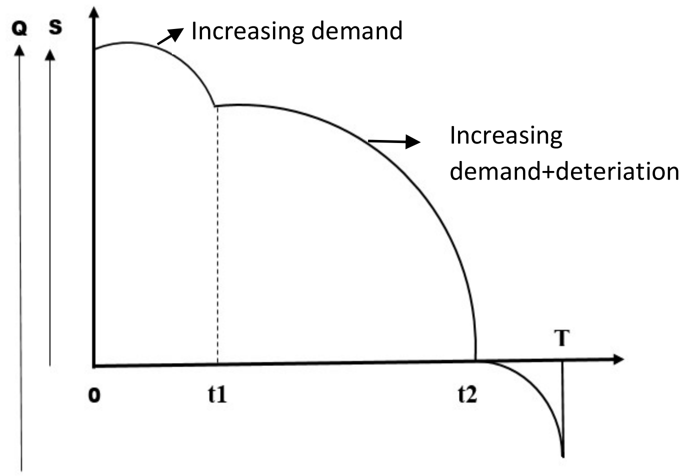

Figure1

$$\frac{d\Im_1(t)}{dt} = -\frac{\delta t^{\frac{1}{m}-1}}{mT^{\frac{1}{m}}} \qquad 0 \le t \le t_1 \qquad (1)$$

$$\frac{d\Im_2(t)}{dt} = -\frac{\delta t^{\frac{1}{m}-1}}{mT^{\frac{1}{m}}} - \theta\Im_2(t) \qquad t_1 \le t \le t_2 (2)$$

$$\frac{d\Im_3(t)}{dt} = -\frac{\delta t^{\frac{1}{m}-1}}{mT^{\frac{1}{m}}} \qquad t_2 \le t \le T \qquad (3)$$

Solving the above differential equations with the boundary conditions

$$\Im_1(0) = S, \quad \Im_2(t_2) = 0 \ , \ \Im_3(t_2) = 0$$

$$\Im_1(t) = -\frac{\delta t^{\frac{1}{m}}}{T^{\frac{1}{m}}} + s \, , \qquad 0 \le t \le t_1 \qquad (5)$$

$$\Im_2(t) = \frac{\delta}{T^{\frac{1}{m}}}\left\{\{1-\theta\, t\}\left\{t_2{}^{\frac{1}{m}} - t^{\frac{1}{m}}\right\} + \frac{\theta}{m+1}\left\{t_2{}^{\frac{1}{m}+1} - t^{\frac{1}{m}+1}\right\}\right\}, \quad t_1 \le t \le t_2 \qquad (6)$$

$$\Im_3(t) = \frac{\delta}{T^{\frac{1}{m}}}\left\{t_1{}^{\frac{1}{m}} - t^{\frac{1}{m}}\right\}, \qquad t_2 \le t \le T \qquad (7)$$

$$\Im_1(t_1) = \Im_2(t_1) \qquad (8)$$

$$S = \frac{\delta}{T^{\frac{1}{m}}}\left\{t_1{}^{\frac{1}{m}} + \{1-\theta\, t_1\}\left\{t_2{}^{\frac{1}{m}} - t_1{}^{\frac{1}{m}}\right\} + \frac{\theta}{m+1}\left\{t_2{}^{\frac{1}{m}+1} - t_1{}^{\frac{1}{m}+1}\right\}\right\} \qquad (9)$$

$$\Im_1(t) = \frac{\delta}{T^{\frac{1}{m}}}\left\{(t_1{}^{\frac{1}{m}} - t^{\frac{1}{m}}) + \{1-\theta\, t_1\}\left\{t_2{}^{\frac{1}{m}} - t_1{}^{\frac{1}{m}}\right\} + \frac{\theta}{m+1}\left\{t_2{}^{\frac{1}{m}+1} - t_1{}^{\frac{1}{m}+1}\right\}\right\} \qquad (10)$$

$$\Im_3(T) = Q - S \qquad (11)$$

$$Q = \frac{\delta}{T^{\frac{1}{m}}}\left\{\left(t_1^{\frac{1}{m}} - T^{\frac{1}{m}}\right) + t_1^{\frac{1}{m}} + \{1-\theta\, t_1\}\left\{t_2^{\frac{1}{m}} - t_1^{\frac{1}{m}}\right\} + \frac{\theta}{m+1}\left\{t_2^{\frac{1}{m}+1} - t_1^{\frac{1}{m}+1}\right\}\right\} \qquad (12)$$

1. **The ordering cost is** $O_C = A$ (13)
2. **The inventory holding cost during $(\mathbf{0}, \boldsymbol{t_2})$ is given by**

$$\mathcal{H}_C = \mathcal{C}_h\{\int_0^{t_1} \mathfrak{I}_1(t)\, dt + \int_{t_1}^{t_2} \mathfrak{I}_2(t)\, dt\}$$

$$\mathcal{H}_C = \mathcal{C}_h \frac{\delta}{T^{\frac{1}{m}}}\left\{\frac{(t_1^{\frac{1}{m}+1} + t_2^{\frac{1}{m}+1})}{m+1} + \{1-\theta\, t_1\}\left\{t_2^{\frac{1}{m}} - t_1^{\frac{1}{m}}\right\} t_1 + \frac{\theta}{m+1}\left\{t_2^{\frac{1}{m}+1} - t_1^{\frac{1}{m}+1}\right\} t_1 \right.$$
$$+\left\{t_2^{\frac{1}{m}} - \frac{m\, t_1^{\frac{1}{m}}}{m+1}\right\} t_1 + \theta\left\{\frac{t_2^{\frac{1}{m}}}{2} - \frac{m\, t_1^{\frac{1}{m}}}{2m+1}\right\} {t_1}^2$$
$$-\frac{\theta}{m+1}\left\{t_2^{\frac{1}{m}+1}\right.$$
$$\left.\left. - \frac{m\, t_1^{\frac{1}{m}+1}}{2m+1}\right\} t_1\right\} \qquad (14)$$

3. **The deterioration cost during $(\boldsymbol{t_1}, \boldsymbol{t_2})$ are**

$$D_C = \frac{\mathcal{C}_d\, \delta}{T^{\frac{1}{m}}}\left\{\{1-\theta\ \ t_1\}\left\{t_2^{\frac{1}{m}} -\ t_1^{\frac{1}{m}}\right\} + \frac{\theta}{m+1}\left\{t_2^{\frac{1}{m}+1} - t_1^{\frac{1}{m}+1}\right\} - \left\{t_2^{\frac{1}{m}} -\ t_1^{\frac{1}{m}}\right\}\right\} \qquad (15)$$

4. **Shortage cost during $(\boldsymbol{t_2}, \boldsymbol{T})$ are**

$$S_C = -\frac{\mathcal{C}_d\, \delta}{T^{\frac{1}{m}}}\left\{t_1^{\frac{1}{m}}(T - t_2) - \frac{m\left(T^{\frac{1}{m}+1} - t_2^{\frac{1}{m}+1}\right)}{m+1}\right\} \qquad (16)$$

The total inventory cost per unit time is given by

$$\text{TC}\,(\text{t}_2, T) = \frac{1}{T}[O_C + \mathcal{H}_C + D_C + S_C]$$

$$\mathrm{TC}\,(\mathrm{t}_2,T)=\frac{1}{T}\Bigg\{A+C_h\frac{\delta}{T^{\frac{1}{m}}}\Bigg\{\frac{(t_1^{\frac{1}{m}+1}+t_2^{\frac{1}{m}+1})}{m+1}+\{1-\theta\,t_1\}\left\{t_2^{\frac{1}{m}}-t_1^{\frac{1}{m}}\right\}t_1+\frac{\theta}{m+1}\left\{t_2^{\frac{1}{m}+1}-t_1^{\frac{1}{m}+1}\right\}t_1+\left\{t_2^{\frac{1}{m}}-\frac{m\,t_1^{\frac{1}{m}}}{m+1}\right\}t_1+\theta\left\{\frac{t_2^{\frac{1}{m}}}{2}-\frac{m\,t_1^{\frac{1}{m}}}{2m+1}\right\}t_1^{2}-\frac{\theta}{m+1}\left\{t_2^{\frac{1}{m}+1}-\frac{m\,t_1^{\frac{1}{m}+1}}{2m+1}\right\}t_1\Bigg\}+\frac{C_d\,\delta}{T^{\frac{1}{m}}}\left\{\{1-\theta\;t_1\}\left\{t_2^{\frac{1}{m}}-\;t_1^{\frac{1}{m}}\right\}+\frac{\theta}{m+1}\left\{t_2^{\frac{1}{m}+1}-t_1^{\frac{1}{m}+1}\right\}-\left\{t_2^{\frac{1}{m}}-\;t_1^{\frac{1}{m}}\right\}\right\}-\frac{C_s\,\delta}{T^{\frac{1}{m}}}\left\{t_1^{\frac{1}{m}}(T-t_2)-\frac{m\left(T^{\frac{1}{m}+1}-t_2^{\frac{1}{m}+1}\right)}{m+1}\right\}\Bigg\} \qquad (17)$$

4. Solution procedure

Now equation (17) can be minimized but as it is difficult to solve the problem by deriving a closed equation of the solution of equation (17), Mathematica 9.0 has been used to determine optimal $\mathrm{t}_2{}^{*}$and T, hence the optimal cost $\mathrm{TC}(\mathrm{t}_2,T)$ can be evaluated. Also, the level of initial inventory level Q* can be determined.

$\mathrm{TC}(\mathrm{t}_2{}^{*},\mathrm{T}^{*})$=$\frac{\partial^2\mathrm{TC}\,(\mathrm{t}_2,\mathrm{T})}{\partial \mathrm{t}_2{}^2}\frac{\partial^2\mathrm{TC}\,(\mathrm{t}_2,\mathrm{T})}{\partial \mathrm{T}^2}-\left[\frac{\partial^2\mathrm{TC}\,(\mathrm{t}_2,\mathrm{T})}{\partial \mathrm{t}_2\,\partial \mathrm{T}}\right]^2>0$ we recommended "D-test" for optimizing functionsof two variables t_2 and T.

Numerical examples

The proposed model is illustrated with some numerical examples as given below.

Example 1 [Case(i) increasing demand 0<m<1]

A = 50, δ = 100, C_h = 2.5, C_d = 4.4,C_s = 12.125, m = 0.5, θ = 0.001, t_1 = 0.35, in appropriate units.
The following results were obtained where t_2 = 0.764723years and T =1.33867years. The Obtained results are $\mathrm{TC}\,(\mathrm{t}_2,T)=\;401.284$, $Q=125.801$units.

Example 2 [Case(ii) Linear demand m=1]

Upon repeating the same example 1 with m= 1,the following results were obtained
$t_2=0.622978\;\;years, T=0.833763\;years, TC(\,t_2,T)=381.596, Q=132.741\;\;units.$

Example 3 [Case(iii) decreasing demand m>1]

Upon repeating the same example 1 with m= 1.5,the following results were obtained
$t_2=0.596353\;\;years, T=0.79564\;\;years,\;TC(\,t_2,T)=331.719,\;Q=124.671\;\;units.$

5. Effect of Neutrosophication of parameter in the proposed inventory model

Neutrosophic number actually deals with the conception of three different kinds of membership function related with real life scenario. It consists of truth, hesitation and falseness of an imprecise number. In this model, holding cost ($\mathcal{C}_h$), deterioration cost ($\mathcal{C}_d$), and shortage cost ($\mathcal{C}_s$) have been considered as neutrosophic fuzzy number, since in reality all the parameters are uncertain and it contains a dilemma in decision maker's mind. So,the model is manifested by introducing neutrosophication with the above cost and rates, and thus observes the effect of the above by comparing it with a crisp model. The neutrosophic form of holding cost, deterioration cost and shortage cost are represented by $\widetilde{\mathcal{C}_h}$, $\widetilde{\mathcal{C}_d}$, and $\widetilde{\mathcal{C}_s}$. Thus,

$$\widetilde{\mathcal{C}_h} =< (\mathrm{h}_1 - \omega_1, \mathrm{h}_1, \mathrm{h}_1 + \omega_2 : \Upsilon), (\mathrm{h}_2 - \omega_1, \mathrm{h}_2, \mathrm{h}_2 + \omega_2 : \lambda), (\mathrm{h}_3 - \omega_1, \mathrm{h}_3, \mathrm{h}_3 + \omega_2 : \eta) > ,$$

$$\widetilde{\mathcal{C}_d} =< (\mathrm{d}_1 - \omega_1, \mathrm{d}_1, \mathrm{d}_1 + \omega_2 : \Upsilon), (\mathrm{d}_2 - \omega_1, \mathrm{d}_2, \mathrm{d}_2 + \omega_2 : \lambda), (\mathrm{d}_3 - \omega_1, \mathrm{d}_3, \mathrm{d}_3 + \omega_2 : \eta) >,$$

$$\widetilde{\mathcal{C}_s} =< (\mathrm{k}_1 - \omega_1, \mathrm{k}_1, \mathrm{h}_1 + \omega_2 : \Upsilon), (\mathrm{k}_2 - \omega_1, \mathrm{k}_2, \mathrm{k}_2 + \omega_2 : \lambda), (\mathrm{k}_3 - \omega_1, \mathrm{k}_3, \mathrm{k}_3 + \omega_2 : \eta) >$$

$where \Upsilon, \lambda, \eta \in [0,1]$ and $0 < \omega_1, \omega_2 < 1$.

This neutrosophic fuzzy number is implemented in this model and thus the total cost obtained using this neutrosophic number is

$$\mathrm{TCneu} = \frac{1}{T}\Bigg\{A + \widetilde{\mathcal{C}_h}\frac{\delta}{T^{\frac{1}{m}}}\Bigg\{\frac{(t_1^{\frac{1}{m}+1} + t_2^{\frac{1}{m}+1})}{m+1} + \{1-\theta\, t_1\}\left\{t_2^{\frac{1}{m}} - t_1^{\frac{1}{m}}\right\}t_1 + \frac{\theta}{m+1}\left\{t_2^{\frac{1}{m}+1} - t_1^{\frac{1}{m}+1}\right\}t_1 + \left\{t_2^{\frac{1}{m}} - \frac{m\, t_1^{\frac{1}{m}}}{m+1}\right\}t_1 + \theta\left\{\frac{t_2^{\frac{1}{m}}}{2} - \frac{m\, t_1^{\frac{1}{m}}}{2m+1}\right\}t_1^{\,2} - \frac{\theta}{m+1}\left\{t_2^{\frac{1}{m}+1} - \frac{m\, t_1^{\frac{1}{m}+1}}{2m+1}\right\}t_1\Bigg\} + \frac{\widetilde{\mathcal{C}_d}\,\delta}{T^{\frac{1}{m}}}\left\{\{1-\theta\ t_1\}\left\{t_2^{\frac{1}{m}} - t_1^{\frac{1}{m}}\right\} + \frac{\theta}{m+1}\left\{t_2^{\frac{1}{m}+1} - t_1^{\frac{1}{m}+1}\right\} - \left\{t_2^{\frac{1}{m}} - t_1^{\frac{1}{m}}\right\}\right\} - \frac{\widetilde{\mathcal{C}_s}\,\delta}{T^{\frac{1}{m}}}\left\{t_1^{\frac{1}{m}}(T-t_2) - \frac{m\left(T^{\frac{1}{m}+1} - t_2^{\frac{1}{m}+1}\right)}{m+1}\right\}\Bigg\} \quad (18)$$

Here,holding cost $\widetilde{\mathcal{C}_h}$, deteriotion cost $\widetilde{\mathcal{C}_d}$and shortage cost $\widetilde{\mathcal{C}_s}$ have been considered as triangular neutrosophic fuzzy number. Thus, the neutrosophic numbers of the above parameters are:

$$h_1 = 2.5, h_2 = 2.45\ , h_3 = 2.55, d_1 = 4.38, d_2 = 4.4, d_3 = 4.42, k_1 = 12.125, k_2 = 12.118, k_3 = 12.132\ ,$$

$$\varepsilon_1 = 0.4, \varepsilon_2 = 0.6. Then, \widetilde{\mathcal{C}_h} = =< (2.1,2.5,3.1), (2.05,2.45,3.05), (2.15,2.55,3.15) >,$$

$$\widetilde{\mathcal{C}_d} =< (3.98,4.38,4.98), (4,4.4,5), (4.02,4.42,5.02) > and$$

$$\widetilde{C_s} =< (11.725,12.125,12.725),(11.718,12.118,12.718),(11.732,12.132,12.132) >$$

5.1 Optimal time and cost of inventory model under neutrosophic domain

Numerical examples

The proposed model is illustrated with some numerical examples as given below.

Example 1 as found in [12] **[Case (i) increasing demand 0<m<1]**

A= 50, δ=100, $\widetilde{C_h}$= 2.25, $\widetilde{C_d}$ = 4.15,$\widetilde{C_s}$ = 11.875, m=0.5, θ= 0.001, t_1= 0.35, in appropriate units. The following results were obtained where t_2 = 0.706622 years and T =1.12976years. We obtain $\text{TCneu}(t_2, T) = 387.348$, $Q = 129.483$ units.

Example 2 [Case(ii) Linear demand m=1]

Upon repeating the same example 1 withm= 1,the following results were obtained

$$t_2 = 0.59554 \ years, T = 0.78266 \ years, TCneu(t_2, T) = 360.171, Q = 131.373 \ units.$$

Example 3 [Case (iii) decreasingdemand m>1]

Upon repeating the same example 1 withm= 1.5,the following results were obtained

$$t_2 = 0.57355 \ years, T = 0.75667 \ years, TCneu(t_2, T) = 312.78, Q = 123.322 \ units.$$

Comparison between crisp model and neutrosophic model

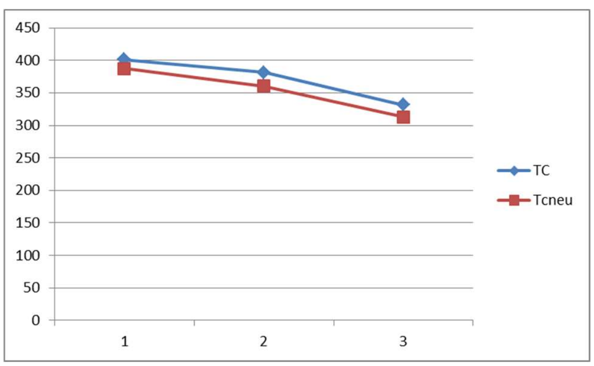

Figure 2

Table 1
Effects of changes in the system parameters of the neutrosophicmodel.

P*	V*	C*	t_2	T	TCneu	Q
δ	120	+20	0.706622	1.07632	455.741	158.98
	110	+10	0.706622	1.09917	421.594	144.262
	100	0	0.706622	1.12976	387.35	129.49
	90	-10	0.706622	1.17327	352.958	114.603
	80	-20	0.706622	1.24154	318.349	99.5307
A	60	+20	0.706622	1.2147	391.784	125.504
	55	+10	0.706622	1.16855	387.422	127.558

	50	0	0.706622	1.12976	387.35	129.49
	45	-10	0.706622	1.09631	382.853	131.31
	40	-20	0.706622	1.06691	378.23	132.874
t_1	0.42	+20	0.84794	1.29156	379.784	132.527
	0.385	+10	0.777281	1.20907	383.267	131.192
	0.35	0	0.70622	1.12976	387.35	129.49
	0.315	-10	0.635962	1.05595	392.176	127.381
	0.28	-20	0.565302	0.993255	397.937	124.456
θ	0.0012	+20	0.706674	1.12985	387.351	129.53
	0.0011	+10	0.706648	1.1298	387.349	129.529
	0.001	0	0.70622	1.12976	387.35	129.49
	0.0009	-10	0.706596	1.12972	387.346	129.527
	0.0008	-20	0.70657	1.12968	387.344	129.525
$\widetilde{C_h}$	2.7	+20	0.848994	1.78476	399.287	118.784
	2.475	+10	0.772685	1.38438	394.61	124.764
	2.25	0	0.70622	1.12976	387.35	129.49
	2.025	-10	0.649021	0.949272	377.137	133.158
	1.8	-20	0.598485	0.814421	363.657	135.542
$\widetilde{C_s}$	14.25	+20	0.614588	0.827734	430.343	137.259
	13.06251	+10	0.653926	0.942815	410.767	134.33
	11.875	0	0.70622	1.12976	387.35	129.49
	10.6875	-10	0.780664	1.50684	359.151	121.448
	9.5	-20	0.891826	1.92279	325.891	118.201
$\widetilde{C_d}$	4.98	+20	0.706679	1.12987	387.352	129.528
	4.565	+10	0.706651	1.12981	387.35	129.528
	4.15	0	0.70622	1.12976	387.35	129.49
	3.735	-10	0.706564	1.12966	387.343	129.527
	3.32	-20	0.706564	1.12966	387.343	129.527

Note: P*= Parameters, V*=Values, C*=%Changes

To understand the effects of changes in the system parameters, on the optimal cost obtained by the considered method. Sensitivity analysis is executed by changing (increasing and decreasing) 10 % in every parameter. The effect of the parameters is detailed below.

Changing the parameter values and different total cost of power demand pattern

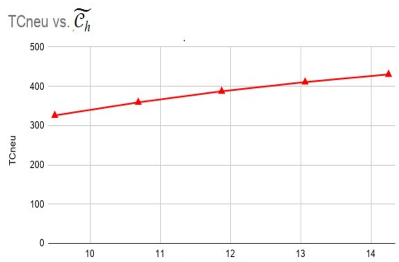

Figure 3 Changing $\widetilde{C_h}$

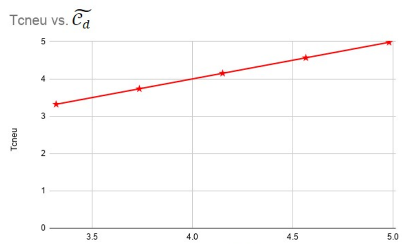

Figure 4 Changing $\widetilde{C_d}$

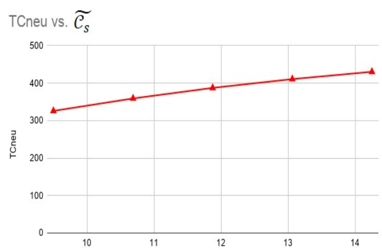

Figure 5 Changing $\widetilde{C_s}$

As the result of the above table ,

(i) Increases in the value of the parameter δthen$TisincreasedandTCneu(t_1,T)$, $Qisdecreased$.

(ii) Increases in the values of either of the parameters A, m then T ,$TCneu(t_1,T)$, $isdecreasedandQisincreased$

(iii) Increases in the values of either of the parameters t_1 then t_2, $T, Q$is decreased and $TCneu(t_1,T)$is increased.

(iv) Increases in the values of the parameter $\widetilde{C_H}$ then t_2, T , $TCneu(t_1,T)$is decreased and $Q$is increased.

(v) Increases in the values of the parameter $\theta, \widetilde{C_d}$ then t_2, T , $Q, andTCneu(t_1,T)$ is decreased

(vi) Increases in the values of the parameter $\widetilde{C_s}$ then t_2, T is increased and $TCneu(t_1,T)$,$Q$is decreased.

6. Conclusion

In this paper, EOQ model for instantaneous deterioration products with power demand pattern over a finite time horizon is discussed. Neutrosophic optimal quantity and neutrosophic optimal cost is determined by defining the accuracy function of triangular neutrosophic numbers. In future, this paper can be extended in the Genetic algorithmandneural network environment and it can be extended to economic production model considering variable deterioration with power demand pattern and shortages.

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