Triangular Neutrosophic-based EOQ model for non-Instantaneous Deteriorating Item under Shortages

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Abstract

In this paper, we applied the concept of triangular Neutrosophic number from a special viewpoint. Additionally, we utilized specific varieties of linear triangular Neutrosophic numbers and de-neutrosofication idea which could be very critical for uncertainty concept. Here, an EOQ model has been developed for a linearly dependent demand of non-instantaneous items under shortages. The paper considers holding cost as triangular neutrosophic number (TNN) and optimizes the model. A comparative study is done under crisps and neutrosophic domain and the model gives better result under the later domain. This noble notion will assist us to resolve a plethora of realistic existence problems in neutrosophic area.

Keywords: EOQ Model, TNN, De-neutrosophication Technique, Shortages.

1. Introduction:

In this modern advancement of science, vagueness theory plays an essential position in disjunctive areas of mathematical modeling, engineering, medical diagnoses, social sciences and management fields. The principle of impreciseness was manifested by Prof. L.A Zadeh [1] (1965) in his research paper. Difference among crisp set and fuzzy set is shown briefly in this newsletter by means of considering membership gradation and its formula.
Further, developments of triangular [2], trapezoidal [3], pentagonal [4], hexagonal [5], heptagonal [6] fuzzy number has already been established by different researchers from all across the glove. Later, in 1986 Prof. Atanassov [7] incorporated an amazing conception of intuitionistic fuzzy set which contains both membership and non-membership functions. Further, in 1998 Prof. Smarandache [8] established an overwhelming idea of neutrosophic fuzzy set which contains three disjunctive forms of membership functions namely i) truthness ii) falseness iii) indeterminacy. Due to the presence of hesitation issue in fuzzy area, neutrosophic quantity will grab more logical and scientific significance in research work. In this present generation, researchers from distinct arena are focusing on neutrosophic idea and developed lots of thrilling articles in this domain. Classification of triangular [9], trapezoidal [10], pentagonal [11-13] neutrosophic quantity has been brought nowadays by Chakraborty et.al and applied it in various domains like networking, graph theory, operation research problem etc. A few new articles [14-18] are also comes out recently with different ideas and extension in neutrosophic areas. Later, bipolarization of triangular bipolar neutrosophic number has been manifested by Chakraborty et.al [19] and Mullai [20] added EOQ version in neutrosophic area and Mondal et.Al [21] incorporated optimization of EOQ Model with limited garage potential with the aid of neutrosophic Geometric Programming utility. Also, Majumdar et.al [22] built up EPQ Model of deteriorating items beneath partial trade credit score financing market in neutrosophic arena. Recently, numerous researchers from disjunctive fields targeted on TNN and its de-neutrosophication technique to study operation research optimization models.

In market financial system, for a single product, many objects are manufactured by using distinct production groups. The producer is seeking to provide wide variety of choice to the customer to advantage competitive gain over their competition. But customers select the ones gadgets which has excessive reliability i.e. higher in exceptional and lower in fee. The firms require to make various plans many years previous to the sales purposed time with an outlook to reduce the total cost and maximize the total profit. Thus the information like deviation in reliability of the manufacturing process, deterioration and shortages are in increasing interest in the modern competitive market.

In this research article we mainly focused on TNN and its different classification and crispification skills. We applied the idea into an EOQ model created in TNN environment. Recently, researcher observed that the demand is not constant but it depends in time. So the researcher consider demand as ramp type [23], linear, etc. Also in general we consider deterioration start as soon as the item produces or comes to the inventory but is not always true. The items always have a life time for expiry. So Rathore [24] has considered non- instantaneous deteriorating items in his model. The effect of shortages in an inventory can't be ignored and thus shortages are either fully backordered [25] or partially backordered and partially lost in sales. Here, we have considered an EOQ model with time dependent demand for deteriorating items where shortages are fully backordered.

2. Mathematical Preliminaries:

Definition 2.1: Fuzzy Set: [1] A Set $\widetilde{H}$ is called a fuzzy set when represented by the ordered pair $(x, \pi_{\widetilde{H}}(x))$ and thus stated as $\widetilde{H} = \{(x, \pi_{\widetilde{H}}(x)) : x \in \cup, \pi_{\widetilde{H}}(\cup) \in [0,1]\}$ where $x \in$ the crisp set $\cup$ and $\mu_{\widetilde{H}}(\cup) \in$ the interval$[0,1]$.

Definition 2.2: Intuitionistic Fuzzy Set (IFS): [7] A fuzzy set [2] $\tilde{P}_F$ in the universal discourse$\cup$, indexed mainly by x is referred as Intuitionistic set if $\tilde{P}_F = \{\langle x; [\rho(x), \sigma(x)]\rangle \vdots x \in \cup\}$, where $\rho(x): \rightarrow [0,1]$ is designated as the certainty membership function which indicates the degree of confidence, $\sigma(x)$:$\cup\rightarrow [0,1]$ is termed as the uncertainty membership function which indicates the degree of impreciseness.

$\rho(x), \sigma(x)$ demonstrate the following the relation

$$0 \leq \rho(x) + \sigma(x) \leq 1.$$

Definition 2.3: Neutrosophic Set: [8] A set $\widetilde{P_N}$ in the universal discourse $\cup$, symbolically denoted by x, it is called a neutrosophic set if $\widetilde{P_N} = \{\langle x; [T_{\widetilde{P_N}}(x), I_{\widetilde{P_N}}(x), F_{\widetilde{P_N}}(x)]\rangle \vdots x \in \cup\}$, where $T_{\widetilde{P_N}}(x)$:$\cup\rightarrow [0,1]$ is said to be the true membership function, which has the index of belongingness, $I_{\widetilde{P_N}}(x)$:$\cup\rightarrow [0,1]$ is said to be the indeterminacy membership, having index of ambiguity, and $F_{\widetilde{P_N}}(x)$:$\cup\rightarrow [0,1]$ is said to be the incorrect membership, which has the index of non-belongingness of the decision maker.

$T_{\widetilde{P_N}}(x), I_{\widetilde{P_N}}(x) \& F_{\widetilde{P_N}}(x)$ demonstrate the following relation:

$$0 \leq T_{\widetilde{P_N}}(x) + I_{\widetilde{P_N}}(x) + F_{\widetilde{P_N}}(x) \leq 3.$$

Definition 2.4: Single-Valued Neutrosophic Set: A Neutrosophic set $\widetilde{P_N}$ in the definition 2.3 also known as single-Valued Neutrosophic Set $(\widetilde{P_{SingN}})$ if x is a single-valued independent variable. $\widetilde{P_{SingN}} = \{\langle x; [T_{\widetilde{P_{SingN}}}(x), I_{\widetilde{P_{SingN}}}(x), F_{\widetilde{P_{SingN}}}(x)]\rangle \vdots x \in \cup\}$, where $T_{\widetilde{P_{SingN}}}(x), I_{\widetilde{P_{SingN}}}(x) \& F_{\widetilde{P_{SingN}}}(x)$ denoted the concept of exactness, indeterminacy and falseness memberships function respectively.

Definition 2.5: Single Valued Neutrosophic Number: Single Valued Neutrosophic Number $(\widetilde{\omega})$ is defined as $\widetilde{\omega} = \langle [(k^1, l^1, m^1, n^1); \theta], [(k^2, l^2, m^2, n^2); \vartheta], [(k^3, l^3, m^3, n^3); \tau]\rangle$ where $\theta, \vartheta, \tau \in [0,1]$.Here the true membership function$(T_{\widetilde{\omega}}): \mathbb{R} \rightarrow [0, \theta]$, the indeterminacy membership function $(I_{\widetilde{\omega}}): \mathbb{R} \rightarrow [\vartheta, 1]$ and the fallacious membership function $(F_{\widetilde{\omega}}): \mathbb{R} \rightarrow [\tau, 1]$are defined as follows:

$$T_{\widetilde{\omega}}(x) = \begin{cases} \aleph_{\widetilde{\omega l}}(x) & k^1 \le x \le l^1 \\ \theta & l^1 \le x \le m^1 \\ \aleph_{\widetilde{\omega u}}(x) & m^1 \le x \le n^1 \\ 0 & otherwise \end{cases}, \quad I_{\widetilde{\omega}}(x) = \begin{cases} \beth_{\widetilde{\omega l}}(x) & k^2 \le x \le l^2 \\ \vartheta & l^2 \le x \le m^2 \\ \beth_{\widetilde{\omega u}}(x) & m^2 \le x \le n^2 \\ 1 & otherwise \end{cases}, F_{\widetilde{\omega}}(x) = \begin{cases} \varphi_{\widetilde{\omega l}}(x) & k^3 \le x \le l^3 \\ \tau & l^3 \le x \le m^3 \\ \varphi_{\widetilde{\omega u}}(x) & m^3 \le x \le n^3 \\ 1 & otherwise \end{cases}$$

3. Triangular Single Valued Neutrosophic number: [9] A Triangular Single Valued Neutrosophic number of Type 1 is defined as $\tilde{P}_{TriN} = (r_1, r_2, r_3; s_1, s_2, s_3; t_1, t_2, t_3)$ whose certainty membership, impreciseness and falsity membership is defined as follows:

$$T_{\tilde{P}_{TriN}}(x) = \begin{cases} \frac{x-r_1}{r_2-r_1} & when r_1 \le x < r_2 \\ 1 & when \ x = r_2 \\ \frac{r_3-x}{r_3-r_2} & when \, r_2 < x \le r_3 \\ 0 & otherwise \end{cases}, \quad I_{\tilde{P}_{TriN}}(x) = \begin{cases} \frac{s_2-x}{s_2-s_1} & when s_1 \le x < s_2 \\ 0 & when \ x = s_2 \\ \frac{x-s_2}{s_3-s_2} & when \, s_2 < x \le s_3 \\ 1 & otherwise \end{cases}$$

$$F_{\tilde{P}_{TriN}}(x) = \begin{cases} \frac{t_2 - x}{t_2 - t_1} & when t_1 \le x < t_2 \\ 0 & when \ x = t_2 \\ \frac{x - t_2}{t_3 - t_2} & when \, t_2 < x \le t_3 \\ 1 & otherwise \end{cases}$$

Where, $0 \le T_{\tilde{P}_{TriN}}(x) + I_{\tilde{P}_{TriN}}(x) + F_{\tilde{P}_{TriN}}(x) \le 3, x \in \tilde{P}_{TriN}$

3.1 Alpha Cut Form: The parametric form of the above type number is

$$\left(\tilde{P}_{TriN}\right)_{\theta,\vartheta,\tau} = [T_{TriN1}(\theta), T_{TriN2}(\theta); I_{TriN1}(\vartheta), I_{TriN2}(\vartheta); F_{TriN1}(\tau), F_{TriN2}(\tau)]$$

Where, $$T_{TriN1}(\theta) = r_1 + \theta(r_2 - r_1), T_{TriN2}(\theta) = r_3 - \theta(r_3 - r_2)$$

$$I_{TriN1}(\vartheta) = s_2 - \vartheta(s_2 - s_1), I_{TriN2}(\vartheta) = s_2 + \vartheta(s_3 - s_2)$$

$$F_{TriN1}(\tau) = t_2 - \tau(t_2 - t_1), F_{TriN2}(\tau) = t_2 + \tau(t_3 - t_2)$$

Here, $0 < \theta \le 1$, $0 < \vartheta \le 1$, $0 < \tau \le 1$ and $0 < \theta + \vartheta + \tau \le 3$

3.2 De-neutrosophication of triangular single valued neutrosophic number: In this model we have utilized removal area method to estimate the de-neutrosophication value [9] of triangular single valued neutrosophic number $\tilde{P}_{DN} =< (u, v, w: \varepsilon), (x, y, z: \partial), (h, i, j: \gamma) >$ then the De-neutrosophication value will be

$$D_{Neu}\left(\breve{D}, 0\right) = \frac{(u+2v+w+x+2y+z+h+2i+j)}{12} \quad …….. (3.2.1)$$

4. An EOQ model

Assumptions and notations:

- Demand is linearly dependent on time i.e. $D(t) = \alpha + \beta t$; $\alpha, \beta > 0$ are scale parameters
- Deterioration rate $(\gamma(t))$ is non-instantaneous and its per unit cost is C_d;

$$\gamma(t) = \begin{cases} 0 & 0 \le t \le t_0 \\ \theta & t_0 \le t \le T_1 \end{cases}$$

Where 0 < θ << 1 and t_0 is the maximum life time of the items.

- Shortages are fully backordered and its per unit cost is C_S;
- Holding cost (h) is considered as triangular neutrosophic number.

4.1 Mathematical model and its analysis

Let us consider an EOQ model where the demand linearly depend on time and the deterioration is non-instantaneous so from [0, t_0] there is no deterioration and then the deterioration starts from $t=t_0$ and ends till the inventory finishes i.e., during [t_0, T_1]. Also the model undergoes shortages during [T_1, T]. Thus the mathematical modelling is given below:

$$\frac{dI_1(t)}{dt} = -(\alpha + \beta t) \quad 0 \le t \le t_0 \tag{1}$$

$$\frac{dI_2(t)}{dt} + \theta I_2(t) = -(\alpha + \beta t) \quad t_0 \le t \le T_1 \tag{2}$$

$$\frac{dI_3(t)}{dt} = -(\alpha + \beta t) \quad T_1 \le t \le T \tag{3}$$

Where, $I_0(0) = Q,\ I_2(T_1) = 0, \mathrm{I}_3(T) = Q,\ I_1(t_0) = I_2(t_0),\ I_2(T_1) = I_3(T_1)$

Thus solving eq. (1, 2, 3) we get the inventory level during different time and it is given in eq. (4, 5, 6) as follows

$$I_1(t) = Q - \alpha t - \frac{\beta t^2}{2} \tag{4}$$

$$I_2(t) = \left(\frac{\alpha}{\theta} + \frac{\beta}{\theta^2}\right)\left(e^{\theta(T_1 - t)} - 1\right) + \frac{\beta}{\theta}\left\{T_1 e^{\theta(T_1 - t)} - 1\right\} \tag{5}$$

$$I_3(t) = -Q_S + \alpha(T - t) + \frac{\beta}{2}(T^2 - t^2) \tag{6}$$

Now using the condition $I_1(t_0) = I_2(t_0)$, we get the maximum inventory Q as:

$$Q = \alpha t_0 + \frac{\beta t_0^2}{2} + \left(\frac{\alpha}{\theta} + \frac{\beta}{\theta^2}\right)\left(e^{\theta(T_1 - t_0)} - 1\right) + \frac{\beta}{\theta}\left\{T_1 e^{\theta(T_1 - t_0)} - t_0\right\}$$

Now using the condition $I_2(T_1) = I_3(T_1)$, we get the maximum shortage quantity in the inventory is Q_S.

$$Q_S = \alpha(T - T_1) + \frac{\beta}{2}\left(T^2 - {T_1}^2\right)$$

Various costs are incurred to maintain an inventory of our model is given below:

Holding Cost (HC): The retailer has to hold the inventory during [0,T_1] where the cost incurred per unit item per unit time is (h) and it is given by HC.

$$HC = h\left(Qt_0 - \frac{\alpha t_0^2}{2} - \frac{\beta t_0^3}{6} + \left(\frac{\alpha}{\theta^2} + \frac{\beta}{\theta^3} + \frac{\beta T_1}{\theta^2}\right)\left(e^{\theta(T_1 - t_0)} - 1\right) - \left(\frac{\alpha}{\theta} + \frac{\beta}{\theta^2} + \frac{\beta}{\theta}\right)\left(T_1 - t_0 - \frac{{T_1}^2 - t_0^2}{2}\right)\right)$$

Deterioration Cost (DC): Since the life expectancy of any item is not infinite so it loses its perfect properties after sometime. Thus we have considered a non instantaneous deterioration rate and it occurs during [t_0, T_1].

$$DC = C_d\left(Q - \alpha T_1 - \frac{\beta {T_1}^2}{2}\right)$$

Shortage cost (SC): The cost gained due the lack of the item in the inventory during [T_1, T].

$$SC = C_S[Q_S(T - T_1) - \frac{\alpha}{2}(T - T_1)^2 - \frac{\beta}{6}\left(2T^3 - 3T^2T_1 + {T_1}^3\right)]$$

Set up cost (S): A cost required to set up the machinery and factory is considered here.

Total cost $TC = \frac{1}{T}(S + HC + DC + SC)$

$$TC = \frac{1}{T}\left\{S + h\left(Qt_0 - \frac{\alpha t_0^2}{2} - \frac{\beta t_0^3}{6} + \left(\frac{\alpha}{\theta^2} + \frac{\beta}{\theta^3} + \frac{\beta T_1}{\theta^2}\right)\left(e^{\theta(T_1 - t_0)} - 1\right) - \left(\frac{\alpha}{\theta} + \frac{\beta}{\theta^2} + \frac{\beta}{\theta}\right)\left(T_1 - t_0 - \frac{{T_1}^2 - t_0^2}{2}\right)\right) + C_S[Q_S(T - T_1) - \frac{\alpha}{2}(T - T_1)^2 - \frac{\beta}{6}\left(2T^3 - 3T^2T_1 + {T_1}^3\right)] + C_d\left(Q - \alpha T_1 - \frac{\beta {T_1}^2}{2}\right)\right\}$$

Now if we consider holding cost as TNN than the holding cost becomes $\widetilde{h_{neu}} = <(h_1 - \varepsilon_1, h_1, h_1 + \varepsilon_2 : \mu), (h_2 - \varepsilon_1, h_2, h_2 + \varepsilon_2 : \vartheta), (h_3 - \varepsilon_1, h_3, h_3 + \varepsilon_2 : \zeta)>$

Then by using removal area technique, the de- neutrosophic number of holding cost is

$\tilde{h} = ((h_1 + h_2 + h_3)/3) - ((\varepsilon_1 + \varepsilon_2)/4).$

Thus the total cost is $\widetilde{TC}$ by considering holding cost as TNN is

$$\widetilde{TC} = \frac{1}{T}\left\{S + \tilde{h}\left(Qt_0 - \frac{\alpha t_0^2}{2} - \frac{\beta t_0^3}{6} + \left(\frac{\alpha}{\theta^2} + \frac{\beta}{\theta^3} + \frac{\beta T_1}{\theta^2}\right)\left(e^{\theta(T_1 - t_0)} - 1\right) - \left(\frac{\alpha}{\theta} + \frac{\beta}{\theta^2} + \frac{\beta}{\theta}\right)\left(T_1 - t_0 - \frac{{T_1}^2 - t_0^2}{2}\right)\right) + C_d\left(Q - \alpha T_1 - \frac{\beta {T_1}^2}{2}\right) + C_S\left[Q_S(T - T_1) - \frac{\alpha}{2}(T - T_1)^2 - \frac{\beta}{6}\left(2T^3 - 3T^2T_1 + {T_1}^3\right)\right]\right\}$$

The main aim of this study is to obtain the optimum value of total cost with respect to the decision variable T_1, the maximum time to finish the inventory. The optimum value is obtained from the necessary condition $\frac{dTC}{dT_1} = 0$ and it satisfies the sufficient condition $\frac{d^2TC}{dT_1^2} > 0$. As the total cost is in complicated form so it is difficult to show the above necessary and sufficient condition analytically. Thus to validate our model we have taken a numerical example in the next section.

4.2 Numerical Examples:

Let us consider the value of the various parameters as $\alpha = 90;\ t_0 = 0.2;\ \beta = 2;\ S = 100;\ h = 4;\ \theta = 0.1; C_S = 20; C_d = 5; T = 2;$

Then the optimal solution in crisps model is $TC^* = 933.86;\ T_1^* = 1.078$ and that in triangular neutrosophic domain we get $TC^* = 911.55;\ T_1^* = 1.093$

Thus we observe from above as well as from figure 1 that if we consider holding cost neutrosophic domain then the optimal cost is minimum while that under crisps arena.

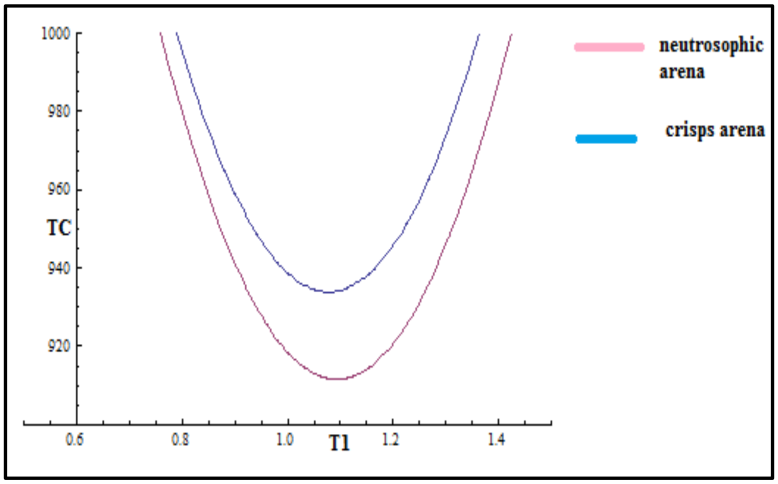

Figure 4.2.1: Behavior of TC in both the environment

5. Conclusion:

In this article, we mainly focused on the application portion of our developed TNN and its crispification technique. Thus to validate the de-neutrosophication technique we have considered an EOQ model for deteriorating item under shortages where the holding cost is considered as triangular neutrosophic number. It is observed that model gives better result in neutrosophic arena than under crisps arena. The total cost is less and the inventory remains for longer time under neutrosophic arena than under crisps arena.

Further, researchers can immensely apply this idea of neutrosophic number in numerous flourishing research fields like engineering problem, mobile computing problems, diagnoses problem, realistic mathematical modeling etc.

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