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Fuzzy Multi Item Inventory Model with Deterioration and Demand Dependent Production Cost Under Space Constraint: Neutrosophic Hesitant Fuzzy Programming Approach

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Abstract. In this paper, we have developed a multi-objective inventory model with constant demand rate, under the limitation on storage of space. Production cost is considered in demand dependent and the deterioration cost is considered in average inventory level dependent. Also inventory holding cost is dependent on time. Due to uncertainty, all cost parameters are taken as generalized trapezoidal fuzzy number. Our proposed model is solved by both neutrosophic hesitant fuzzy programing approach and fuzzy non-linear programming technique. Numerical example has been given to illustrate the model. Finally sensitivity analysis has been presented graphically.

Keywords: Inventory, Deterioration, Multi-item, Generalized trapezoidal fuzzy number, Neutrosophic Hesitant fuzzy programming approach.

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1. Introduction

An inventory model deal with decision that minimum the total average cost or maximum the total average profit. In that way to construct a real life mathematical inventory model on base on various assumptions and notations and approximation.

In ordinary inventory system inventory cost i.e set-up cost, holding cost, deterioration cost, etc. are taken fixed amount but in real life inventory system these cost not always fixed. So consideration of fuzzy variable is more realistic and interesting.

Inventory problem for deteriorating items have been widely studied, deterioration is defined as the spoilage, damage, dryness, vaporization etc., this result in decrease of usefulness of the commodity. Economic order quantity model was first introduced in February 1913 by Harris [1], afterwards many researchers developed EOQ model in inventory systems like as Singh, T., Mishra, P.J. and Pattanayak, H. [4], Jong Wuu Wu & Wen Chuan Lee [5] etc.

Deterioration of an item is the most important factor in the inventory systems. Ghare and Schrader [15], developed the inventory model by considering the constant demand rate and constant deterioration rate. Jong-Wuu Wu, Chinho Lin, Bertram Tan & Wen-Chuan Lee [6] developed an EOQ inventory model with time-varying demand and Weibull deterioration with shortages. Mishra, U. [13] presented a paper on an inventory model for Weibull deterioration with stock and price dependent demand. Jong Wuu Wu & Wen Chuan Lee [5] discussed an EOQ inventory model for items with Weibull deterioration, shortages and time varying demand. Singh, T., Mishra, P.J. and Pattanayak, H. [4] studied an EOQ inventory model for deteriorating items with time-dependent deterioration rate, ramp-type demand rate and shortages. Roy, T. K. & Maity, M, N. K. Mondal [14] discussedc inventory model of deteriorating items with a constraint: A geometric programming approach.

The concept of fuzzy set theory was first introduced by Zadeh, L.A. [16]. Afterward Zimmermann, H.J [17], [18] applied the fuzzy set theory concept with some useful membership functions to solve the linear programming problem with some objective functions. Then the various ordinary inventory model transformed to fuzzy versions model by various authors such as Roy, T. K. & Maity, M [2] presented on a fuzzy inventory model with constraints.

Also Smarandache, F. introduced the nutrosophic set. Smarandache, F [19] presented Neutrosophic Set, a generalization of the intuitionistic fuzzy set also discussed a geometric interpretation of the NS set a generalization of the intuitionistic fuzzy set. Multi-item and limitations of spaces is the important in the business world. Ye, J. [7] studied on multiple-attribute decision-making method under a single-valued neutrosophic hesitant fuzzy environment. Firoz Ahmad, Ahmad Yusuf Adhami, F. Smarandache [12] established single valued Neutrosophic Hesitant Fuzzy Computational Algorithm for multi objective nonlinear optimization problem. Islam, S. and Mandal, W. A. [10] considered a fuzzy inventory model with unit production cost, time depended holding cost, with-out shortages under a space constraint: a parametric geometric programming approach. B. Mondal, C. Kar, A. Garai, T. Kr. Roy [8, 25] studied on optimization of EOQ Model with Limited Storage Capacity by neutrosophic geometric programming. Mullai, M. and Surya, R. [22] developed neutrosophic EOQ model with price break. Mohana, K., Christy, V. and Smarandache, F. [24] discussed on multi-criteria decision making problem via bipolar single-valued neutrosophic. Nabeeh, N. A.; Abdel-Basset, M.; El-Ghareeb, H. A.; Aboelfetouh, A. Discussed neutrosophic multi-criteria decision making approach for iot-based enterprises. Biswas, P., Pramanik, S., Giri, B. C. [11] presented multi-attribute group decision making based on expected value of neutrosophic trapezoidal numbers. Pramanik, S., Mallick, R., Dasgupta, [9] discussed a Contributions of selected Indian researchers to multi attribute decision making in neutrosophic environment: an over view.

In this paper, we have considered the constant demand rate, under the restriction on storage area. Production cost is considered in demand dependent and the deterioration cost is considered in average inventory and also holding cost is time dependent. Due to uncertainty, all the required parameters are considered generalized trapezoidal fuzzy number. The formulated inventory problem has been solved by using FNLP and crisp and neutrosophic hesitant fuzzy programing approach. Finally numerical example has been given to illustrate the model.

2. Preliminaries

2.1 Definition of Fuzzy Set

Let X be a collection of objects called the universe of discourse. A fuzzy set is a subset of X denoted by $\tilde{A}$ and is defined by a set of ordered pairs $\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) : x \in X\}$. Here $\mu_{\tilde{A}}: X \to [0,1]$ is a function which is called the membership function of the fuzzy set $\tilde{A}$ and $\mu_{\tilde{A}}(x)$ is called the grade of membership of $x \in X$ in the fuzzy set $\tilde{A}$.

2.2 Union of two fuzzy sets

The union of $\tilde{A}$ and $\tilde{B}$ is fuzzy set in X, denoted by $\tilde{A} \cup \tilde{B}$, and defined by the membership function $\mu_{\tilde{A}\cup\tilde{B}}(x) = \mu_{\tilde{A}}(x) \vee \mu_{\tilde{B}}(x) = \max\{\mu_{\tilde{A}}(x), \mu_{\tilde{B}}(x)\}$ for each x ∈ X.

2.3 Intersection of two fuzzy sets

The intersection of two fuzzy sets $\tilde{A}$ and $\tilde{B}$ in X, denoted by $\tilde{A} \cap \tilde{B}$, and defined by the membership function $\mu_{\tilde{A}\cap\tilde{B}}(x) = \mu_{\tilde{A}}(x) \wedge \mu_{\tilde{B}}(x) = \min\{\mu_{\tilde{A}}(x),\ \mu_{\tilde{B}}(x)\}$ for each x ∈ X.

2.4 Generalized Trapezoidal Fuzzy Number (GTrFN)

A generalized trapezoidal fuzzy number (GTrFN) $\tilde{A}$ ≡(a,b,c,d; w) is a fuzzy set of the real line R whose membership function $\mu_{\tilde{A}}$ (x) : R → [0,w] is defined as

$$\mu_{\tilde{A}}(x) = \begin{cases} \mu^{w}_{LA}(x) = w\left(\frac{x-a}{b-a}\right) & \text{for } a \le x \le b \\ w & \text{for } b \le x \le c \\ \mu^{w}_{RA}(x) = w\left(\frac{d-x}{d-c}\right) & \text{for } c \le x \le d \\ 0 & \text{for otherwise} \end{cases}$$

where a < b < c < d and w ∈ (0, 1]. If w = 1, the generalized fuzzy number $\tilde{A}$ is called a trapezoidal fuzzy number (TrFN) denoted $\tilde{A}$ ≡(a, b, c, d).

2.5 Definition of Neutrosophic Set (NS)

Let X be a collection of objects called the universe of discourse. A neutrosophic set A in X is defined by

$$A = \{(x, T_A(x), I_A(x), F_A(x)) | x \in X\}$$

Here $T_A(x), I_A(x)$ *and* $F_A(x)$ are called truth, indeterminacy and falsity membership function respectively. This membership functions are defined by

$$T_A(x): X \to]0^-, 1^+[\ ,\ I_A(x): X \to]0^-, 1^+[,\ F_A(x): X \to]0^-, 1^+[\ \text{ so we have}$$

$$0^- \le sup T_A(x) + sup I_A(x) + sup F_A(x) \le 3^+$$

2.6 Definition of Single valued Neutrosophic Set (SVNS)

Let X be a collection of objects called the universe of discourse. A single valued neutrosophic set A in X is defined by $A = \{(x, T_A(x), I_A(x), F_A(x)) | x \in X\}$. Here $T_A(x): X \to [0,1]$, $I_A(x): X \to [0,1]$, $F_A(x): X \to [0,1]$ and $0 \le T_A(x) + I_A(x) + F_A(x) \le 3$ for all $x \in X$.

2.7 Hesitant Fuzzy Set (HFS)

Let X be a non-empty reference set, a hesitant fuzzy set A on X is defined in terms of a function $h_A(x)$ which is applied to X returns a finite subset of [0,1]. It's mathematical representation is

$$A = \{\langle x, h_A(x)\rangle | x \in X\}$$

Where $h_A(x)$ is a set of some different values in [0,1], representing the possible membership degree of the element $x \in X$ to A. the set $h_A(x)$ is called the hesitant fuzzy element (HFE).

Example 1: Let $X = \{x_1, x_2, x_3\}$ be a reference set, $h_A(x_1) = \{0.4,0.7,0.8\}$, $h_A(x_2) = \{0.7,0.5,0.6\}$, $h_A(x_3) = \{0.3,0.8,0.9,0.7\}$ be hesitant fuzzy element of x_1, x_2, x_3 respectively to a set A. Then hesitant fuzzy set A is $A = \{\langle x_1, \{0.4,0.7,0.8\}\rangle, \langle x_2, \{0.7,0.5,0.6\}\rangle, \langle x_3, \{0.3,0.8,0.9,0.7\}\rangle\}$.

2.8 Definition of Single valued Neutrosophic Hesitant Fuzzy Set (SVNHFS)

It is based on the combination of SVNS and HFS. Concept of SVNHFS is proposed by Ye [7].

Let X be a non-empty reference set, an single valued neutrosophic hesitant fuzzy set A on X is defined as

$$A = \{\langle x, \widetilde{T_A}(x), \widetilde{I_A}(x), \widetilde{F_A}(x)\rangle | x \in X\}$$

Where $\widetilde{T_A}(x) = \{\alpha | \alpha \in \widetilde{T_A}(x)\}$, $\widetilde{I_A}(x) = \{\beta | \beta \in \widetilde{I_A}(x)\}$ and $\widetilde{F_A}(x) = \{\gamma | \gamma \in \widetilde{F_A}(x)\}$ are three sets of some different values in [0,1], denoting the possible truth membership hesitant, indeterminacy membership hesitant and falsity membership hesitant degree of $x \in X$ to the set A respectively. This are satisfied the following conditions

$$\alpha, \beta, \gamma \subseteq [0,1] \text{ and } 0 \le sup\ \alpha^+ + sup\beta^+ + sup\gamma^+ \le 3$$

Where $\alpha^+ = \cup_{\alpha\in\widetilde{T_A}(x)} max\{\alpha\}$, $\beta^+ = \cup_{\beta\in\widetilde{I_A}(x)} max\{\beta\}$ and $\alpha^+ = \cup_{\gamma\in\widetilde{F_A}(x)} max\{\gamma\}$ for $x \in X$.

2.9 Union of two SVNS sets

Let X be a collection of objects called the universe of discourse and A and B are any two subsets of X. Here $T_A(x): X \to [0,1]$, $I_A(x): X \to [0,1]$, $F_A(x): X \to [0,1]$ are called truth, indeterminacy and falsity membership function of A respectively. The union of A and B denoted by $A \cup B$ and define by

$$A \cup B = \left\{ \left(x, max\left(T_A(x), T_B(x) \right), max\left(I_A(x), I_B(x) \right), min\left(F_A(x), F_B(x) \right) \right) \middle| x \in X \right\}$$

2.10 Intersection of two SVNS sets

Let X be a collection of objects called the universe of discourse and A and B are any two subsets of X. Here $T_A(x): X \to [0,1]$, $I_A(x): X \to [0,1]$, $F_A(x): X \to [0,1]$ are called truth, indeterminacy and falsity membership function of A respectively. The intersection of A and B denoted by $A \cap B$ and define by

$$A \cap B = \left\{ \left(x, min\left(T_A(x), T_B(x) \right), min\left(I_A(x), I_B(x) \right), max\left(F_A(x), F_B(x) \right) \right) \middle| x \in X \right\}$$

3. Mathematical model formulation for ith item

3.1 Notations

c_i: Ordering cost per order for ith item.
$H_i (= h_i t)$: Holding cost per unit per unit time for ith item.
θ_i: Constant deterioration rate for the ith item.
θ_c: Deterioration cost depend average inventory level.
T_i: The length of cycle time for i^{th}item, $T_i > 0$.
D_i : Demand rate per unit time for the ith item.
$I_i(t)$: Inventory level of the ith item at time t.
Q_i: The order quantity for the duration of a cycle of length T_i for ith item.
$TAC_i(T_i, D_i)$: Total average profit per unit for the ith item.
w_i: Storage space per unit time for the ith item.
W: Total area of space.
$\widetilde{c_i}$: Fuzzy ordering cost per order for the ith item.
$\widetilde{\theta_i}$: Fuzzy deterioration rate for the ith item.
$\widetilde{w_i}$: Fuzzy storage space per unit time for the ith item.
$\widetilde{H_i} (= \widetilde{h_i} t)$: Fuzzy holding cost per unit per unit time for the ith item.
$\widetilde{TAC_i}(T_i, D_i)$: Fuzzy total average cost per unit for the ith item.
$\widehat{c_i}$: Defuzzyfication of the fuzzy ordering cost per order for the ith item.
$\widehat{\theta_i}$: Defuzzyfication of the fuzzy deterioration rate for the ith item.
$\widehat{w_i}$: Defuzzyfication of the fuzzy storage space per unit time for the ith item.
$\widehat{H_i} (= \widehat{h_i} t)$: Defuzzyfication of the fuzzy holding cost per unit per unit time for the ith item.
$\widehat{TAC_i}$ (T_i, D_i): Defuzzyfication of the fuzzy total average cost per unit for the ith item.

3.2 Assumptions

1. The inventory system involves multi-item.

2. The replenishment occurs instantaneously at infinite rate.

3. The lead time is negligible.

4. Shortages are not allowed.

5. The unit production cost C_p^i of i^{th} item is inversely related to the demand rate D_i. So we take the following form $C_p^i(D_i) = \alpha_i {D_i}^{-\beta_i}$, where $\alpha_i > 0$ and $\beta_i > 1$ are constant real number.

6. The deterioration cost is proportionality related to the average inventory level. So we take the form

$\theta_c{}^i(Q) = \gamma_i \left(\frac{Q_i}{2}\right)^{\delta_i}$ where $0 < \gamma_i$ and $0 < \delta_i \ll 1$ are constant real number.

3.3 Model formation in scrip model

The inventory level for ith item is illustrated in Figure-1. During the period $[0, T_i]$ the inventory level reduces due to demand rate and deterioration rate for ith item. In this time period, the inventory level is described by the differential equation-

$$\frac{dI_i(t)}{dt} + \theta_i I_i(t) = -D, 0 \le t \le T_i \quad (1)$$

With boundary condition, $I_i(0) = Q_i$, $I_i(T_i) = 0$.

Solving (1) we have,

$$I_i(t) = \frac{D_i}{\theta_i}\left[e^{\theta_i(T_i - t)} - 1\right] \quad (2)$$

$$Q_i = \frac{D_i}{\theta_i}\left(e^{\theta_i T_i} - 1\right) \quad (3)$$

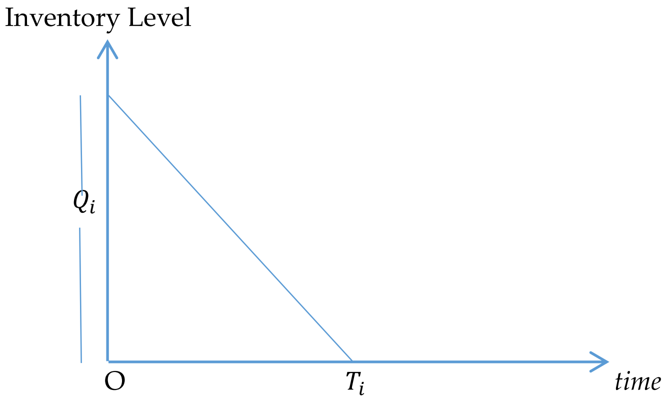

Figure-1 (Inventory level for the ith item.)

Now calculating various cost for ith item

i) Production cost $(PC_i) = \frac{Q_i C_p^i(D_i)}{T_i}$

$$= \frac{D_i^{(1-\beta_i)}\alpha_i}{\theta_i T_i}\left(e^{\theta_i T_i} - 1\right)$$

ii) Inventory holding cost $(HC_i) = \frac{1}{T_i}\int_0^{T_i} h_i t I_i(t)dt$

$$= \frac{D_i h_i}{\theta_i T_i}\left\{-\frac{T_i}{\theta_i} + \frac{1}{\theta_i^2}\left(e^{\theta_i T_i} - 1\right) - \frac{T_i^2}{2}\right\}$$

iv) Deterioration cost $(DC_i) = \theta_i \gamma_i \left(\frac{Q_i}{2}\right)^{\delta_i}$

$$= \theta_i \gamma_i \left(\frac{D_i}{2\theta_i}\left(e^{\theta_i T_i} - 1\right)\right)^{\delta_i}$$

v) Ordering cost $(OC_i) = \frac{c_i}{T_i}$

Total average cost per unit time for ith item

$$TAC_i(T_i, D_i) = (PC_i + HC_i + DC_i + OC_i)$$

$$= \frac{D_i^{(1-\beta_i)}\alpha_i}{\theta_i T_i}\left(e^{\theta_i T_i}-1\right)+\frac{D_i h_i}{\theta_i T_i}\left\{-\frac{T_i}{\theta_i}+\frac{1}{\theta_i^2}\left(e^{\theta_i T_i}-1\right)-\frac{T_i^2}{2}\right\}+\theta_i\gamma_i\left(\frac{D_i}{2\theta_i}\left(e^{\theta_i T_i}-1\right)\right)^{\delta_i}+\frac{c_i}{T_i} \quad (4)$$

A multi-item inventory model (MIIM) can be written as:

Min

$$TAC_i(T_i, D_i) = \frac{D_i^{(1-\beta_i)}\alpha_i}{\theta_i T_i}\left(e^{\theta_i T_i}-1\right)+\frac{D_i h_i}{\theta_i T_i}\left\{-\frac{T_i}{\theta_i}+\frac{1}{\theta_i^2}\left(e^{\theta_i T_i}-1\right)-\frac{T_i^2}{2}\right\}+\theta_i\gamma_i\left(\frac{D_i}{2\theta_i}\left(e^{\theta_i T_i}-1\right)\right)^{\delta_i}+\frac{c_i}{T_i}$$

Subject to, $\sum_{i=1}^{n} w_i \frac{D_i}{\theta_i}\left(e^{\theta_i T_i}-1\right) \leq W$, for $i = 1,2, \dots\dots\dots . . n$. (5)

4. Fuzzy Model

Generally the parameters for holding cost, unit production cost, and storage spaces, deterioration are not particularly known to us. Due to uncertainty, we assume all the parameters $(\alpha_i, \beta_i, \theta_i, h_i, \gamma_i, \delta_i, c_i)$ and storage space w_i as generalized trapezoidal fuzzy number (GTrFN)$(\widetilde{\alpha_i}, \widetilde{\beta_i}, \widetilde{\theta_i}, \widetilde{h_i}, \widetilde{\gamma_i}, \widetilde{\delta_i}, \widetilde{c_i}\widetilde{w_i})$. Let us assume,

$\widetilde{\alpha_i} = (\alpha_i^1, \alpha_i^2, \alpha_i^3, \alpha_i^4; \omega_{\alpha_i}), 0 < \omega_{\alpha_i} \leq 1; \widetilde{\theta_i} = (\theta_i^1, \theta_i^2, \theta_i^3, \theta_i^4; \omega_{\theta_i}), 0 < \omega_{\theta_i} \leq 1;$

$\widetilde{\beta_i} = (\beta_i^1, \beta_i^2, \beta_i^3, \beta_i^4; \omega_{\beta_i}), 0 < \omega_{\beta_i} \leq 1; \widetilde{h_i} = (h_i^1, h_i^2, h_i^3, h_i^4; \omega_{h_i}), 0 < \omega_{h_i} \leq 1;$

$\widetilde{\gamma_i} = (\gamma_i^1, \gamma_i^2, \gamma_i^3, \gamma_i^4; \omega_{\gamma_i}), 0 < \omega_{\gamma_i} \leq 1; \widetilde{w_i} = (w_i^1, w_i^2, w_i^3, w_i^4; \omega_{w_i}), 0 < \omega_{w_i} \leq 1;$

$\widetilde{\delta_i} = (\delta_i^1, \delta_i^2, \delta_i^3, \delta_i^4; \omega_{\delta_i}), 0 < \omega_{\delta_i} \leq 1; \widetilde{c_i} = (c_i^1, c_i^2, c_i^3, c_i^4; \omega_{c_i}), 0 < \omega_{c_i} \leq 1; (i = 1,2, \dots\dots\dots, n).$

Then the above crisp inventory model (5) becomes the fuzzy model as

$$\text{Min } \widetilde{TAC_i}(T_i, D_i) = \frac{D_i^{(1-\widetilde{\beta_i})}\widetilde{\alpha_i}}{\widetilde{\theta_i} T_i}\left(e^{\widetilde{\theta_i} T_i}-1\right)+\frac{D_i \widetilde{h_i}}{\widetilde{\theta_i} T_i}\left\{-\frac{T_i}{\widetilde{\theta_i}}+\frac{1}{\widetilde{\theta_i}^2}\left(e^{\widetilde{\theta_i} T_i}-1\right)-\frac{T_i^2}{2}\right\}+\widetilde{\theta_i}\widetilde{\gamma_i}\left(\frac{D_i}{2\widetilde{\theta_i}}\left(e^{\widetilde{\theta_i} T_i}-1\right)\right)^{\widetilde{\delta_i}}+\frac{\widetilde{c_i}}{T_i}$$

Subject to, $\sum_{i=1}^{n} \widetilde{w_i} \frac{D_i}{\widetilde{\theta_i}}\left(e^{\widetilde{\theta_i} T_i}-1\right) \leq W$, for $i = 1,2, \dots\dots\dots . . n$. (6)

In defuzzification of fuzzy number technique, if we consider a GTrFN $\tilde{A} = (a, b, c, d; \omega)$, then the total λ- integer value of $\tilde{A} = (a, b, c, d; \omega)$ is

$$I_\lambda^w(\tilde{A}) = \lambda\omega\frac{c+d}{2} + (1-\lambda)\omega\frac{a+b}{2}$$

Taking $= 0.5$, therefore we get approximated value of a GTrFN $\tilde{A} = (a, b, c, d; \omega)$ is $\omega\left(\frac{a+b+c+d}{4}\right)$.

So using approximated value of GTrFN, we have the approximated values $(\widehat{\alpha_i}, \widehat{\beta_i}, \widehat{\theta_i}, \widehat{h_i}, \widehat{\gamma_i}, \widehat{\delta_i}, \widehat{c_i}, \widehat{w_i})$ of the GTrFN parameters $(\widetilde{\alpha_i}, \widetilde{\beta_i}, \widetilde{\theta_i}, \widetilde{h_i}, \widetilde{\gamma_i}, \widetilde{\delta_i}, \widetilde{c_i}, \widetilde{w_i})$. So the above model (6) reduces to

$$\text{Min } \widehat{TAC_i}(T_i, D_i) = \frac{D_i^{(1-\widehat{\beta_i})}\widehat{\alpha_i}}{\widehat{\theta_i} T_i}\left(e^{\widehat{\theta_i} T_i}-1\right)+\frac{D_i \widehat{h_i}}{\widehat{\theta_i} T_i}\left\{-\frac{T_i}{\widehat{\theta_i}}+\frac{1}{\widehat{\theta_i}^2}\left(e^{\widehat{\theta_i} T_i}-1\right)-\frac{T_i^2}{2}\right\}+\widehat{\theta_i}\widehat{\gamma_i}\left(\frac{D_i}{2\widehat{\theta_i}}\left(e^{\widehat{\theta_i} T_i}-1\right)\right)^{\widehat{\delta_i}}+\frac{\widehat{c_i}}{T_i}$$

Subject to, $\sum_{i=1}^{n} \widehat{w_i} \frac{D_i}{\widehat{\theta_i}}\left(e^{\widehat{\theta_i} T_i}-1\right) \leq W$, for $i = 1,2, \dots\dots\dots . . n$. (7)

5. Neutrosophic hesitant fuzzy programming technique to solve multi item inventory model (MIIM). (That is NHFNP method)

Solve the MIIM (7) as a single objective NLP using only one objective at a time and we ignoring the others. So we get the ideal solutions.

From the above results, we find out the corresponding values of every objective function at each solution obtained. With these values the pay-off matrix can be prepared as follows:

$$\begin{array}{c} \\ (T_1{}^1, D_1^1) \\ (T_2{}^2, D_2^2) \\ \\ \\ (T_n{}^n, D_n^n) \end{array} \begin{array}{cccc} TAC_1(T_1, D_1) & TAC_2(T_2, D_2) & \ldots & TAC_n(T_n, D_n) \\ \left(\begin{array}{c} TAC_1{}^*(T_1{}^1, D_1^1) \\ TAC_1(T_2{}^2, D_2^2) \\ \ldots \\ \ldots \\ TAC_1(T_n{}^n, D_n^n) \end{array}\right. & \begin{array}{c} TAC_2(T_1{}^1, D_1^1) \\ TAC_2{}^*(T_2{}^2, D_2^2) \\ \ldots \\ \ldots \\ TAC_2(T_n{}^n, D_n^n) \end{array} & \begin{array}{c} \ldots \\ \ldots \\ \ldots \\ \ldots \\ \ldots \end{array} & \left.\begin{array}{c} TAC_n(T_1{}^1, D_1^1) \\ TAC_n(T_2{}^2, D_2^2) \\ \ldots \\ \ldots \\ TAC_n{}^*(T_n{}^n, D_n^n) \end{array}\right) \end{array}$$

Let $U^k = \max\{TAC_k(T_i{}^i, D_i^i), i = 1,2, \ldots, n\}$ for $k = 1,2, \ldots, n$

and $L^k = TAC_k{}^*(T_k{}^k, D_k^k),\ k = 1,2, \ldots, n.$

There $L^k \le TAP_k(T_i{}^i, D_i^i) \le U^k$, for $i = 1,2, \ldots, n\,; k = 1,2, \ldots, n.$ (8)

Now we define the different hesitant membership function more elaborately under neutrosophic hesitant fuzzy environment as follows

The truth hesitant- membership function:

$$T_{\bar{h}}^{E_1}(TAC_k(T_k, D_k)) = \begin{cases} 1 & \text{if } TAC_k(T_k, D_k) < L^k \\ \sigma_1 \dfrac{(U^k)^t - (TAC_k(T_k, D_k))^t}{(U^k)^t - (L^k)^t} & \text{if } L^k \le TAC_k(T_k, D_k) \le U^k \\ 0 & \text{if } U^k < TAC_k(T_k, D_k) \end{cases}$$

$$T_{\bar{h}}^{E_2}(TAC_k(T_k, D_k)) = \begin{cases} 1 & \text{if } TAC_k(T_k, D_k) < L^k \\ \sigma_2 \dfrac{(U^k)^t - (TAC_k(T_k, D_k))^t}{(U^k)^t - (L^k)^t} & \text{if } L^k \le TAC_k(T_k, D_k) \le U^k \\ 0 & \text{if } U^k < TAC_k(T_k, D_k) \end{cases}$$

$$T_{\bar{h}}^{E_n}(TAC_k(T_k, D_k)) = \begin{cases} 1 & \text{if } TAC_k(T_k, D_k) < L^k \\ \sigma_n \dfrac{(U^k)^t - (TAC_k(T_k, D_k))^t}{(U^k)^t - (L^k)^t} & \text{if } L^k \le TAC_k(T_k, D_k) \le U^k \\ 0 & \text{if } U^k < TAC_k(T_k, D_k) \end{cases}$$

The indeterminacy hesitant- membership function:

$$I_{\bar{h}}^{E_1}(TAC_k(T_k, D_k)) = \begin{cases} 1 & \text{if } TAC_k(T_k, D_k) < L^k - s^k \\ \rho_1 \dfrac{(U^k)^t - (TAC_k(T_k, D_k))^t}{(s^k)^t} & \text{if } U^k - s^k \le TAC_k(T_k, D_k) \le U^k \\ 0 & \text{if } U^k < TAC_k(T_k, D_k) \end{cases}$$

$$I_{\bar{h}}^{E_2}(TAC_k(T_k, D_k)) = \begin{cases} 1 & \text{if } TAC_k(T_k, D_k) < L^k - s^k \\ \rho_2 \dfrac{(U^k)^t - (TAC_k(T_k, D_k))^t}{(s^k)^t} & \text{if } U^k - s^k \le TAC_k(T_k, D_k) \le U^k \\ 0 & \text{if } U^k < TAC_k(T_k, D_k) \end{cases}$$

$$I_{h^-}^{E_n}\big(TAC_k(T_k,D_k)\big)=\begin{cases}1 & if\ TAC_k(T_k,D_k)<L^k-s^k\\ \rho_n\dfrac{(U^k)^t-\big(TAC_k(T_k,D_k)\big)^t}{(s^k)^t} & if\ U^k-s^k\le TAC_k(T_k,D_k)\le U^k\\ 0 & if\ U^k<TAC_k(T_k,D_k)\end{cases}$$

The falsity hesitant- membership function:

$$F_{h^-}^{E_1}\big(TAC_k(T_k,D_k)\big)=\begin{cases}0 & if\ TAC_k(T_k,D_k)<L^k+v^k\\ \tau_1\dfrac{\big(TAC_k(T_k,D_k)\big)^t-(L^k)^t-(v^k)^t}{(U^k)^t-(L^k)^t-(v^k)^t} & if\ L^k+v^k\le TAC_k(T_k,D_k)\le U^k\\ 1 & if\ U^k<TAC_k(T_k,D_k)\end{cases}$$

$$F_{h^-}^{E_2}\big(TAC_k(T_k,D_k)\big)=\begin{cases}0 & if\ TAC_k(T_k,D_k)<L^k+v^k\\ \tau_2\dfrac{\big(TAC_k(T_k,D_k)\big)^t-(L^k)^t-(v^k)^t}{(U^k)^t-(L^k)^t-(v^k)^t} & if\ L^k+v^k\le TAC_k(T_k,D_k)\le U^k\\ 1 & if\ U^k<TAC_k(T_k,D_k)\end{cases}$$

$$F_{h^-}^{E_n}\big(TAC_k(T_k,D_k)\big)=\begin{cases}0 & if\ TAC_k(T_k,D_k)<L^k+v^k\\ \tau_1\dfrac{\big(TAC_k(T_k,D_k)\big)^t-(L^k)^t-(v^k)^t}{(U^k)^t-(L^k)^t-(v^k)^t} & if\ L^k+v^k\le TAC_k(T_k,D_k)\le U^k\\ 1 & if\ U^k<TAC_k(T_k,D_k)\end{cases}$$

Where parameter $t>0$ and $s^k, v^k \epsilon (0,1)\ \forall\ k=1,2,3,\dots\dots,n$ are indeterminacy and falsity tolerance values, which are assigned by decision making and h^- represent the minimization type hesitant objective function.

$T_{h^-}^{E_1}\big(TAC_k(T_k,D_k)\big)$, $I_{h^-}^{E_1}\big(TAC_k(T_k,D_k)\big)$, $F_{h^-}^{E_1}\big(TAC_k(T_k,D_k)\big)$ are truth, indeterminacy and falsity hesitant membership degrees assigned by 1st expert.

$T_{h^-}^{E_2}\big(TAC_k(T_k,D_k)\big)$, $I_{h^-}^{E_2}\big(TAC_k(T_k,D_k)\big)$, $F_{h^-}^{E_2}\big(TAC_k(T_k,D_k)\big)$ are truth, indeterminacy and falsity hesitant membership degrees assigned by 2nd expert.

$T_{h^-}^{E_n}\big(TAC_k(T_k,D_k)\big)$, $I_{h^-}^{E_n}\big(TAC_k(T_k,D_k)\big)$, $F_{h^-}^{E_n}\big(TAC_k(T_k,D_k)\big)$ are truth, indeterminacy and falsity hesitant membership degrees assigned by nth expert.

Using the above membership function, the multi-item nonlinear inventory problem formulated as follows

Max $\frac{\sum_1^n \sigma_i}{n}$

Max $\frac{\sum_1^n \rho_i}{n}$

Min $\frac{\sum_1^n \tau_i}{n}$

Subject to

$$T_{h^-}^{E_i}\big(TAC_k(T_k, D_k)\big) \geq \sigma_i, I_{h^-}^{E_i}\big(TAC_k(T_k, D_k)\big) \geq \rho_i, F_{h^-}^{E_i}\big(TAC_k(T_k, D_k)\big) \leq \tau_i$$

$$\sum_{i=1}^n w_i \frac{D_i}{\theta_i}\left(e^{\theta_i T_i} - 1\right) \leq W, \sigma_i + \rho_i + \tau_i \leq 3, \sigma_i \geq \rho_i, \sigma_i \geq \tau_i, \forall\, i = 1,2,3, \ldots., n \qquad (9)$$

Using above linear membership function, we can written as

Max $\frac{\sigma_1+\sigma_2+ \ldots\ldots+\sigma_n}{n} + \frac{\rho_1+\rho_2+ \ldots\ldots\ldots+\rho_n}{n} - \frac{\tau_1+\tau_2+ \ldots\ldots\ldots+\tau_n}{n}$

Subject to

$T_{h^-}^{E_i}\big(TAC_k(T_k, D_k)\big) \geq \sigma_i, I_{h^-}^{E_i}\big(TAC_k(T_k, D_k)\big) \geq \rho_i, F_{h^-}^{E_i}\big(TAC_k(T_k, D_k)\big) \leq \tau_i$

$\sum_{i=1}^n w_i \frac{D_i}{\theta_i}\left(e^{\theta_i T_i} - 1\right) \leq W, \sigma_i + \rho_i + \tau_i \leq 3, \sigma_i \geq \rho_i, \sigma_i \geq \tau_i, \forall\, i = 1,2,3, \ldots., n$,

$0 \leq \sigma_1, \sigma_2, \ldots\ldots, \sigma_n \leq 1, 0 \leq \rho_1, \rho_2, \ldots\ldots\ldots.., \rho_n \leq 1, 0 \leq \tau_1, \tau_2, \ldots\ldots\ldots, \tau_n \leq 1, T_k \geq 0, D_k \geq 0$ (10)

Above gives the solution D_i^* , T_i^* and then TAC_i^* for $i = 1,2,3, \ldots., n$.

6. Algorithm to solve MIIM in Neutrosophic hesitant fuzzy programming technique

Following steps have been used to solve MIIM in neutrosophic hesitant fuzzy programming Technique.

Step-1: Solve only one objective at time and ignoring the others and using the all restrictions. These solutions are known as ideal solution.

Step-2: Form pay-off matrix using the step-1.

Step-3: Determine U^k and L^k. (U^k and L^k are the upper and lower bounds of the k-th item respectively)

Step-4: Using U^k and L^k define all hesitant membership function, i.e truth hesitant membership function $T_{h^-}^{E_i}(TAC_k)$, Indeterminacy hesitant membership function $I_{h^-}^{E_i}(TAC_k)$, Falsity hesitant membership function $F_{h^-}^{E_i}(TAC_k)$, $i = 1,2,3, \ldots., n$, $k = 1,2,3, \ldots., n$

Step-5: Ask for the truth hesitant, Indeterminacy hesitant and falsity hesitant membership degrees from different experts E_i, $i = 1,2,3, \ldots., n$.

Step-6: Formulate multi-objective non-linear programming problem under neutrosophic hesitant fuzzy system.

Step-7: Solve multi-objective non-linear programming problem using suitable technique or optimization software package.

7. Fuzzy programming technique (Multi-Objective on max-min operators) to solve MIIM. (That is FNLP method)

Firstly derive (8) and then we use following way for solving the problem (7)

Now objective functions of the problem (7) are considered as fuzzy constraints. Therefore fuzzy linear membership function $\mu_{TAC_k}\big(TAC_k(T_k, D_k)\big)$ for the k[th] objective function $TAC_k(T_k, D_k)$ is defined as follows:

$$\mu_{TAC_k}\big(TAC_k(T_k, D_k)\big) = \begin{cases} 1 & for\ TAC_k(T_k, D_k) < L^k \\ \dfrac{U^k - TAC_k\big(T_{k,}D_k\big)}{U^k - L^k} & for\ L^k \le TAC_k(T_k, D_k) \le U^k \\ 0 & for\ \ TAC_k(T_k, D_k) > U^k \end{cases}$$

for $k = 1,2, \dots, n$.

Using the above membership function, fuzzy non-linear programming problem is formulated as follows:

$Max\ \alpha$

Subject to

$\alpha\ (U^k - L^k) + TAC_k(T_k, D_k) \le U^k$

$0 \le \alpha \le 1,\ T_k \ge 0, D_k \ge 0$ for $k = 1,2, \dots, n$ (11)

And same constraints and restrictions of the problem (7).

This problem (11) can be solved easily and we shall get the optimal solution of (7).

8. Numerical Example

Let us consider an inventory model which consist two items with following parameter values in proper units. Total storage area $W = 900m^2$.

Table-1

Input imprecise data for shape parameters

Parameters	Item	
	I	II
$\widetilde{\alpha_\iota}$	(10000,12000,11000,13000; 0.7)	(20000,22000,25000,30000; 0.8)
$\widetilde{\theta_\iota}$	(0.02,0.05,0.09,0.07; 0.9)	(0.02,0.05,0.09,0.07; 0.9)
$\widetilde{\beta_\iota}$	(30,40,60,70; 0.8)	(50,70,80,90; 0.9)
$\widetilde{h_\iota}$	(0.6,0.8,0.9,0.5; 0.9)	(0.4,0.6,0.9,0.7; 0.7)
$\widetilde{\gamma_\iota}$	(8000,10000,12000,15000; 0.9)	(10000,13000,15000,18000; 0.9)
$\widetilde{\delta_\iota}$	(0.04,0.06,0.08,0.07; 0.8)	((0.04,0.06,0.08,0.07; 0.8))
$\widetilde{c_\iota}$	(100,150,200,210; 0.7)	(150,180,190,200; 0.9)
$\widetilde{w_\iota}$	(10,11,12,13; 0.9)	(20,21,24,23; 0.8)

The problem (7) reduces to the following:

$$\text{Min } TAC_1(T_1, D_1) = \frac{{D_1}^{-39}8050}{0.05.T_1}(e^{0.05.T_1} - 1) + \frac{D_1.0.63}{0.05.T_1}\left\{-\frac{T_1}{0.05} + \frac{1}{0.05^2}(e^{0.05.T_1} - 1) - \frac{{T_1}^2}{2}\right\} + 393.75\left(\frac{D_1}{0.1}(e^{0.05.T_1} - 1)\right)^{0.05} + \frac{115.50}{T_1}$$

$$\text{Min } TAC_2(T_2, D_2) = \frac{{D_2}^{-64.25}19400}{0.05.T_2}(e^{0.05.T_2} - 1) + \frac{D_2 0.46}{0.05.T_2}\left\{-\frac{T_2}{0.05} + \frac{1}{0.05^2}(e^{0.05.T_2} - 1) - \frac{{T_2}^2}{2}\right\} + 630\left(\frac{D_2}{0.1}(e^{0.05.T_2} - 1)\right)^{0.05} + \frac{162}{T_2}$$

Subject to, $210(e^{0.05 T_1}-1)D_1+352(e^{0.05 T_2}-1)D_2 \leq 900$, T_1, D_1, T_2, D_2 are positive. (12)

Table –2

Optimal solutions of MIIM (12) using different methods

Methods	$D_1{}^*$	$T_1{}^*$	$TAC_1{}^*$	$D_2{}^*$	$T_2{}^*$	$TAC_2{}^*$
CRISP	1.28	4.12	446.51	1.18	4.07	703.52
FNLP	1.28	4.07	446.52	1.18	4.07	703.52
NHFNP	1.28	4.06	446.52	1.18	4.07	703.52

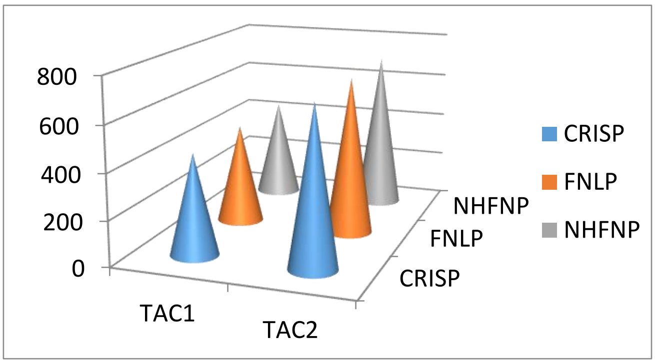

Figure 2. Minimizing cost of 1st and 2nd item using different methods

From the above Figure 2 shows that CRISP, FNLP and NHFNP method gives the almost same result of MIIM.

9. Sensitivity Analysis

The optimal solutions of the MIIM (7) by CRISP, FNLP and NHFNP techniques for different values of θ, h are given in Tables-3 and 4 respectively.

Table – 3

Optimal solutions of MIIM (7) by CRISP, FNLP and NHFNP for different values of θ

Methods	θ	$D_1{}^*$	$T_1{}^*$	$TAC_1{}^*$	$D_2{}^*$	$T_2{}^*$	$TAC_2{}^*$
CRISP	0.05	1.28	4.12	446.51	1.18	4.07	703.52
	0.10	1.26	2.43	858.92	1.17	2.23	1358.15
	0.15	1.25	1.69	1262.44	1.16	1.52	1997.44
	0.20	1.24	1.29	1659.65	1.16	1.16	2626.53
FNLP	0.05	1.28	4.07	446.52	1.18	4.07	703.52
	0.10	1.26	2.42	858.92	1.18	2.19	1358.34
	0.15	1.25	1.69	1262.44	1.16	1.52	1997.44
	0.20	1.24	1.31	1659.45	1.16	1.15	2626.50
NHFNP	0.05	1.28	4.06	446.52	1.18	4.07	703.52
	0.10	1.26	2.43	858.92	1.18	2.21	1358.34
	0.15	1.25	1.68	1262.42	1.16	1.53	1997.45
	0.20	1.24	1.29	1659.65	1.17	1.16	2626.52

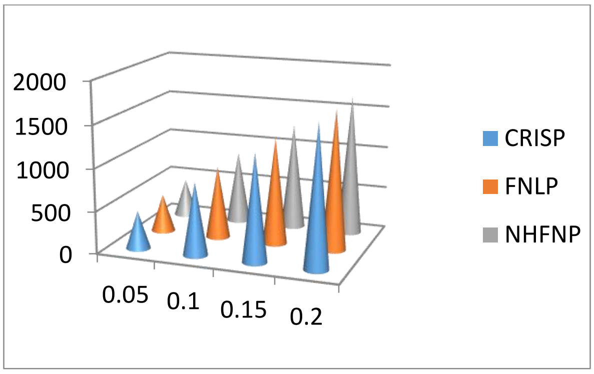

Figure 3. total average cost (TAC_1) of 1st item using different methods for different values of θ.

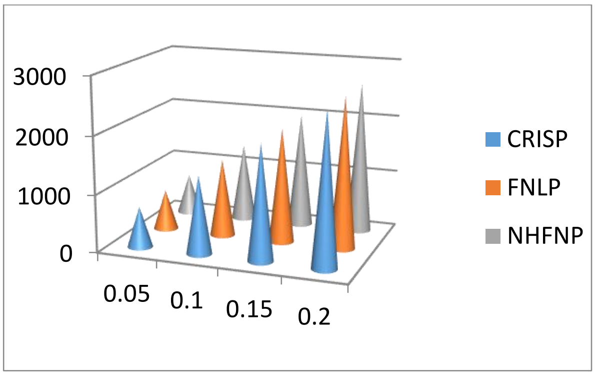

Figure 4. total average cost (TAC_2) of 2nd item using different methods for different values of θ.

From the above Figure 3 and Figure 4 shows that for all different methods when θ is increased then minimum cost of both items are increased

Table – 4

Optimal solution of MIIM (7) by CRISP, FNLP and NHFNP for different values of h_1 and h_2.

Methods	h_1	h_2	$D_1{}^*$	$T_1{}^*$	$TAC_1{}^*$	$D_2{}^*$	$T_2{}^*$	$TAC_2{}^*$
CRISP	0.63	0.46	1.28	4.12	446.51	1.18	4.07	703.52
	1.13	0.96	1.28	3.81	448.26	1.18	3.83	705.13
	1.63	1.46	1.28	3.59	449.79	1.18	3.66	706.57
	2.13	1.96	1.28	3.42	451.15	1.18	3.52	707.89
FNLP	0.63	0.46	1.28	4.07	446.52	1.18	4.07	703.52
	1.13	0.96	1.28	3.81	448.26	1.18	3.80	705.13
	1.63	1.46	1.28	3.65	449.80	1.18	3.67	706.57
	2.13	1.96	1.28	3.43	451.17	1.18	3.50	707.92
NHFNP	0.63	0.46	1.28	4.06	446.52	1.18	4.07	703.52
	1.13	0.96	1.27	3.80	448.30	1.18	3.78	705.33
	1.63	1.46	1.28	3.65	449.80	1.18	3.67	706.57
	2.13	1.96	1.28	3.42	451.19	1.18	3.49	707.91

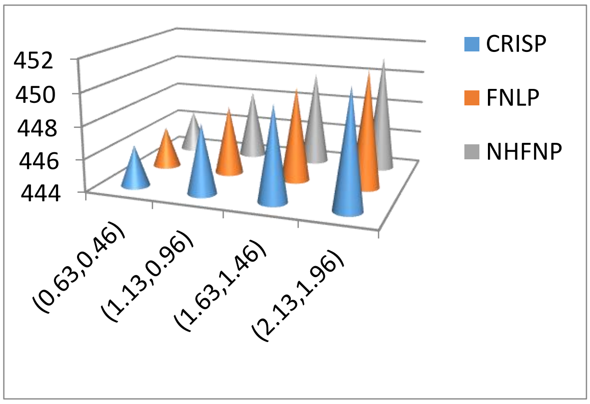

Figure 5. total average cost (TAC_1) of 1st item using different methods for different values of h_1 and h_2

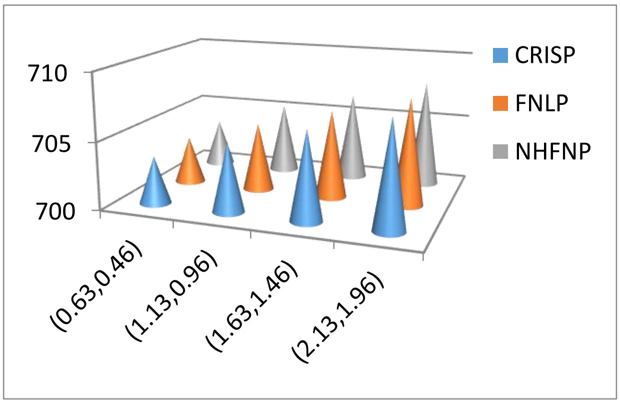

Figure-6. total average cost (TAC_2) of 2nd item using different methods for different values of h_1 and h_2

From the above Figure 5 and Figure 6 shows that all different methods, when h_1 and h_2 are continuously increasing then minimum cost of both items are continuously increasing.

10. Conclusions

Here we have considered the constant demand rate, under the restriction on storage area. Production cost is considered in demand dependent and the deterioration cost is considered in average inventory also holding cost is time dependent. The model have been formulated using multi-items. Due to uncertainty all the required parameters are taken as generalized trapezoidal fuzzy number. Multi-objective inventory model is solved by using neutrosophic hesitant fuzzy programing approach and fuzzy non-linear programming technique.

In the future study, it is hoped to further incorporate the proposed model into more realistic assumptions, such as probabilistic demand, ramp type demand, power demand, shortages, under two-level credit period strategy etc. Also inflation can be used to develope the model. Other type of fuzzy numbers like as triangular fuzzy number, Parabolic Flat Fuzzy Number (PfFN), Pentagonal Fuzzy Number etc. may be used for all cost parameters of the model to form the fuzzy model. Generalised single valued neutrosophic Number and its application can be used in this model.

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References

1. Harris, F. W. How many parts to make at once factory. *Mag Mannage.* 1913, 10(2), 135-136.
2. Roy, T.K.; Maity, M. A fuzzy inventory model with constraints. *Operation research.* 1995, 32(4), 287-298.
3. Pramanik, S. Neutrosophic multi-objective linear programming, *Global Journal of Engineering Science and Research Management*, 2016, 3(8), 36-46.
4. Singh, T.; Mishra, P.J.; Pattanayak, H. An EOQ inventory model for deteriorating items with time-dependent deterioration rate, ramp-type demand rate and shortages. *Int. J. Mathematics in Operational Research*. 2018, 12(4), 423- 437.
5. Jong Wuu Wu ; Wen Chuan Lee. An EOQ inventory model for items with Weibull deterioration, shortages and time varying demand. *Journal of Information and Optimization Sciences*, 2003, 24:1, 103-122.
6. Jong-Wuu Wu; Chinho Lin; Bertram Tan; Wen-Chuan Lee. An EOQ inventory model with time-varying demand and Weibull deterioration with shortages. *International Journal of Systems Science*, 2000, 31(6), 677-683.
7. Ye, J. Multiple-attribute decision-making method under a single-valued neutrosophic hesitant fuzzy environment. *J. Intell. Syst*. 2014, 24, 23–36
8. Mondal, B.; Kar, C.; Garai, A.; Roy, T.K. Optimization of EOQ Model with Limited Storage Capacity by Neutrosophic Geometric Programming, *Neutrosophic Sets and Systems*, 2018, 22, 5-29.
9. Pramanik, S.; Mallick, R.; Dasgupta, A. Contributions of selected indian researchers to multi attribute decision making in neutrosophic environment: an over view. *Neutrosophic Sets and Systems*, 2018, 20, 108-131.
10. Islam, S.; Mandal, W. A. A Fuzzy Inventory Model with Unit Production Cost, Time Depended Holding Cost, with-out Shortages under A Space Constraint: A Parametric Geometric Programming Approach. *The Journal of Fuzzy Mathematics*, 2017, 25(3), 517-532.
11. Biswas, P.; Pramanik, S.; Giri, B. C. Multi-attribute group decision making based on expected value of neutrosophic trapezoidal numbers, New Trends in Neutrosophic Theory and Application, *Pons Editions, Brussells*, 2018, II, 103-124.
12. Ahmad, F.; Adhami, A.Y.; Smarandache, F. Single Valued Neutrosophic Hesitant Fuzzy Computational Algorithm for Multi objective Nonlinear Optimization Problem, *Neutrosophic Sets and Systems*, 2018, 22, 76-86.
13. Mishra, U., An Inventory Model for Weibull Deterioration with Stock and Price Dependent Demand, *Int. J. Appl. Comput. Math*, 2017, 3, 1951-1967.
14. Roy, T. K.; Maity, M.; Mondal, N. K. Inventory model of deteriorating items with a constraint: A geometric programming approach, *European Journal of Operational Research*, 2006, 173, 199–210.
15. Ghare, P.N.; Schrader, G.F. A model for exponentially decaying inventories, *The Journal of Industrial Engineering*, 1963, 15(5), 238–243.
16. Zadeh, L.A. Fuzzy sets, *Information and Control*, 1965, 8, 338-353.

17. Zimmermann, H.J. Application of fuzzy set theory to mathematical programming, *Information Science,* 1985, 36, 29-58.
18. Zimmermann, H. J. Methods and applications of Fuzzy Mathematical programming, in an introduction to Fuzzy Logic Application in Intelligent Systems. *Kluwer publishers, Boston,* 1992, 97- 120.
19. Smarandache, F. Neutrosophic Set, A Generalization of the Intuitionistic Fuzzy Set, *International Journal of Pure and Applied Mathematics*, 2005, 24(3), 287–297.
20. Smarandache, F. A geometric interpretation of the NS set A generalization of the intuitionistic fuzzy set, IEEE International Conference on Granular Computing, 2011, 602–606.
21. Mullai, M.; Surya, R. Neutrosophic EOQ Model with Price Break, *Neutrosophic Sets and Systems*, 2018, 19, 24-29.
22. Bera,T.; Mahapatra, N.K. Generalised Single Valued Neutrosophic Number and Its Application to Neutrosophic Linear Programming, *Neutrosophic Sets and Systems*, 2019, 25, 85-103.
23. Mohana, K.; Christy, V.; Smarandache, F. On Multi-Criteria Decision Making problem via Bipolar Single-Valued Neutrosophic Settings , *Neutrosophic Sets and Systems,* 2019, 25, 125-135.
24. Kar, C.; Mondal, B.; Roy, T. K. An Inventory Model under Space Constraint in Neutrosophic Environment: A Neutrosophic Geometric Programming Approach, *Neutrosophic Sets and Systems*, 2018, 21, 93-109.
25. Nabeeh, N. A.; Abdel-Basset, M.; El-Ghareeb, H. A.; Aboelfetouh, A. Neutrosophic multi-criteria decision making approach for iot-based enterprises. *IEEE Access,* 2019, 7, 59559-59574.

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