Graded Mean Integral Distance Measure and VIKOR Strategy Based MCDM Skill in Trapezoidal Neutrosophic Number

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Abstract:

This article exceedingly induces a completely new impression of graded mean integral representation in trapezoidal neutrosophic number domain corresponding to each membership function. Furthermore employing these integral representations, a new fangled graded mean integral distance measure is produced between two trapezoidal neutrosophic numbers. Notably, a numerical business economy based Multi Criteria Decision Making (MCDM) problem is fabricated along with the explication of neutrosophic theory to authenticate our suggested course of action in the decision making policy with the prominent solution scheme of VlseKriterijumska Optimizcija I Kaompromisno Resenje (VIKOR) technique for recognising the best alternative from a finite set. Lastly, the comparison work acts as an additional encouragement of our proposed scheme.

Keyword: Trapezoidal neutrosophic number; VIKOR; graded mean integral representation; MCDM.

Introduction:

The brain-storming impression of fuzzy set theory (F.S.) first pioneered by L.A.Zadeh [1] in the year 1965, with this continuation; researchers established the theory of pentagonal [40], hexagonal [46], and heptagonal [44] numbers in F.S and applied it proficiently in multiple arenas of research topics. Subsequently, in 1986 , Atanassov [2] demonstrated the postulation of intuitionistic fuzzy set (IFS) with a gratifying combination of membership and non-membership functions. Later Liu and Yuan [7] projected the notion of triangular neutrosophic numbers and Ye [12] expounded the proposition of trapezoidal IFS in this connection. Till now several notable works have been subjected

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in F.S and IFS views. Afterwards, in 1998 F. Smarandache [4] anticipated the configuration of neutrosophic set (NS) for developing the solution of any kind of real world problem in a reasonable way. NS contains three membership functions namely truth, false, hesitant and all the membership functions are belongs to [0, 1]. This is more advanced and modified structure in imprecise domain rather than fuzzy set as it can grab all the special three components of an uncertain parameter. Later in 2010 , Wang et al. [10] revealed the construction of single typed neutrosophic set which demands a crucial position in NS theory. Of late, in 2018-2019 Chakraborty et al. [33,37] put forth the observation of triangular and trapezoidal neutrosophic number (TNN, TrNN) respectively and its classification in accordance with the ground of dependency of the membership function. Additionaly, in 2021, Chakraborty et al. [38] projected a logarithmic and aggregation operator law basis MCDM problem in trapezoidal neutrosophic arena to detect the most harmful virus. Presently, Chakraborty et al. [47] investigated the scheme of aggregation operator on PNN and utilised it in MCGDM segment, networking ground and graph theoretical issues [48, 49].Later Chakraborty et al.[50] established de bipolarization technique associated with cloud service based MCGDM problem in trapezoidal neutrosophic domain. More than a few articles are produced in neutron-logic field like, Basset et al. [41] projected type- 2 NS, Deli et al. [26] explored the ranking result of single valued trapezoidal number, Smarandache [23] resolved the notion of neutrosophic set on complex ground, Nabeeh et al. [36] characterized neutrosophic AHP strategy, Biswas et al. [24] put forth the TOPSIS skill for MADM under the realm of trapezoidal neutrosophic numbers, S.Pal [51] formed EOQ model by means of NS, Haque [52] established exponential operational law in trapezoidal neutrosophic number in a pollution issue based MCGDM problem.

In the recent study, MCDM, MADM and MCGDM problems are the most relevant, useful and principally pertinent topics in this contemporary age of science. A good number of researchers brought out different articles on decision making grounds like, Wang et al. [34,35] established linguistic MCGDM problem in technological ground, Jiang [3] set forth learning model by means of defuzzification proficiency, Mahata et al. [45] exhibited diabetes related mathematical model on fuzzy background, Yuo et al. [13] projected image segmentation in neutrosophic sphere, Huang et al. [27] initiated MCGDM applying VIKOR strategy, Basset et al. [11] conceptualised hybrid neutrosophic approach in MCGDM problem, Chakraborty et al. [43] masterminded bipolar neutro-logic interrelated MCGDM difficulty, Stanujkic et al [28] put forth MCDM applying MULTIMOORA proficiency, Xu [34] developed MCGDM on several linguistic conditions, Ye [15] determined MADM under interval netro-logic issue, Broumi [17] suggested TOPSIS technique in interval based neutro ground, Deli [18] introduced Decision making model by means of soft matrices, Liu [19] planned MADM model utilising power operator, Peng and Dai [20] offered a bibliometric analysis in their article, Zhang [21] initiated MADM model under weighted correlation sense, Wu XH [25] conceptualised MADM model via cross entropy operations, Peng et al. [16] demonstrated MCGDM with power aggregation operator etc. In the year 1998, Opricovic [5] first revealed the VIKOR scheme to carry out MCGDM within contradictory objectives [6,8]. Implementing TOPSIS and VIKOR, Pouresmaeil et al.[29] anticipated an MAGDM policy in SVNS situation. Bausys and Zavadskas[22] projected the VIKOR approach in interval neutrosophic set (INS) background. Liu and Zhang[14] considered VIKOR tactic in neutrosophic uncertain fuzzy set situation. In 2017, Hu et al.[30] patronized a projection related VIKOR technique for doctor recruitment problem in INS situation. Additionally, Selvakumari et al. [31] calculated VIKOR strategy via octagonal

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neutrosophic soft matrix, Pramanik et al. [32] set up a VIKOR based MAGDM scheme in bipolar neutrosophic set setting. Kundogdu et al. [53] solved a decision making problem for waste management using VIKOR methodology.

In this article, we mainly focus on VIKOR based MCDM problem along with the construction of generalised trapezoidal neutrosophic numbers from disjunctive characteristic views. Some basic operational laws of trapezoidal neutrosophic numbers are demonstrated to enhance the pertinence of our proposed theory. With the progression of the study, a newly conceptualised graded mean integral technique is established under trapezoidal neutrosophic number background. Utilising this constructive tool, a new kind of distance measure namely, graded mean integral distance measure is manifested here to analyse the distance between two trapezoidal neutrosophic numbers. Notably, the well known VIKOR strategy is elucidated here under trapezoidal neutrosophic background and most significantly, a numerical business investment related mathematical problem is set forth to validate our anticipated hypothesis. Lastly, the comparison work involving the ranking system of the alternatives uplifts the superiority of our proposed supposition.

1.1 Motivation:

Due to the sharp growth of vagueness cum complexity in current world, realistic mathematical modelling and many flourishing research domains in the spheres of engineering and architecture, researchers diligently enforced the neutrosophic theory with a good hand. Gradually neutrosophic theory extended its circumference in disjunctive field of research domain with modified and extended version. With the advent of the considerable governance of uncertainty issue in the contemporary research of neutrosophic ground MCDM, MADM difficulties have amazingly achieved a prominent influential support. Naturally, question arises what will be the graded mean integral concept of TrNN? How we can resolve a MCDM problem in neutrosophic environment? How do we erect the MCDM structure in generalised trapezoidal neutrosophic number arena? Which scheme of solution methodology will be convenient for handling the suggested MCDM problem? Recalling all these affairs in mind we construct this article justifying the VIKOR method and appointed it to sort out our recommended MCDM problem.

1.2 Novelties:

In this contemporary period, researchers have conceived their progressive thoughts to build the improvement of the theories correlated to neutrosophic sphere and unceasingly strive to implement its plenty range of implications in unlike branches of neutrosophic provinces. However, accounting all the perspectives connecting to trapezoidal neutrosophic number theory our prime purpose is to endorse the supposition resourcefully with these subsequent features.
(1) Construction of graded mean integral representation corresponding to each membership function with graphical demonstration.
(2) Set up new distance measure (graded mean integral distance).
(3) Figure out VIKOR method in trapezoidal neutrosophic number arena.
(4) Implement the concept of our VIKOR strategy in trapezoidal neutrosophic number field to determine our proposed MCDM problem.

Hence these are the motivation and novelties of the present work and the remaining part of the paper is organized as follows. In section 2, some of the preliminaries are given. In section 3, different operational laws are presented. In section 4, graded mean integration technique for trapezoidal neutrosophic number is proposed with the graphical representation and the distance measure based on graded mean. In section 5, a new methodology is proposed for VIKOR based multi criteria decision making process. In section 6, using the proposed methodology and the proposed distance measure based on graded mean are applied for finding the best country to invest money under trapezoidal neutrosophic environment. In section 7, comparative analysis is done to show the effectiveness of the proposed method. In section 8, conclusion of the present work is given.

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2. Mathematical Preliminaries:

2.1 Definition: Fuzzy Set (F.S): **[1]** $\tilde{F}$ is recognised as a fuzzy set, represented by the ordered pair $(x, \alpha_{\tilde{F}}(x))$ can be written as $\tilde{F} = \{(x, \alpha_{\tilde{F}}(x)) : x \in X, \alpha_{\tilde{F}}(X) \in [0,1]\}$ where $x \in X$ and $\alpha_{\tilde{F}}(X) \in [0,1]$.

2.2 Definition: Intuitionistic Fuzzy Set (IFS): [2] $\tilde{F}_I$ is acknowledged as an Intuitionistic set if $\tilde{F}_I = \{\langle x; [\beta(x), \gamma(x)]\rangle \vdots x \in X = Universal\ set\}$, where $\beta(x): X \to [0,1]$ is phrased as membership function, $\gamma(x): X \to [0,1]$ is phrased as non-membership function. $\beta(x), \gamma(x)$ assure the mentioned relation $0 \leq \beta(x) + \gamma(x) \leq 1$.

2.3 Definition: Neutrosophic Set (NS): [4] A set $\widetilde{NE(F)}$ is recognized as a neutrosophic set if $\widetilde{NE(F)} = \{\langle x; [\emptyset_{\widetilde{NE(F)}}(x), \delta_{\widetilde{NE(F)}}(x), \sigma_{\widetilde{NE(F)}}(x)]\rangle \vdots x \in X\}$, where $\emptyset_{\widetilde{NE(F)}}(x): X \to]0^-, 1^+[$ is termed as the truthiness function, $\varphi_{\widetilde{NE(F)}}(x): X \to]0^-, 1^+[$ is declared as the ambiguity function, and $\mu_{\widetilde{NE(F)}}(x): X \to]0^-, 1^+[$ is affirmed as the falseness function.
$\emptyset_{\widetilde{NE(F)}}(x), \delta_{\widetilde{NE(F)}}(x)$ & $\mu_{\widetilde{NE(F)}}(x)$ exhibit the following relation:

$$0^- \leq Sup\,\{\emptyset_{\widetilde{NE(F)}}(x)\} + Sup\,\{\delta_{\widetilde{NE(F)}}(x)\} + \text{Sup}\,\{\mu_{\widetilde{NE(F)}}(x)\} \leq 3^+$$

2.4 Definition: Single-Valued Neutrosophic Set (SNS): [10] A set $\widetilde{NEU}_M$ in the definition 2.3 is called as a SNS $(\widetilde{SNEU}_M)$ if x is a single-valued independent variable. $\widetilde{SNEU}A = \{\langle x; [\theta_{\widetilde{SNEU}_M}(x), \varphi_{\widetilde{SNEU}_M}(x), \sigma_{\widetilde{SNEU}_M}(x)]\rangle \vdots x \in X\}$, $\theta_{\widetilde{SNEU}_M}(x), \varphi_{\widetilde{SNEU}_M}(x)$ & $\sigma_{\widetilde{SNe}_M}(x)$ signified the notion of correct, indefinite and incorrect memberships function respectively .Also $\theta_{\widetilde{SNEU}_M}(x): X \to]0,1[$,$\varphi_{\widetilde{SNEU}_M}(x): X \to]0,1[$and $\sigma_{\widetilde{SNe}_M}(x): X \to]0,1[$. Here also $\theta_{\widetilde{SNEU}_M}(x), \varphi_{\widetilde{SNEU}_M}(x)$ & $\sigma_{\widetilde{SNe}_M}(x)$ exhibit the following relation:

$$0 \leq \theta_{\widetilde{SNEU}_M}(x) + \varphi_{\widetilde{SNEU}_M}(x) + \sigma_{\widetilde{SNe}_M}(x) \leq 3$$

2.5 Definition: Trapezoidal Neutrosophic Number (TrNN): [37] A TrNN $(\tilde{z})$ is described as $\tilde{z} = \langle[(i^1, j^1, k^1, l^1; i^2, j^2, k^2, l^2; i^3, j^3, k^3, l^3)]\rangle$, the truthfulness membership function$(\tau_{\tilde{z}}): \mathbb{R} \to [0,1]$, the ambiguity membership function $(\iota_{\tilde{z}}): \mathbb{R} \to [0,1]$ and the inaccuracy membership function $(\varepsilon_{\tilde{z}}): \mathbb{R} \to [0,1]$ are given as:

$$\tau_{\tilde{z}}(x) = \begin{cases} \dfrac{x - i^1}{j^1 - i^1} & i^1 \leq x \leq j^1 \\ 1 & j^1 \leq x \leq k^1 \\ \dfrac{l^1 - x}{l^1 - k^1} & k^1 \leq x \leq l^1 \\ 0 & otherwise \end{cases}, \quad \iota_{\tilde{z}}(x) = \begin{cases} \dfrac{j^2 - x}{j^2 - i^2} & i^2 \leq x \leq j^2 \\ 0 & j^2 \leq x \leq k^2 \\ \dfrac{x - k^2}{l^2 - k^2} & k^2 \leq x \leq l^2 \\ 1 & otherwise \end{cases}$$

$$\varepsilon_{\tilde{z}}(x) = \begin{cases} \dfrac{j^3 - x}{j^3 - i^3} & i^3 \leq x \leq j^3 \\ 0 & j^3 \leq x \leq k^3 \\ \dfrac{x - k^3}{l^3 - k^3} & k^3 \leq x \leq l^3 \\ 1 & otherwise \end{cases}$$

3. Different operational laws of two trapezoidal neutrosophic numbers:

If $\tilde{A}_{Ne}$ and $\tilde{B}_{Ne}$ are two trapezoidal Neutrosophic numbers having truth-membership $T_{\tilde{A}_{Ne}}$& $T_{\tilde{B}_{Ne}}$, indeterminacy-membership $I_{\tilde{A}_{Ne}}$& $I_{\tilde{B}_{Ne}}$and falsity-membership $F_{\tilde{A}_{Ne}}$& $F_{\tilde{B}_{Ne}}$respectively such as: $\tilde{A}_{Ne} = \langle a_1, a_2, a_3, a_4; b_1, b_2, b_3, b_4; c_1, c_2, c_3, c_4\rangle$ and $\tilde{B}_{Ne} = \langle a_5, a_6, a_7, a_8; b_5, b_6, b_7, b_8; c_5, c_6, c_7, c_8\rangle$. Where a, b & c are the score given by decision maker in the scale ranging from lower limit L_l to upper limit U_l.

3.1. Addition:

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$\tilde{C}_{Ne} = \tilde{A}_{Ne} + \tilde{B}_{Ne} =$

$$\langle \begin{matrix} \{min(a_1 + a_5, U_l), min(a_2 + a_6, U_l), min(a_3 + a_7, U_l), min(a_4 + a_8, U_l)\}; \\ \{min(b_1 + b_5, U_l), min(b_2 + b_6, U_l), min(b_3 + b_7, U_l), min(b_4 + b_8, U_l)\}; \\ \{min(c_1 + c_5, U_l), min(c_2 + c_6, U_l), min(c_3 + c_7, U_l), min(c_1 + c_8, U_l)\} \end{matrix} \rangle \text{ --- (1)}$$

3.2. Negative of TrNNs:

$\tilde{S}_{Ne} = -\tilde{A}_{Ne}$

$= \langle -a_4, -a_3, -a_2, -a_1; -b_4, -b_3, -b_2, -b_1; -c_4 - c_3, -c_2, -c_1 \rangle$ ----- (2)

3.3 Subtraction:

$$\tilde{D}_{Ne} = \tilde{A}_{Ne} - \tilde{B}_{Ne}$$

$$= \tilde{A}_{Ne} + (-\tilde{B}_{Ne})$$

$$= \langle \begin{matrix} \{max(a_1 - a_8, L_l), max(a_2 - a_7, L_l), max(a_3 - a_6, L_l), max(a_4 - a_5, L_l)\}; \\ \{max(b_1 - b_8, L_l), max(b_2 - b_7, L_l), max(b_3 - b_6, L_l), max(b_4 - b_3, L_l)\}; \\ \{max(c_1 - c_8, L_l), max(c_2 - c_7, L_l), max(c_3 - c_6, L_l), max(c_4 - c_3, L_l)\} \end{matrix} \rangle \text{ -(3)}$$

3.4. Multiplication by a constant:

$$\tilde{E}_{Ne} = k[\tilde{A}_{Ne}]$$

$$= k \times \langle a_1, a_2, a_3, a_4; b_1, b_2, b_3, b_4; c_1, c_2, c_3, c_4 \rangle$$

$$= \langle ka_1, ka_2, ka_3, ka_4; kb_1, kb_2, kb_3, kb_4; kc_1, kc_2, kc_3, kc_4 \rangle \text{-(4)}$$

3.5. Inverse of TrNNs:

$$\tilde{F}_{Ne} = \tilde{A}_{Ne}^{-1} = \frac{1}{\langle a_1, a_2, a_3, a_4; b_1, b_2, b_3, b_4; c_1, c_2, c_3, c_4 \rangle}$$

$$= \langle \frac{1}{a_4}, \frac{1}{a_3}, \frac{1}{a_2}, \frac{1}{a_1}; \frac{1}{b_4}, \frac{1}{b_3}, \frac{1}{b_2}, \frac{1}{b_1}; \frac{1}{c_4}, \frac{1}{c_3}, \frac{1}{c_2}, \frac{1}{c_1} \rangle \; for\ (a, b, c) > 0 \text{ --- (5a)}$$

$$= \langle \frac{1}{a_1}, \frac{1}{a_2}, \frac{1}{a_3}, \frac{1}{a_4}; \frac{1}{b_1}, \frac{1}{b_2}, \frac{1}{b_3}, \frac{1}{b_4}; \frac{1}{c_1}, \frac{1}{c_2}, \frac{1}{c_3}, \frac{1}{c_4} \rangle \; for\ (a, b, c) < 0 \text{ --- (5b)}$$

4. Graded Mean Integration Technique for Trapezoidal Neutrosophic Number:

Graded mean integration method represents the generalized trapezoidal neutrosophic number. This technique adopts grade as the weight by taking the average of left and right h-level values of the generalized trapezoidal neutrosophic fuzzy number and produces deneutrosophized left and right trapezoidal neutrosophic number. Using this technique, depiction values of trapezoidal neutrosophic numbers can be obtained with the step form truth, indeterminacy and falsity membership functions and by comparing these values rank of the trapezoidal neutrosophic number can be acquired. Here Fig.1-Fig.3 represents the graphical representation of truth, indeterminacy and falsity membership functions with graded mean with graded mean integration representation. In all these figures $L_T(x)$ and $R_T(x)$

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are the straight lines and $L_T^{-1}(\mathrm{h})$, $R_T^{-1}(\mathrm{h})$ are the graded mean h-level values of the inverse functions of left and right functions.

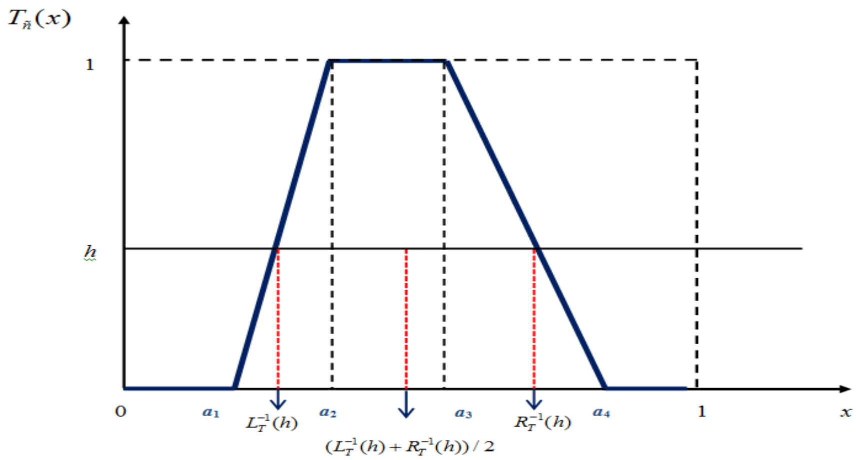

Fig. 1. Graded mean integration representation of truth membership fucntion

Suppose $\tilde{n} =< (a_1, a_2, a_3, a_4), (b_1, b_2, b_3, b_4), (c_1, c_2, c_3, c_4) >$ be a trapezoidal neutrosophic number. Since,

$$L_T(x) = T(\frac{x-a_1}{a_2-a_1}), \quad a_1 \le x \le a_2,$$

$$R_T(x) = T(\frac{a_4-x}{a_4-a_3}), \quad a_3 \le x \le a_4$$

Then,

$$L_T^{-1}(h) = a_1 + \frac{h(a_2-a_1)}{T}, \quad 0 \le h \le T,$$

$$R_T^{-1}(h) = a_4 - \frac{h(a_4-a_3)}{T}, \quad 0 \le h \le T,$$

and $$\frac{L_T^{-1}(h)+R_T^{-1}(h)}{2} = \frac{a_1+a_4+\dfrac{h(a_2-a_1-a_4+a_3)}{T}}{2}.$$

So the graded mean integration representation of truth membership function of trapezoidal neutrosophic number $\tilde{n}$ is

$$P_T(\tilde{n}) = \int_0^T h \frac{a_1+a_4+\dfrac{h(a_2-a_1-a_4+a_3)}{T}}{2} dh \Big/ \int_0^T hdh$$

$$= \frac{1}{2}[\frac{(a_1+a_4)h^2}{2} + \frac{h^3(a_2-a_1-a_4+a_3)}{3T}]\Big|_0^T / [\frac{1}{2}h^2]\Big|_0^T$$

$$= \frac{a_1+2a_2+2a_3+a_4}{6}$$

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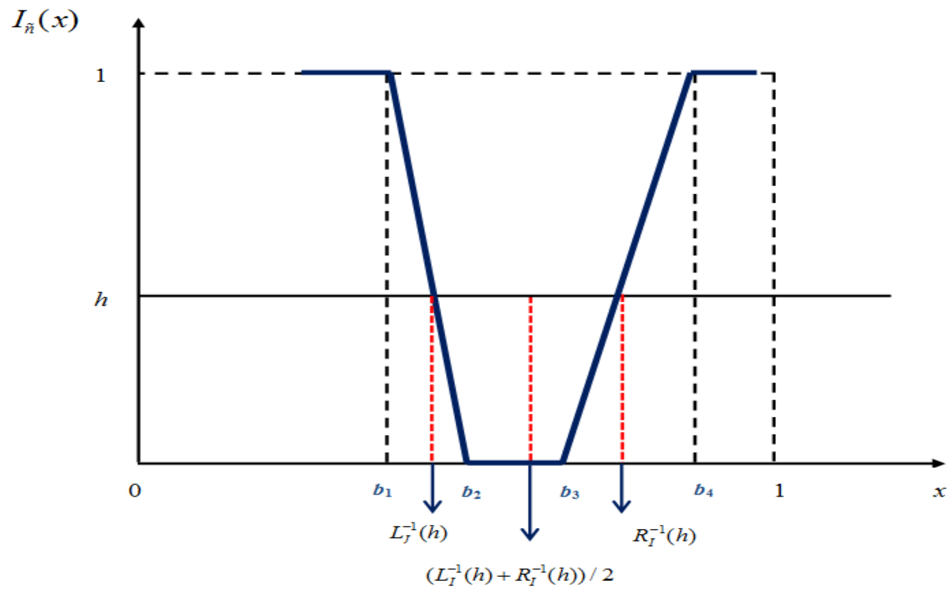

Fig. 2. Graded mean integration representation of indeterminacy membership fucntion

$$L_I(x) = I(\frac{b_2 - x}{b_2 - b_1}), \quad b_1 \le x \le b_2,$$
$$R_I(x) = I(\frac{x - b_3}{b_4 - b_3}), \quad b_3 \le x \le b_4$$

Then

$$L_I^{-1}(h) = b_2 - \frac{h(b_2 - b_1)}{I}, \quad 0 \le h \le I, \; R_I^{-1}(h) = b_3 + \frac{h(b_4 - b_3)}{I}, \quad 0 \le h \le I,$$

And $$\frac{L_I^{-1}(h) + R_I^{-1}(h)}{2} = \frac{b_2 + b_3 + \frac{h(b_4 - b_3 - b_2 + b_1)}{I}}{2}.$$

So the graded mean integration representation of indeterminacy membership function of trapezoidal neutrosophic number $\tilde{n}$ is

$$P_I(\tilde{n}) = \int_0^I h \frac{b_2 + b_3 + \frac{h(b_4 - b_3 - b_2 + b_1)}{I}}{2} dh \Big/ \int_0^I h dh$$
$$= \frac{1}{2}[\frac{(b_2 + b_3)h^2}{2} + \frac{h^3(b_4 - b_3 - b_2 + b_1)}{3I}]\Big|_0^I / [\frac{1}{2}h^2]\Big|_0^I$$
$$= \frac{2b_1 + b_2 + b_3 + 2b_4}{6}.$$

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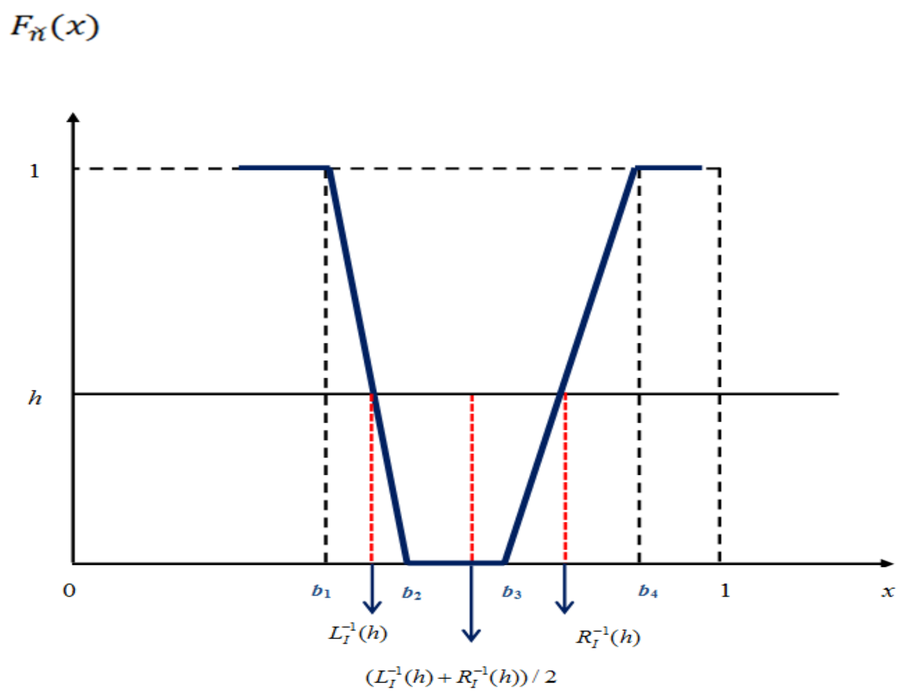

Fig. 3. Graded mean integration representation of falsity membership fucntion

So the graded mean integration representation of falsity membership function of trapezoidal neutrosophic number $\tilde{n}$ is

$$P_F(\tilde{n}) = \int_0^F h \frac{c_2 + c_3 + \frac{h(c_4 - c_3 - c_2 + c_1)}{F}}{2} dh \Big/ \int_0^F h dh$$
$$= \frac{1}{2}\Big[\frac{(c_2+c_3)h^2}{2} + \frac{h^3(c_4 - c_3 - c_2 + c_1)}{3F}\Big]\Big|_0^F \Big/ \Big[\frac{1}{2}h^2\Big]\Big|_0^F$$
$$= \frac{2c_1 + c_2 + c_3 + 2c_4}{6}.$$

4.1 Definition: Let us consider that $\tilde{n}_1 = \langle (a_1,a_2,a_3,a_4),(b_1,b_2,b_3,b_4),(c_1,c_2,c_3,c_4) \rangle$ and $\tilde{n}_2 = \langle (e_1,e_2,e_3,e_4),(f_1,f_2,f_3,f_4),(g_1,g_2,g_3,g_4) \rangle$ be two trapezoidal neutrosophic numbers, and their graded mean integration representations are $P(\tilde{n}_1) = (P_T(\tilde{n}_1), P_I(\tilde{n}_1), P_F(\tilde{n}_1))$, $P(\tilde{n}_2) = (P_T(\tilde{n}_2), P_I(\tilde{n}_2), P_F(\tilde{n}_2))$ respectively. Assume

$$s_i^T = (a_i - P_T(\tilde{n}_1) + e_i - P_T(\tilde{n}_2))/2, \quad i = 1,2,3,4; \; s_i^I = (b_i - P_I(\tilde{n}_1) + f_i - P_I(\tilde{n}_2))/2, \quad i = 1,2,3,4;$$

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$$s_i^F = (c_i - P_F(\tilde{n}_1) + g_i - P_F(\tilde{n}_2))/2, \quad i = 1,2,3,4;$$

$$d_i^T = |P_T(\widetilde{n_1}) - P_T(\widetilde{n_2})| + S_i^T \text{ , for } i = 1,2,3,4$$

$$d_i^I = |P_I(\widetilde{n_1}) - P_I(\widetilde{n_2})| + S_i^I \text{ , for } i = 1,2,3,4$$

$$d_i^F = |P_F(\widetilde{n_1}) - P_F(\widetilde{n_2})| + S_i^F \text{ , for } i = 1,2,3,4$$

Then the neutrosophic mean distance between $\widetilde{n_1}, \widetilde{n_2}$ is defined as,

$$D = \frac{(d_1^T+d_2^T+d_3^T+d_4^T+d_1^I+d_2^I+d_3^I+d_4^I+d_1^F+d_2^F+d_3^F+d_4^F)}{12} \text{ ..... (6)}$$

5. VIKOR Based Multi Criteria Decision Making Problem in Trapezoidal Neutrosophic Environment:

Multi criteria decision making trouble is one of the most consistent, well discussed and predominantly applied topics in this present age. The foremost purpose of this method is to detect the finest alternatives among restricted number of different alternatives with the connection of finite unlike attribute weights.

Step 1: Composition of Decision Matrices

Here, we construct the single decision matrix corresponding to the finite alternatives $(H_i)$and finite set of attributes(K_j). The notable point is that the entries h_{ij} of the constructed matrix are all trapezoidal neutrosophic numbers. Thus, we settle the matrix which is given as follows:

$$H = \begin{pmatrix} . & K_1 & K_2 & K_3 & . & . & . & K_m \\ H_1 & h_{11} & h_{12} & h_{13} & . & .. & . & h_{1m} \\ H_2 & h_{21} & h_{22} & h_{23} & . & . & . & h_{2m} \\ H_3 & \cdot & \cdot & \cdot & . & . & . & . \\ . & : & \cdot & \cdot & . & . & . & . \\ H_n & h_{n1} & h_{n2} & h_{n3} & . & . & . & h_{nm} \end{pmatrix} \text{...(7)}$$

Step 2: Standardization of Decision Matrices

Let $H^*= (h_{ij})_{mn}$ be the constructed decision matrix where each entry of the decision matrix is a general trapezoidal neutrosophic number where h_{ij} =($[t_{ij}^1 , t_{ij}^2 , t_{ij}^3 , t_{ij}^4]$; $[i_{ij}^1 , i_{ij}^2 , i_{ij}^3 , i_{ij}^4]$; $[f_{ij}^1 , f_{ij}^2 , f_{ij}^3 , f_{ij}^4]$) is the assessment worth of alternative H_i w.r.t. the attribute K_j .

We regard as the following technique of normalization to attain the standardized decision matrix where $H^*=(\bar{h}_{ij})_{mn}$ in which the entity $\bar{h}_{ij} = ([\bar{t}_{ij}^1, \bar{t}_{ij}^2, \bar{t}_{ij}^3, \bar{t}_{ij}^4; \bar{\iota}_{ij}^1, \bar{\iota}_{ij}^2, \bar{\iota}_{ij}^3, \bar{\iota}_{ij}^4; \bar{f}_{ij}^1, \bar{f}_{ij}^2, \bar{f}_{ij}^3, \bar{f}_{ij}^4])$ is formulated as

$$\bar{h}_{ij} = ([\frac{t_{ij}^1}{p_{ij}}, \frac{t_{ij}^2}{p_{ij}}, \frac{t_{ij}^3}{p_{ij}}, \frac{t_{ij}^4}{p_{ij}}];[\frac{i_{ij}^1}{r_{ij}}, \frac{i_{ij}^2}{r_{ij}}, \frac{i_{ij}^3}{r_{ij}}, \frac{i_{ij}^4}{r_{ij}}]; [\frac{f_{ij}^1}{s_{ij}}, \frac{f_{ij}^2}{s_{ij}}, \frac{f_{ij}^3}{s_{ij}}, \frac{f_{ij}^4}{s_{ij}}]) \text{ ....(8)}$$

Where $p_{ij}= \sqrt{{t_{ij}^1}^2 + {t_{ij}^2}^2 + {t_{ij}^3}^2 + {t_{ij}^4}^2}$ .....(9)

$$r_{ij}= \sqrt{{i_{ij}^1}^2 + {i_{ij}^2}^2 + {i_{ij}^3}^2 + {i_{ij}^4}^2} \text{......(10)}$$

$$s_{ij}= \sqrt{{f_{ij}^1}^2 + {f_{ij}^2}^2 + {f_{ij}^3}^2 + {f_{ij}^4}^2} \text{....(11)}$$

Thus we attain the following standardized matrix:

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$$H^{*}=\begin{pmatrix} . & K_1 & K_2 & K_3 & . & . & . & K_m \\ H_1 & \bar{h}_{11} & \bar{h}_{12} & \bar{h}_{13} & . & .. & . & \bar{h}_{1m} \\ H_2 & \bar{h}_{21} & \bar{h}_{22} & \bar{h}_{23} & . & . & . & \bar{h}_{2m} \\ H_3 & \cdot & \cdot & \cdot & . & . & . & \cdot \\ . & \vdots & . & . & . & . & . & . \\ H_n & \bar{h}_{n1} & \bar{h}_{n2} & \bar{h}_{n3} & . & . & . & \bar{h}_{nm} \end{pmatrix} \text{.....(12)}$$

Step 3: Formulating Positive and Negative Ideal Solution

In this step we formulate Positive Ideal Solution and Negative Ideal Solution from the standardized decision matrix. The defined formulae are given as follows

Positive Ideal Solution $h^{+}=(h_{11}^{+}, h_{12}^{+}, h_{13}^{+} \dots \dots h_{1m}^{+})$.....(13)

Negative Ideal Solution $h^{-}=(h_{11}^{-}, h_{12}^{-}, h_{13}^{-} \dots \dots . h_{1m}^{-})$..... (14)

Where, $h_{1c}^{+} =< [\bar{t}^{1+}{}_{1c}, \bar{t}^{2+}{}_{1c}, \bar{t}^{3+}{}_{1c}, \bar{t}^{4+}{}_{1c}]; [\bar{\iota}^{1+}{}_{1c}, \bar{\iota}^{2+}{}_{1c}, \bar{\iota}^{3+}{}_{1c}, \bar{\iota}^{4+}{}_{1c}]; [\bar{f}^{1+}{}_{1c}, \bar{f}^{2+}{}_{1c}, \bar{f}^{3+}{}_{1c}, \bar{f}^{4+}{}_{1c}] >$

$$=<[\max_{1\le q\le n} \bar{t}_{qc}{}^{1}, \max_{1\le q\le n} \bar{t}_{qc}{}^{2}, \max_{1\le q\le n} \bar{t}_{qc}{}^{3}, \max_{1\le q\le n} \bar{t}_{qc}{}^{4}]; [\min_{1\le q\le n} \bar{\iota}_{qc}{}^{1}, \min_{1\le q\le n} \bar{\iota}_{qc}{}^{2}, \min_{1\le q\le n} \bar{\iota}_{qc}{}^{3}, \min_{1\le q\le n} \bar{\iota}_{qc}{}^{4}]; [\min_{1\le q\le n} \bar{f}_{qc}{}^{1}, \min_{1\le q\le n} \bar{f}_{qc}{}^{2}, \min_{1\le q\le n} \bar{f}_{qc}{}^{3}, \min_{1\le q\le n} \bar{f}_{qc}{}^{4}] > \text{......(15)}$$

$h_{1c}^{-} =< [\bar{t}^{1-}{}_{1c}, \bar{t}^{2-}{}_{1c}, \bar{t}^{3-}{}_{1c}, \bar{t}^{4-}{}_{1c}]; [\bar{\iota}^{1-}{}_{1c}, \bar{\iota}^{2-}{}_{1c}, \bar{\iota}^{3-}{}_{1c}, \bar{\iota}^{4-}{}_{1c}]; [\bar{f}^{1-}{}_{1c}, \bar{f}^{2-}{}_{1c}, \bar{f}^{3-}{}_{1c}, \bar{f}^{4-}{}_{1c}] >$

$$=<[\min_{1\le q\le n} \bar{t}_{qc}{}^{1}, \min_{1\le q\le n} \bar{t}_{qc}{}^{2}, \min_{1\le q\le n} \bar{t}_{qc}{}^{3}, \min_{1\le q\le n} \bar{t}_{qc}{}^{4}]; [\max_{1\le q\le n} \bar{\iota}_{qc}{}^{1}, \max_{1\le q\le n} \bar{\iota}_{qc}{}^{2}, \max_{1\le q\le n} \bar{\iota}_{qc}{}^{3}, \max_{1\le q\le n} \bar{\iota}_{qc}{}^{4}]; [\max_{1\le q\le n} \bar{f}_{qc}{}^{1}, \max_{1\le q\le n} \bar{f}_{qc}{}^{2}, \max_{1\le q\le n} \bar{f}_{qc}{}^{3}, \max_{1\le q\le n} \bar{f}_{qc}{}^{4}] >$$

.....(16), Here $c = 1,2, \dots \dots m$

Step 4: Composition of Stretch Factors

In this step we compute stretch factors utilizing our newly erected distance measure mentioned in equation (6). The formula is given as follows.

$S_i = \sum_{j=1}^{m} \frac{D(\bar{h}_{ij}, h_{1j}^{+})\omega_j}{D(h_{1j}^{+}, h_{1j}^{-})}$ ...... (17) Here $i = 1,2, \dots n$

Step 5: Detection of Stretching Coefficient

In this step we compute stretching Coefficient. The formula is given as follows.

$S_{Ci} = \max_{j} \frac{D(\bar{h}_{ij}, h_{1j}^{+})\omega_j}{D(h_{1j}^{+}, h_{1j}^{-})}$...... (18) Here $i = 1,2, \dots n$

Step 6: Composition of Compromising Factors

In this step we compose compromising factors of each of the alternatives. The formula is given as follows

$C_{i} = \frac{|S_i - S_{Ci}|}{S_i}$ .....(19) Here $i = 1,2, \dots n$

Step 7: Ranking

In this step we rank the alternatives in accordance with the values of their connecting compromising factors.

5.1 Flowchart:

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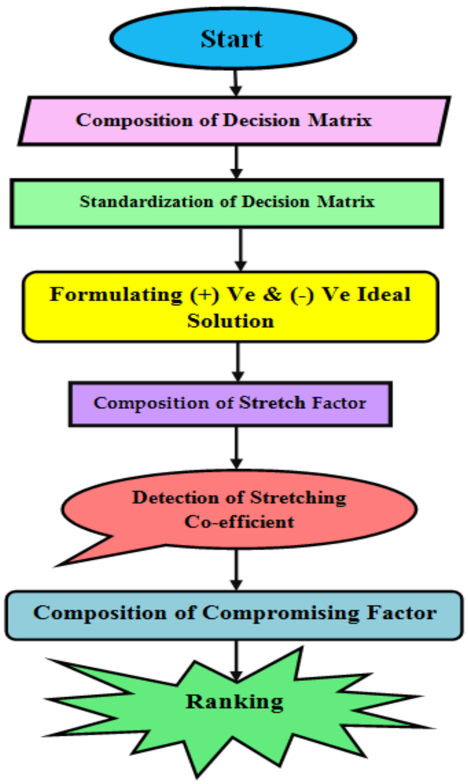

Fig. 4. Proposed methodology

6. Illustrative Example:

Let us assume a realistic problem in this globalisation era. A Businessman wants to invest money in suitable country during globalisation. In this phenomena, he will observe some essential factors like i) Business Trade policies of the Country ii) Socio-Economic condition of the country iii) Demand and labour cost. We consider these factors as attribute functions namely K_1 = Trade Polices, K_2 = Socio-Economic condition, K_3 = Demand and labour cost. Moreover, after analysing these factors he wants to invest money in the suitable country. We consider three different countries here H_1 = Country-1, H_2 = Country-2, H_3 = Country-3 as alternatives position. Our aim is to find out the best alternative (Country) on the basis of business factors such that profit can be generated very fruitfully. Since, the hypothetical data contains lots of hesitation, thus we considered this problem in TrNN environment. Here, we will apply the above graded mean distance measure based VIKOR method and will find out the best alternatives. Let ω = $(0.33, 0.34, 0.33)$ be the weight vector which are related to these four major analyses k_j,$(j = 1, 2, 3)$.

Step 1: Composition of Decision Matrix

In this step we construct a single decision matrix corresponding to finite set of alternatives and finite set of attribute values.

$$\begin{pmatrix} . & K_1 & K_2 & K_3 \\ H_1 & < 4.5,6,7.5,9; 4.25,5.5,7,8.75; 5.5,7,8.5,10.5 > & < 3.5,5,6.5,8; 3.25,4.5,6,7.75; 4.5,6,7.5,9.5 > & < 4,7,10,13; 3.5,6,9,12.5; 6,9,12,16 > \\ H_2 & < 0.4,1,1.5,2; 0.25,0.5,0.7,1.5; 0.45,1.05,1.20,1.45 > & < 1.5,3,4.5,6; 1.25,2.5,4,5.75; 2.5,4,5.5,7.5 > & < 2.5,4.5,5,7; 2.25,4,5,6.25; 3.5,5,6.5,8.5 > \\ H_3 & < 4.5,6,7.5,9; 4.25,5.5,7,8.75; 5.5,7,8.5,10.5 > & < 4.4,5,5.5,6; 4.25,4.5,4.7,5.5; 4.45,5.05,5.20,5.45 > & < 3.5,5,6.5,8; 3.25,4.5,6,7.75; 4.5,6,7.5,9.5 > \end{pmatrix}$$

Step 2: Standardization of Decision Matrices

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In this step we standardize the above mentioned decision matrix in accordance with the defined rules mentioned in equations (8), (9), (10), (11)

$$\begin{pmatrix} . & K_1 & K_2 & K_3 \\ H_1 & <0.32,0.43,0.54,0.64; 0.32,0.42,0.53,0.66; 0.34,0.43,0.53,0.65> & <0.29,0.42,0.54,0.67; 0.29,0.4,0.53,0.69; 0.32,0.42,0.53,0.67> & <0.22,0.38,0.55,0.71; 0.20,0.35,0.53,0.74; 0.26,0.40,0.53,0.7> \\ H_2 & <0.15,0.37,0.55,0.74; 0.14,0.28,0.4,0.86; 0.2,0.48,0.54,0.66> & <0.18,0.36,0.55,0.73; 0.17,0.33,0.53,0.77; 0.24,0.38,0.53,0.72> & <0.25,0.45,0.5,0.7; 0.24,0.43,0.54,0.68; 0.28,0.41,0.53,0.7> \\ H_3 & <0.32,0.43,0.53,0.64; 0.32,0.42,0.53,0.66; 0.34,0.43,0.52,0.65> & <0.42,0.48,0.52,0.57; 0.45,0.47,0.49,0.58; 0.44,0.5,0.51,0.54> & <0.30,0.42,0.54,0.67; 0.30,0.40,0.53,0.70; 0.32,0.42,0.53,0.67> \end{pmatrix}$$

Step 3: Formulating Positive and Negative Ideal Solution

In this step we formulate Positive and Negative Ideal solutions using equations (15), (16)

Positive Ideal Solution:

$$\begin{pmatrix} \widetilde{K_1} & \widetilde{K_2} & \widetilde{K_3} \\ <0.32,0.43,0.55,0.74; 0.14,0.28,0.40,0.66; 0.2,0.43,0.52,0.65> & <0.42,0.48,0.55,0.73; 0.17,0.33,0.49,0.58; 0.24,0.38,0.51,0.54> & <0.30,0.45,0.55,0.71; 0.20,0.35,0.53,0.68; 0.26,0.40,0.53,0.67> \end{pmatrix}$$

Negative Ideal Solution:

$$\begin{pmatrix} K_1 & K_2 & K_3 \\ <0.15,0.37,0.53,0.64; 0.32,0.42,0.53,0.86; 0.34,0.48,0.54,0.66> & <0.18,0.36,0.52,0.57; 0.45,0.47,0.53,0.77; 0.44,0.50,0.53,0.72> & <0.22,0.38,0.50,0.67; 0.30,0.43,0.54,0.74; 0.32,0.42,0.53,0.70> \end{pmatrix}$$

Step 4: Composition of Stretch Factors

In this step we compute stretching factors from the equation (17)

$$S_1 = \frac{0.05 \times 0.34}{0.09} + \frac{0.05 \times 0.32}{0.13} + \frac{0.03 \times 0.34}{0.05} = 0.51$$

$$S_2 = \frac{0.04 \times 0.34}{0.09} + \frac{0.14 \times 0.32}{0.13} + \frac{0.05 \times 0.34}{0.05} = 0.83$$

$$S_3 = \frac{0.06 \times 0.34}{0.09} + \frac{0.03 \times 0.32}{0.13} + \frac{0.01 \times 0.34}{0.05} = 0.37$$

Step 5: Detection of Stretching Coefficient

In this step we compute stretching coefficients utilising the equations (18)

$$S_{C1} = max\left\{\frac{0.05 \times 0.34}{0.09}, \frac{0.05 \times 0.32}{0.13}, \frac{0.03 \times 0.34}{0.05}\right\} = 0.20$$

$$S_{C2} = max\left\{\frac{0.04 \times 0.34}{0.09}, \frac{0.14 \times 0.32}{0.13}, \frac{0.05 \times 0.34}{0.05}\right\} = 0.34$$

$$S_{C3} = max\left\{\frac{0.06 \times 0.34}{0.09}, \frac{0.03 \times 0.32}{0.13}, \frac{0.01 \times 0.34}{0.05}\right\} = 0.23$$

Step 6: Composition of Compromising Factors

In this step compromising factors of each of the alternatives are computed from the equation (19)

$$C_1 = 0.61$$
$$C_2 = 0.59$$
$$C_3 = 0.38$$

Step 7: Ranking

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The ranking of the alternatives are performed corresponding to their compromising factors.

$$H_1 > H_2 > H_3$$

Hence country-I is the best company to invest money.

7. Comparison of Work:

In this section, we compare our constructed work with the recognized works proposed by various researchers to detect the best alternative and it is observed that in each turn H_1 (Country-1) becomes the finest business suitable country. The comparison table is presented as follows:

Approach	Ranking
Liu and Zhang [14]	$H_1 > H_3 > H_2$
Deli and Subas [26]	$H_1 > H_2 > H_3$
Selvakumari and Priyadharshini [31]	$H_3 > H_2 > H_1$
Wang et al. [35]	$H_1 > H_2 > H_3$
Gundogdu et al. [53]	$H_3 > H_1 > H_2$
Our Proposed	$H_1 > H_2 > H_3$

Table 1. Comparative analysis of the proposed work with the exiting works.

From Table 1, it is perceived that our proposed method is outperforming in comparison with the existing methods under trapezoidal neutrosophic environment based on graded mean integral distance measure and VIKOR methodology.

8. Conclusion:

In this research article, the idea of trapezoidal neutrosophic number is outstandingly put forth with its widespread applications in neutrosophic sphere of influence to solve our recommended MCDM complicacies. Further a newly formulated graded mean integral representation corresponding to each membership function is described in an elegant manner in the realm of trapezoidal neutrosophic number and applying this relevant tool, a newly conceptualized distance measure is constructed. Further, VIKOR strategy is developed in the trapezoidal neutrosophic environment and a numerical business economy based MCDM problem is erected to intensify our proposed strategy. Finally the comparison analysis with the established approaches of our recommended trapezoidal based VIKOR strategy exhibit some trust worthy ranking results of the alternatives in our proposed numerical problem. Further, upcoming researchers can profitably carry out the idea of VIKOR strategy under neutrosophic field in disjunctive thriving research grounds like structural modelling, diagnostic problems, realistic modelling, management and designing, big data analysis, cloud computing issues, image processing, diagnostic problems, granular computing issues, pattern recognition etc.

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