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Fuzzy Multi-Criteria Decision Support System for the Best Anti-Aging Treatment Selection Process through Normal Wiggly Hesitant Fuzzy Sets

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ABSTRACT

This socialized environment among educated and developed people causes them to focus more on their appearance and health, which turns them towards medical-related treatments, leading us to discuss anti-aging treatment methods for each age group, particularly for urban people who are interested in this. Some anti-aging therapies are used to address the alterations brought on by aging in human life without the need for surgery or negative effects. Five anti-aging therapies such as microdermabrasion or dermabrasion, laser resurfacing anti-aging skin treatments, chemical peels, dermal fillers for aged skin, and botox injections are considered in this study. Based on the criteria of safety risk, investment cost, customer happiness, and side effects, the optimal alternative is picked. As a result, a Normal Wiggly Hesitant Pythagorean Fuzzy Set (NWHPF) is constructed and used in Multi-Criteria Decision-Making (MCDM) using traditional wavy mathematical approaches. The entropy approach is utilized to determine weight values, and the Normal Wiggly Hesitant Pythagorean-VlseKriterijumska Optimizacija I Kompromisno Resenje (NWHPF-VIKOR) method is utilized to rank alternatives using MCDM methodologies. Sensitivity analysis and comparative analysis were performed to ensure the robustness and reliability of the proposed method. The smart final choice will undoubtedly assist Decision Makers (DM) in making the right judgments, and the MCDM approach will undoubtedly assist individuals in understanding the medicine.



KEYWORDS

Normal wiggly hesitant pythagorean fuzzy set; hesitant pythagorean fuzzy set; anti-aging treatment; entropy; VlseKriterijumska Optimizacija I Kompromisno Resenje

1 Introduction

As the skin grows, it loses its natural elasticity and appears thin, broken, and wrinkled. There are usually two types of skin aging: natural aging and mild aging. The former mainly indicates body aging, which is due to factors such as genetic, mediating, endocrine, and protective functions of suppressors. The latter is due to frequent changes in the role of Ultraviolet (UV) rays, weather, and environmental pollution that accelerate the natural aging process. Three types of processes can be summarized based on the process of skin maturation. This usually includes protection from external environmental factors, repair of infrared-induced free radical damage, and the use of personal care products to enhance skin appearance. This study investigates anti-aging cosmetics and examines both internal and external skin development techniques.

Aging is a natural and inevitable phenomenon. But the bar set by the beauty industry is driving people to aspire to look younger. A young-looking skin can be achieved through surgical and non-surgical processes. Various factors such as UV rays, poor eating and sleeping habits, pollution, and blue light cause rapid aging of the skin. The skin care industry mainly focuses on the protection of the skin from harmful UV rays from the sun. Now, a variety of products and treatments are available in the market for delaying the sagging and wrinkling of the skin. Chemicals such as hyaluronic acids, retinoids, polyphenols, amino acids peptides, etc., are available in the market to hydrate and prevent skin from wrinkling. They can also boost collagen formation which is responsible for the elasticity in the skin. To create anti-aging products, regular pigmentation modulators are essential. While some products and treatments can significantly lessen or delay the symptoms of skin damage, it is more accurate to think of reducing the overall appearance of aged skin. While these modern techniques can be used to improve the quality of the skin, it is to be noted that every product that is available on the market is not as safe and effective as it claims. Several cosmetic products claim they can reduce the clinical symptoms of skin damage, but there are not many reliable, double-blind, placebo-controlled scientific clinical trials to support these claims.

This study focuses on anti-aging treatments such as Microdermabrasion, laser resurfacing, chemical peel, dermal fillers, and Botox injections. These techniques focus on the regeneration of skin and enhance collagen production. This reduces wrinkles, fades acne scars, and provides healthy and luminous skin. It is to be noted that these techniques differ both in terms of methodology and results. Therefore, it is important to choose, based on experience, the ideal technique that will deliver the best results for the skin. The selection of an optimal technique involves ambiguities and uncertainty that arise during the conversion of real-life scenarios into mathematical models. This necessitates the need for a fuzzy decision-making environment. Decision makers (DMs) can provide several assessment values for membership and non-membership degrees using the Pythagorean Hesitant Fuzzy Set (PHFS). In this study, the Normal Wiggly Pythagorean Hesitant Fuzzy Set (NWPHFS) is proposed to comprehensively mine the uncertain preferences from original Pythagorean hesitant fuzzy information, since many cognitive preferences of DMs may be hidden in the evaluation information and cannot be fully expressed. While providing the original assessment data, NWPHFS can assist DMs

in more precisely expressing their potentially useful preferences for things. The names of the acronyms defined in this paper are given in the [Table 1](#).

Table 1: Nomenclature

HFS	Hesitant Fuzzy Set
NWHPFS	Normal Wiggly Hesitant Pythagorean Fuzzy Set
VIKOR	VIseKriterijumska Optimizacija I Kompromisno Resenje
MCDM	Multi-criteria decision making
IHFS	Intuitionistic Hesitant Fuzzy Set
PIS	Positive Ideal Solution
NIS	Negative Ideal Solution
m.f	Membership function
n.m.f	Non-membership function

2 Related Works

Adhami et al. [1] considered a versatile behavior uncertain problem and extended the reluctant fuzzy Pythagorean algorithm to solve the considered problem. A decision-making approach is proposed with fuzzy Pythagorean value, which contains a set of preferable values for the limb, also nonmember phases of all objective activities in ambiguously hesitant environments. Energy-saving technologies (ESTs) help bridge the gap between energy sources by saving more energy for use when required. Thus, the evaluation of technologies on energy-saving options is extremely important and is seen as a multiple-decision problem. Colak et al. [2] presented a case study on ESTs using a hesitant fuzzy approach. Krishankumar et al. [3] discovered a goal, which was to propose a novel method of presenting findings in the framework of Interval Value Probability Liability (IVPHFS). The weight information environment is completely unknown. Green suppliers for a big baking firm were chosen to ensure structural compatibility. By linking Spearman's sensitivity analysis with the weight and classification values, the structure is efficient, practical, and systematic for rational decision making in the hesitant fuzzy environment. Gül et al. [4] has presented interval valued-neutrosophic environment for the drone selection problem. Kumar et al. [5] helped a secure online application to last longer. For optimising the lifespan of a secure online application, a security life cycle measurement evaluation is crucial. As a result, the goal of this research is to look at the security capabilities of a web application in order to optimize security efforts for a certain life cycle. This study uses the Hybrid Assurance Group, the Analytical Hierarchy Process (AHP), and a hybrid approach to the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) based on a hesitant fuzzy environment. The effectiveness of the combined Hesitant Fuzzy-AHP-TOPSIS strategy has been carefully tested. The implanted tip's personal safety is graded. The initiative seeks to make a significant contribution to the advancement of safety and will help security experts. Ali et al. [6] have established distance and similarity measures for normal wiggly dual hesitant fuzzy sets and successfully applied the developed method in the detection of diseases in the medical field. The application of the fuzzy sets in a hypothetical war environment has been established by Xia et al. [7] in the normal wiggly probabilistic hesitant fuzzy environment. Zhang et al. [8] have made use of the normal wiggly hesitant fuzzy-based multi-criteria method in the evaluation of electric vehicle charging location. Zindani et al. [9] have evaluated the agro-waste fibers under normal wiggly hesitant fuzzy environments and have presented a tool to design optimal

parameters that can be used to evaluate the green products. A failure mode and effect analysis model based on Normal Wiggly Hesitant Fuzzy Set (NWHFS) was demonstrated by Zhang et al. [10] for the risk analysis of the electric bus systems. Xian et al. [11] have proposed an aggregation operator for the Pythagorean fuzzy environment and developed an algorithm to suggest optimal routes for travelers that could reduce the time, cost, and distance during their travel.

Zhou et al. [12] have evaluated the risk associated with the power transformer parts under the hesitant fuzzy environment using the improved hesitant fuzzy weighted averaging operator. Jeon et al. [13] have studied the probabilistic hesitant fuzzy environment in India's strategies during the COrona VIRus Disease-19 (COVID-19) pandemic. Feng et al. [14] proposed an adequate technical concept of the environmental aspects that occur when products are primarily designed with the product life cycle model in mind. The VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method has been used to prove this selected application. Joshi [15] have presented a novel framework as a criterion for ambiguous entropy in images. With the VIKOR approach, a novel and efficient R-Norm picture of ambiguous information action has been created. Khan et al. [16] focused on expanding the traditional VIKOR technique as in case of Multi-Criteria Decision Making (MCDM) situations that involve ambiguous Pythagorean data. Compromise resolution is essentially decided by VIKOR's compromise categorization approach, which provides the "majority" the most "group utility" and the "opponent" the least "individual regret," making it an excellent tool for resolving MCDM situations. Li et al. [17] provide a novel approach to choosing the finest machine tool. Decision Making Trial and Evaluation Laboratory (DEMATEL) and VIKOR were utilized to choose a suitable alternative using a new unified MCDM model that was built. Ren et al. [18] suggested a combination approach called VIKOR-AHP, which is utilized to tackle the Artificial Intelligence (AI) selection strategy problem. Finally, a literature review on the selection of AI strategy proves the technique's application and use. Table 1 lists various reviews of literature studies that are relevant to our planned investigation. Ali et al. [19] have proposed r, s, t -spherical fuzzy set, which is an extension of the t -spherical fuzzy set and defined the basic operational laws, distance measures, score, and accuracy functions and has combined the fuzzy set with VIKOR method. A VIKOR method based on the Pythagorean hesitant fuzzy decision-making method has been proposed by Zhang et al. [20] to obtain compromise alternatives based on regret theory. Singh et al. [21] proposed an Intuitionistic fuzzy-based Entropy-VIKOR method and analyzed similarity and dissimilarity measures for the extended VIKOR method. Abdul et al. [22] analyzed renewable energy technologies based on the Integrated Delphi-AHP-VIKOR approach towards sustainable energy resources. A literature review on various MCDM methods is given in the Table 2.

Table 2: Literature review

Authors	Title	Description
Guleria et al. [23]	A robust decision making approach for hydrogen power plant site selection utilizing (R, S)-Norm Pythagorean Fuzzy information measures are based on VIKOR and TOPSIS method.	The VIKOR and TOPSIS MCDM methods were updated within the (R, S) Pythagorean framework. This framework was utilized to formulate the problem of hydrogen selection.

(Continued)

Table 2 (continued)

Authors	Title	Description
Liu et al. [24]	Normal wiggly hesitant fuzzy linguistic power Hamy mean aggregation operators and their application to multi-attribute decision-making.	Introduced a new fuzzy set, Normal wiggly hesitant fuzzy linguistic term set and its methodology.
Liu et al. [25]	The selection of third-Party Reverse Logistics providers (3PRLs) on self-service mobile recycling machine: Interval-valued Pythagorean hesitant fuzzy best-worst multi-criteria group decision-making.	The suitability of the suggested technique is demonstrated quantitatively while addressing a real-world problem, and the major result is that the technical aspect has been the most important factor in influencing the choice of 3 PRL.
Narayanamoorthy et al. [26]	Application of normal wiggly dual hesitant fuzzy sets to site selection for hydrogen underground storage.	New approach of the normal wiggly dual hesitant fuzzy set are provided.
Wei et al. [27]	Dual Hesitant Pythagorean Fuzzy Hamy Mean Operators in Multiple Attribute Decision Making.	The suggested method is more successful in handling multi-attribute decision-making issues wherein the decision-making data is described by dual-hesitant Pythagorean fuzzy components as well as the attributes are interactive.

Fletcher [28] provided an indisputably strong relationship between contemporary anti-aging technologies and several social science-related biological aging studies. Traditional conceptions of ecological and chronological aging were challenged, and researchers tried to enhance functions as people aged and aged more sophisticatedly. From the cross-sectional approach of Rajan-Rankin et al. [29], this theoretical study investigates the intersections between race and old age. It looks at cultural archaeology (particularly aging simulation studies) and post-colonial approaches to aging as ideological lenses for understanding aging national bodies, with a focus on the body and transportation. Rostkowska et al. [30] have discussed extensively the properties of the skin, factors affecting skin aging, and Invasive and non-invasive methods for skin aging treatment. It also reveals the active ingredients in cosmetics that help delay skin aging. Liang et al. [31] have deeply analyzed the skin architecture

and has studied the aging of the skin on a molecular level. Goberdan et al. [32] have experimented with Dermabrasion treatment on Dry, hyperpigmented, photodamaged, or acne-prone/oily skin and have shown long-term improvement in the skin. Markiewicz-Tomczyk et al. [33] have studied that chemical peeling can improve hydration of the skin and reduce wrinkles. Nanda et al. [34] have studied the application of lasers in the treatment of Keratoacanthomas. McKenzie et al. [35] have studied the effects of botulinum toxin and dermal fillers on the skin of color (Asian, Black, Latinx) population and have concluded that these treatments provide a higher satisfaction degree for the patients.

2.1 Motivation

The research work is aimed to choose the best alternative among the available anti-aging treatments. The MCDM method is processed to get results after performing various tests. In MCDM techniques, criterion selection is the most critical factor in determining the validity of the proposed results.

Uncertainty is represented using fuzzy sets, specifically the Pythagorean Fuzzy Set (PFS), which extends the membership function (m.f.) and non-membership function (n.m.f.) from Intuitionistic Fuzzy Set (IFS) and Hesitant Fuzzy Sets (HFS) utilized in ordinary fuzzy sets. A collection of hesitant ambiguities aids in resolving the uncertainties inherent in human cognition.

In this study, we propose an extended NWHFS derived from HFS. The NWHFS addresses the deep and latent hesitant thoughts that decision-makers encounter, thereby aiding in their resolution. This approach enables the derivation of a clear and definitive solution. By combining Pythagoras fuzzy sets with NWHFS, we improved the decision-making process for anti-aging treatments. Common MCDM methods, such as weight detection and alternative ranking, were utilized in this study.

To find this utility, we have used the entropy weight detection method and VIKOR alternative ranking system. The VIKOR method assumes that choosing an alternative is not biased with DM while making decisions. The result of this method is that they do not like an exchange not between wishes and possibilities but between the different interests of the decision-makers. Thus the best alternative is selected using NWPFS.

2.2 Research Contributions

The contributions of this research are summarized as follows: [Section 2](#) contains definitions of fuzzy sets, including the proposed set definitions and operations. [Section 3](#) provides details of the applications selected for the study and a complete description of the chosen alternatives. [Section 4](#) outlines the algorithm for the NWPFS, an extension of the HFS proposed in this research, and includes the algorithm for the VIKOR method, selected as part of the MCDM approach. [Section 5](#) illustrates the selection of the best alternative by presenting an illustrative example of the chosen application and the proposed set. Finally, [Section 7](#) concludes with the method proposed and a summary of the findings related to the proposed set.

3 Preliminaries

Definition 3.1. According to [36], let Υ , a fixed set, the following expression is denoted as PFS (Pythagorean Fuzzy Set), $P \in \Upsilon$:

$$P = \{ \{v, h_f(v), g_f(v)\} / v \in \Upsilon \} \quad (1)$$

The functions $h_f(v)$ and $g_f(v)$ belongs to $[0, 1]$. Here, $h_f(v)$ -membership degree (m. d.) and $g_f(v)$ -non-membership degree (n.m.d.) of P . $0 \leq (h_f(v)^2) + (g_f(v)^2) \leq 1$ is the condition of PFS. $\pi_f(v) = \sqrt{1 - (h_f(v))^2 - (g_f(v))^2}$, an indeterminacy degree of q to P .

Definition 3.2. In accordance with [36], The Hesitant Pythagorean Fuzzy Set (HPFS), \tilde{P} on Υ is,

$$\tilde{P} = \left\{ \langle v, h_{p_f}(v), g_{p_f}(v) \rangle / v \in \Upsilon \right\} \tag{2}$$

Here, the two set $h_{p_f}(v)$ -m.d. and $g_{p_f}(v)$ -n.m.d. $\in [0, 1]$. The m.f. and n.m.f. satisfies with $(h_{p_f}^+)^2 + (g_{p_f}^+)^2$ lies between $[0, 1]$, where $0 \leq h_{p_f} \leq 1, 0 \leq g_{p_f} \leq 1$, here, $h_{p_f}, g_{p_f} \in v \in \Upsilon$ where,

$$h_{p_f}^+ = \max_{h_{p_f} \in v} \{ h_{p_f} \} \tag{3}$$

$$g_{p_f}^+ = \max_{g_{p_f} \in v} \{ g_{p_f} \} \tag{4}$$

for all $v \in \Upsilon$.

Definition 3.3. In [26], An Intuitionistic Hesitant Fuzzy Set (IHFS), the function $B \in \Upsilon$ is with h_{p_f} , m.f. and g_{p_f} , n.m.f. is applied to Υ , returns $\subset [0, 1]$, the IHFS can be expressed,

$$B = \left\{ \langle v, h_{p_f}(v), g_{p_f}(v) \rangle / v \in \Upsilon \right\} \tag{5}$$

where $h_{p_f}(v)$ and $g_{p_f}(v)$ in $[0, 1]$, let $v \in \Upsilon$, an element in B , then the condition must be met,

$$\text{Max}(h_{p_f}(v)) + \text{Min}(g_{p_f}(v)) \leq 1 \tag{6}$$

$$\text{Min}(h_{p_f}(v)) + \text{Max}(g_{p_f}(v)) \leq 1 \tag{7}$$

Here, the IHFS element is $h_{p_f}(v)$ and $g_{p_f}(v)$.

Definition 3.4. Let $P_1 = (h_{p_{f1}}, g_{p_{f1}})$ and $P_2 = (h_{p_{f2}}, g_{p_{f2}})$ are two PHFS elements. Some operation laws between P_1 and P_2 may be shown below:

1.

$$P_1 \oplus P_2 = \bigcup_{\substack{\vartheta_1 \in h_{p_{f1}}, \vartheta_2 \in h_{p_{f2}}, \\ \varphi_1 \in g_{p_{f1}}, \varphi_2 \in g_{p_{f2}}}} \left\{ \sqrt{(\vartheta_1)^2 + (\vartheta_2)^2 - (\vartheta_1)^2(\vartheta_2)^2}, \{ \varphi_1, \varphi_2 \} \right\} \tag{8}$$

2.

$$P_1 \otimes P_2 = \bigcup_{\substack{\vartheta_1 \in h_{p_{f1}}, \vartheta_2 \in h_{p_{f2}}, \\ \varphi_1 \in g_{p_{f1}}, \varphi_2 \in g_{p_{f2}}}} \left\{ \{ \vartheta_1, \vartheta_2 \}, \sqrt{(\varphi_1)^2 + (\varphi_2)^2 - (\varphi_1)^2(\varphi_2)^2} \right\} \tag{9}$$

3.

$$P_1^n = \bigcup_{\vartheta_1 \in h_{p_{f1}}, \varphi_1 \in g_{p_{f1}}} \left\{ \vartheta_1^n, \sqrt{1 - (1 - \varphi_1^2)^n} \right\}, n > 0 \tag{10}$$

4.

$$nP_1 = \bigcup_{\vartheta_1 \in h_{p_{f1}}, \varphi_1 \in g_{p_{f1}}} \left\{ \sqrt{1 - (1 - \vartheta_1^2)^n}, \varphi_1^n \right\}, n > 0 \tag{11}$$

4 Some Basic Preliminaries of NWHPFS

Definition 4.1. According to [26], $f_{\tilde{E}(v)}$ and $f'_{\tilde{E}(v)}$ are the Normal Wiggly Triangular Hesitant Pythagorean Fuzzy Set (NWTHPFS), a function, \tilde{P} on Υ provides some different NWTHPF-Number Set (NWTHPFN).

$$\tilde{P} = \{ \{v, f_{\tilde{E}(v)}, f'_{\tilde{E}(v)}\} / v \in \Upsilon \} \quad (12)$$

The Triangular Hesitant Pythagorean Fuzzy Set (THPFS) is represent as $f_{\tilde{E}(v)}$ and $f'_{\tilde{E}(v)}$. The THPFS gives some different counts of NWTHPFN.

$$f_{\tilde{E}(v)} = \{P(\tau_i)\} \Rightarrow \{P(\tau_i^L, \tau_i^M, \tau_i^U) / P(\tau_i) \in f_{\tilde{E}(v)}, i = 1, 2, \dots, \#f_{\tilde{E}(v)}\} \quad (13)$$

$$f'_{\tilde{E}(v)} = \{P(v_i)\} \Rightarrow \{P(v_i^L, v_i^M, v_i^U) / P(v_i) \in f'_{\tilde{E}(v)}, i = 1, 2, \dots, \#f'_{\tilde{E}(v)}\} \quad (14)$$

Here, the triangular NWHPFS are denoted as $P(\tau_i)$ and $P(v_i)$. Then, the triangular lower, middle, and upper values are denoted as $P(\tau_i^L \leq \tau_i^M \leq \tau_i^U)$ and $P(v_i^L \leq v_i^M \leq v_i^U)$. The total number of NWHPFN is $\#f_{\tilde{E}(v)}$ and $\#f'_{\tilde{E}(v)}$.

Definition 4.2. According to [26], let, the hesitant Pythagorean fuzzy element $h_{p_f} = \{\vartheta_1, \vartheta_2, \vartheta_3, \dots, \vartheta_{\#h}\}$ and $g_{p_f} = \{\varphi_1, \varphi_2, \varphi_3, \dots, \varphi_{\#g}\}$. Then, the set of mean values is,

$$\bar{h}_{p_f} = \frac{1}{\#h} \sum_{i=1}^{\#h} \vartheta_i \quad (15)$$

$$\bar{g}_{p_f} = \frac{1}{\#g} \sum_{i=1}^{\#g} \varphi_i \quad (16)$$

Definition 4.3. As per [26], let the Standard Deviation can be addressed with m.d.-(\hat{h}) and n.m.d.-(\hat{g}).

$$\sigma_{h_{p_f}} = \sqrt{\frac{1}{\#h} \sum_{i=1}^{\#h} (\vartheta_i - \bar{h}_{p_f})^2} \quad (17)$$

$$\sigma_{g_{p_f}} = \sqrt{\frac{1}{\#g} \sum_{i=1}^{\#g} (\varphi_i - \bar{g}_{p_f})^2} \quad (18)$$

The m.f., n.m.f. \hat{h} and \hat{g} satisfy the equations,

$$\tilde{f}(\vartheta_i) = \sigma_{h_{p_f}} e^{-\frac{(\vartheta_i - \bar{h}_{p_f})^2}{2\sigma_{h_{p_f}}^2}} \quad (19)$$

$$\tilde{f}(\varphi_i) = \sigma_{g_{p_f}} e^{-\frac{(\varphi_i - \bar{g}_{p_f})^2}{2\sigma_{g_{p_f}}^2}} \quad (20)$$

The Pythagorean wiggly ranges of ϑ_i and φ_i are denoted the interval $[\vartheta_i - \tilde{f}(\vartheta_i), \vartheta_i + \tilde{f}(\vartheta_i)]$ and $[\varphi_i - \tilde{f}(\varphi_i), \varphi_i + \tilde{f}(\varphi_i)]$.

Definition 4.4. In [26], let a Real Preference Degrees (rpd) are,

$$rpd(\tilde{h}_{p_f}) = \begin{cases} \sum_{i=1}^{\#\tilde{h}} \tilde{\vartheta}_i \left(\frac{\#\tilde{h}_{p_f} - i}{\#\tilde{h}_{p_f} - 1} \right) & \text{if } h_{p_f} < 0.5 \\ 1 - \sum_{i=1}^{\#\tilde{h}} \tilde{\vartheta}_i \left(\frac{\#\tilde{h}_{p_f} - i}{\#\tilde{h}_{p_f} - 1} \right) & \text{if } h_{p_f} > 0.5 \\ 0.5 & \text{if } h_{p_f} = 0.5 \end{cases} \tag{21}$$

$$rpd(\tilde{g}_{p_f}) = \begin{cases} \sum_{i=1}^{\#\tilde{g}} \tilde{\varphi}_i \left(\frac{\#\tilde{g}_{p_f} - i}{\#\tilde{g}_{p_f} - 1} \right) & \text{if } g_{p_f} < 0.5 \\ 1 - \sum_{i=1}^{\#\tilde{g}} \tilde{\varphi}_i \left(\frac{\#\tilde{g}_{p_f} - i}{\#\tilde{g}_{p_f} - 1} \right) & \text{if } g_{p_f} > 0.5 \\ 0.5 & \text{if } g_{p_f} = 0.5 \end{cases} \tag{22}$$

Definition 4.5. Let the HFS $H = \{\langle v, \hat{h}(v) \rangle / v \in \Upsilon\}$, a Υ 's reference set. The set NWHPFS on \tilde{P} implies,

$$\tilde{p}' = \{\langle v, p(\hat{h}(v)), p(\hat{g}(v)), \zeta(p(\hat{h}(v))), \zeta(p(\hat{g}(v))) \rangle / v \in \Upsilon\} \tag{23}$$

Here, the possible NWHPFS's m.f. and n.m.f. are represented $(p(\hat{h}(v)))$ and $(p(\hat{g}(v)))$, respectively. The Normal Wiggly Hesitant Pythagorean Fuzzy Element (NWHPFE) are $\zeta(p(\hat{h}(v)))$, $\zeta(p(\hat{g}(v)))$, for all $v \in \Upsilon$. Then, we get the equation as,

$$\begin{aligned} \zeta(p(\hat{h}(v))) = \{\tilde{\vartheta}_1, \tilde{\vartheta}_2, \dots, \tilde{\vartheta}_{\#\hat{h}(v)}\} &= \{\max(\vartheta_i - \tilde{f}(\vartheta_i), 0), (2rpd(p(\hat{h}(v))) - 1)\tilde{f}(\vartheta_i) \\ &+ \vartheta_i, \min(\vartheta_i + \tilde{f}(\vartheta_i), 1)\}, \end{aligned} \tag{24}$$

$p(\hat{h}(v))$ value is ϑ_i . Likewise,

$$\begin{aligned} \zeta(p(\hat{g}(v))) = \{\tilde{\varphi}_1, \tilde{\varphi}_2, \dots, \tilde{\varphi}_{\#\hat{g}(v)}\} &= \{\max(\varphi_i - \tilde{f}(\varphi_i), 0), (2rpd(p(\hat{g}(v))) - 1)\tilde{f}(\varphi_i) \\ &+ \varphi_i, \min(\varphi_i + \tilde{f}(\varphi_i), 1)\}, \end{aligned} \tag{25}$$

$p(\hat{g}(v))$ value is φ_i .

Definition 4.6. Let NWHPFE is $\{\langle v, p(\hat{h}(v)), p(\hat{g}(v)), \zeta(p(\hat{h}(v))), \zeta(p(\hat{g}(v))) \rangle / v \in \Upsilon\}$, the score function $\langle v, p(\hat{h}(v)), \zeta(p(\hat{h}(v))) \rangle$ and $\langle v, p(\hat{g}(v)), \zeta(p(\hat{g}(v))) \rangle$ is,

$$\begin{aligned}
 & S_{NWPHF} \left(\langle \nu, p(\widehat{h}(\nu)), p(\widehat{g}(\nu)), \zeta(p(\widehat{h}(\nu))), \zeta(p(\widehat{g}(\nu))) \rangle \right) \\
 &= \left[\mu(\bar{h}_{p_f} - \sigma_{h_{p_f}}) + (1 - \mu) \left(\frac{1}{\#p(\widehat{h}(\nu))} \sum_{i=1}^{\#p(\widehat{h}(\nu))} \check{\vartheta}_i - \sigma_{\check{\vartheta}_i} \right) \right. \\
 &\quad \left. - \mu'(P_{\widehat{g}} - \sigma_{P_{\widehat{g}}}) + (1 - \mu') \left(\frac{1}{\#P(\widehat{g}(\nu))} \sum_{i=1}^{\#P(\widehat{g}(\nu))} \check{\varphi}_i - \sigma_{\check{\varphi}_i} \right) \right] \tag{26}
 \end{aligned}$$

where,

$$\check{\vartheta}_i = \frac{\vartheta_i^L + \vartheta_i^M + \vartheta_i^U}{3} \tag{27}$$

$$\check{\varphi}_i = \frac{\varphi_i^L + \varphi_i^M + \varphi_i^U}{3}, \tag{28}$$

$$\sigma_{\check{\vartheta}_i} = \sqrt{(\vartheta_i^L)^2 + (\vartheta_i^M)^2 + (\vartheta_i^U)^2 - (\vartheta_i^L \vartheta_i^M) - (\vartheta_i^L \vartheta_i^U) - (\vartheta_i^M \vartheta_i^U)}, \tag{29}$$

$$\sigma_{\check{\varphi}_i} = \sqrt{(\varphi_i^L)^2 + (\varphi_i^M)^2 + (\varphi_i^U)^2 - (\varphi_i^L \varphi_i^M) - (\varphi_i^L \varphi_i^U) - (\varphi_i^M \varphi_i^U)}. \tag{30}$$

Now, $\vartheta, \varphi \in (0, 1)$.

4.1 Operation Laws of NWHPFEs

Let $B_1 = \{\widehat{h}_1, \widehat{g}_1\}, \{\zeta(\widehat{h}_1), \zeta(\widehat{g}_1)\}$ and $B_2 = \{\widehat{h}_2, \widehat{g}_2\}, \{\zeta(\widehat{h}_2), \zeta(\widehat{g}_2)\}$ are two NWHPFEs, then,

1.

$$\begin{aligned}
 B_1 \oplus B_2 = & \left\langle \bigcup_{\vartheta_1 \in \widehat{h}_1, \vartheta_2 \in \widehat{h}_2, \varphi_1 \in \widehat{g}_1, \varphi_2 \in \widehat{g}_2} (\vartheta_1 + \vartheta_2 - \vartheta_1 \vartheta_2, \varphi_1 \varphi_2), \right. \\
 & \left. \bigcup_{\vartheta_1 \in \zeta(\widehat{h}_1), \vartheta_2 \in \zeta(\widehat{h}_2), \varphi_1 \in \zeta(\widehat{g}_1), \varphi_2 \in \zeta(\widehat{g}_2)} (\check{\vartheta}_1 \oplus \check{\vartheta}_2, \check{\varphi}_1 \oplus \check{\varphi}_2) \right\rangle \tag{31}
 \end{aligned}$$

2.

$$\begin{aligned}
 B_1 \otimes B_2 = & \left\langle \bigcup_{\vartheta_1 \in \widehat{h}_1, \vartheta_2 \in \widehat{h}_2, \varphi_1 \in \widehat{g}_1, \varphi_2 \in \widehat{g}_2} (\vartheta_1 + \vartheta_2 - \vartheta_1 \vartheta_2, \varphi_1 \varphi_2), \right. \\
 & \left. \bigcup_{\vartheta_1 \in \zeta(\widehat{h}_1), \vartheta_2 \in \zeta(\widehat{h}_2), \varphi_1 \in \zeta(\widehat{g}_1), \varphi_2 \in \zeta(\widehat{g}_2)} (\check{\vartheta}_1 \otimes \check{\vartheta}_2, \check{\varphi}_1 \otimes \check{\varphi}_2) \right\rangle \tag{32}
 \end{aligned}$$

3.

$$\begin{aligned}
 B_1^n = & \left\langle \bigcup_{\vartheta_1 \in \widehat{h}_1, \varphi_1 \in \widehat{g}_1} (\vartheta_1^n, 1 - (1 - \varphi_1)^n), \right. \\
 & \left. \bigcup_{\vartheta_1 \in \zeta(\widehat{h}_1), \varphi_1 \in \zeta(\widehat{g}_1)} (\check{\vartheta}_1^n, \check{\varphi}_1^n) \right\rangle \tag{33}
 \end{aligned}$$

4.

$$nB_1 = \left\langle \bigcup \vartheta_1 \in \widehat{h}_1, \varphi_1 \in \widehat{g}_1(1 - (1 - \vartheta_1)^n, \varphi_1^n), \right. \\ \left. \bigcup \vartheta_1 \in \zeta(\widehat{h}_1), \varphi_1 \in \zeta(\widehat{g}_1)(n\check{\vartheta}_1^n, n\check{\varphi}_1^n) \right\rangle \tag{34}$$

Here, $n > 0$, $\check{\vartheta}_1 \oplus \check{\vartheta}_2$ is the basic operational addition rule of triangular fuzzy set and $\check{\vartheta}_1 \otimes \check{\vartheta}_2$ goes with the triangular fuzzy set multiplication rules. Both of the rules are given as follows:

1.

$$\check{\vartheta}_1 \oplus \check{\vartheta}_2 = \{\tau_1^L, \tau_1^M, \tau_1^U\} \oplus \{\tau_2^L, \tau_2^M, \tau_2^U\} \\ = \{\tau_1^L + \tau_2^L, \tau_1^M + \tau_2^M, \tau_1^U + \tau_2^U\}, \tag{35}$$

2.

$$\check{\vartheta}_1 \otimes \check{\vartheta}_2 = \{\tau_1^L, \tau_1^M, \tau_1^U\} \otimes \{\tau_2^L, \tau_2^M, \tau_2^U\} \\ = \{\tau_1^L \tau_2^L, \tau_1^M \tau_2^M, \tau_1^U \tau_2^U\}, \tag{36}$$

3.

$$\check{\vartheta}_1^n = \{(\tau_1^L)^n, (\tau_1^M)^n, (\tau_1^U)^n\} \tag{37}$$

4.

$$n\check{\vartheta}_1 = \{n\tau_1^L, n\tau_1^M, n\tau_1^U\} \tag{38}$$

Also, $\check{\varphi}_1 \oplus \check{\varphi}_2$ is satisfies the same rules as $\check{\vartheta}_1 \oplus \check{\vartheta}_2$ and $\check{\varphi}_1 \otimes \check{\varphi}_2$ is satisfies the same rules as $\check{\vartheta}_1 \otimes \check{\vartheta}_2$. $\check{\varphi}_1^n$ is is satisfying the same rules as $\check{\vartheta}_1^n$ and $n\check{\varphi}_1$ satisfies the same rules as $n\check{\vartheta}_1$.

5 Anti-Aging Treatments

1. Dermabrasion or Microdermabrasion

Microdermabrasion is a subtle yet effective procedure that restores overall skin tone and texture. It significantly improves skin texture affected by conditions such as sun exposure, melasma, fine lines, wrinkles, age spots, pimples, and other skin issues. Microdermabrasion is generally safe for a variety of skin types and tones. This peeling procedure employs a rotary tool to remove the outer layers of the skin. It is popular among individuals seeking to enhance the appearance and radiance of their skin, addressing concerns like fine lines, acne scars, and sun damage. During the procedure, the dermatologist will first use an anesthetic to numb the skin and then remove the outer layer. Patients can typically recover at home following the treatment.

2. Laser Resurfacing

Laser therapy, also known as light therapy, is an anti-aging treatment that utilizes the power of light to repair and regenerate skin cells. This technique involves directing intense and focused rays of light through the skin to target damaged areas. Commonly referred to as laser peeling or laser ablation, this procedure is popular for its effectiveness in improving skin texture and appearance.

3. Chemical Peel

Chemical peeling is a skin restorative procedure that involves applying acidic chemical solutions to the face. This method removes the outer layers of skin and smooths the skin's surface, resulting in a reduction of fine lines. Many chemical peels have a gel-like consistency and can be used not only on the face but also on other areas such as the neck, arms, and chest. After the chemical application, the skin develops controlled blisters that eventually shed, leading to improved texture. This treatment enhances the appearance of fine wrinkles, acne scars, and skin discoloration by removing dead skin cells from the surface.

4. Dermal Fillers

As people age, it is natural for the skin to lose elasticity, suppleness, and moisture, leading to the development of wrinkles. Commonly affected areas include the cheeks, nose, eyes, mouth, and jaws. To enhance the skin's appearance, smooth tissue is applied to targeted areas. For medical or cosmetic procedures, needle points are used for infusions. An antibiotic substance is applied to disinfect the area, and an anesthetic agent is used to ensure patient comfort during the procedure. Subsequently, a filler—typically hyaluronic acid or a collagen-stimulating agent—is injected using a fine needle. The reaction to the injection can vary among patients, with some experiencing a slight odor or a burning sensation from the filler.

5. Botox Injections

Botox, also known as botulinum neurotoxin, is a toxin injected into the skin to temporarily paralyze muscle activity. This intervention helps prevent the formation or worsening of wrinkles. Botulinum neurotoxin is a protein that targets presynaptic nerve cells at neuromuscular junctions. It functions by inhibiting the release of the neurotransmitter acetylcholine, which leads to reduced muscle contraction. By entering the muscles and blocking nerve signals to these tissues, Botox diminishes muscular function, resulting in a smoother appearance.

6 Problem Formulation-Proposed Method

This section proposes an extended VIKOR method with NWHPFS. The calculation method of the proposed method and procedure for its improvement are also provided. The decision matrix is formulated based on the knowledge of the experts in this field and the linguistic measurement is fixed within the interval $[0, 1]$ and satisfies the conditions of NWHPFS. The research methodology of the NWHPFS-VIKOR method is given in the [Fig. 1](#).

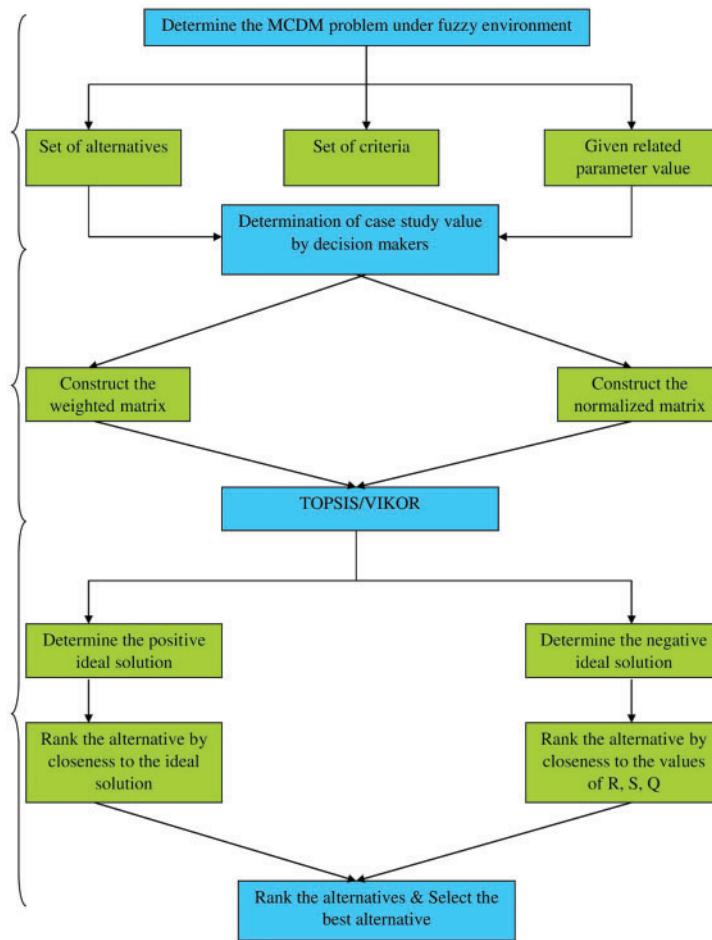


Figure 1: The mathematical procedure for NWHPF-VIKOR method

Here, we define the alternative is $A_i (i = 1, 2, 3, \dots, n)$. The criteria are define as $R_j (j = 1, 2, 3, \dots, m)$. The following expression represents the NWHPFE:

$$\tilde{p}(H_{ij}) = \{[\zeta(p(\hat{h}(v_{ij}))), \zeta(p(\hat{g}(v_{ij})))]/p(\hat{h}(v_{ij})), p(\hat{g}(v_{ij})) \in \Upsilon\} \tag{39}$$

Step 1:

Define the NWHPFS decision matrix. Experts determine the values for the MCDM issue. The value of NWHPFS is represented in the [Table 3](#) below:

$$\tilde{H} = \tilde{p}(H_{ij}) = \{[p(\hat{h}(v_{ij})), p(\hat{g}(v_{ij}))]/\zeta(p(\hat{h}(v_{ij}))), \zeta(p(\hat{g}(v_{ij}))) \in \Upsilon_{ij}\} \tag{40}$$

Step 2:

The score function is determined using the following equation. Such an equation has both membership and non-membership functions. The score function equation contains both standard deviation and mean values. The membership score function and non-membership score functions of

$\langle p(\widehat{h}_{ij}), \zeta p(\widehat{h}_{ij}) \rangle, \langle p(\widehat{g}_{ij}), \zeta p(\widehat{g}_{ij}) \rangle$ is,

$$S_{NWPHF} \left(\langle v, p(\widehat{h}(v)), p(\widehat{g}(v)), \zeta(p(\widehat{h}(v))), \zeta(p(\widehat{g}(v))) \rangle \right)$$

$$= \left[\mu(\bar{h}_{pf} - \sigma_{\bar{h}_{pf}}) + (1 - \mu) \left(\frac{1}{\#p(\widehat{h}(v))} \sum_{i=1}^{\#p(\widehat{h}(v))} \tilde{\vartheta}_i - \sigma_{\tilde{\vartheta}_i} \right) \right.$$

$$\left. - \mu'(\bar{g}_{pf} - \sigma_{\bar{g}_{pf}}) + (1 - \mu') \left(\frac{1}{\#p(\widehat{g}(v))} \sum_{i=1}^{\#p(\widehat{g}(v))} \tilde{\varphi}_i - \sigma_{\tilde{\varphi}_i} \right) \right] \tag{41}$$

Table 3: Decision matrix with NWHPFs

	R_1	R_2	\dots	R_n
A_1	$\langle \zeta(p(\widehat{h}(v_{11}))), \zeta(p(\widehat{g}(v_{11}))) \rangle$	$\langle \zeta(p(\widehat{h}(v_{12}))), \zeta(p(\widehat{g}(v_{12}))) \rangle$	\dots	$\langle \zeta(p(\widehat{h}(v_{1n}))), \zeta(p(\widehat{g}(v_{1n}))) \rangle$
A_2	$\langle \zeta(p(\widehat{h}(v_{21}))), \zeta(p(\widehat{g}(v_{21}))) \rangle$	$\langle \zeta(p(\widehat{h}(v_{22}))), \zeta(p(\widehat{g}(v_{22}))) \rangle$	\dots	$\langle \zeta(p(\widehat{h}(v_{2n}))), \zeta(p(\widehat{g}(v_{2n}))) \rangle$
\vdots	\vdots	\vdots	\vdots	\vdots
A_m	$\langle \zeta(p(\widehat{h}(v_{m1}))), \zeta(p(\widehat{g}(v_{m1}))) \rangle$	$\langle \zeta(p(\widehat{h}(v_{m2}))), \zeta(p(\widehat{g}(v_{m2}))) \rangle$	\dots	$\langle \zeta(p(\widehat{h}(v_{mn}))), \zeta(p(\widehat{g}(v_{mn}))) \rangle$

Step 3:

By using weighted entropy, we calculate the criteria weight values.

$$E(A) = 1 - \sum_{i=1}^m \sum_{j=1}^n \frac{[\zeta(p(\widehat{h}(v_{ij}))) + \zeta(p(\widehat{g}(v_{ij})))]}{2} = 0. \tag{42}$$

To determine the entropy matrix E , we use \tilde{H} relative to the end matrix.

$$E = \begin{bmatrix} E_{11} & E_{12} & \dots & E_{1n} \\ E_{21} & E_{22} & \dots & E_{2n} \\ \dots & \dots & \ddots & \dots \\ E_{m1} & E_{m2} & \dots & E_{mn} \end{bmatrix}$$

\tilde{E} is the normalized entropy matrix. The following equation is used to calculating the normalized entropy matrix \tilde{E} .

$$\tilde{E}_{ij} = \frac{E_{ij}}{\max \{E_{i1}, E_{i2}, \dots, E_{in}\}} \tag{43}$$

Here, m and n represent the alternatives and criteria for $1 \leq i, j \leq m, n$. The criteria weights are denoted as W_j . The following equation is used to calculate the weight values. The weight value is calculated with the values of the criteria.

$$W_j = \frac{(1 - e_j)}{\sum_{j=1}^n (1 - e_j)}, (1 \leq j \leq n). \tag{44}$$

In above equation n represent the number of indicators and $0 \leq W_j \leq 1, \sum_{j=1}^n W_j = 1$.

Step 4:

The Positive Ideal Solution (PIS) and Negative Ideal Solutions (NIS) of NWHPPFS must be computed in Step 4. The PIS and NIS of NWHPPFS are indicated by \hat{V}_+ and \hat{V}_- , respectively.

$$\hat{V}_+ = \left\{ \left(\left[\max \zeta(p(\hat{h}(v_{ij}))), \min \zeta(p(\hat{g}(v_{ij}))) \right] / p(\hat{h}_{ij}) \in \zeta(p(\hat{h}(v_{ij}))), p(\hat{g}_{ij}) \in \zeta(p(\hat{g}(v_{ij}))) \right) \right. \\ \left. \left(\left[\min \zeta(p(\hat{h}(v_{ij}))), \max \zeta(p(\hat{g}(v_{ij}))) \right] / p(\hat{h}_{ij}) \in \zeta(p(\hat{h}(v_{ij}))), p(\hat{g}_{ij}) \in \zeta(p(\hat{g}(v_{ij}))) \right) \right\} \quad (45)$$

$$\hat{V}_- = \left\{ \left(\left[\min \zeta(p(\hat{h}(v_{ij}))), \max \zeta(p(\hat{g}(v_{ij}))) \right] / p(\hat{h}_{ij}) \in \zeta(p(\hat{h}(v_{ij}))), p(\hat{g}_{ij}) \in \zeta(p(\hat{g}(v_{ij}))) \right) \right. \\ \left. \left(\left[\max \zeta(p(\hat{h}(v_{ij}))), \min \zeta(p(\hat{g}(v_{ij}))) \right] / p(\hat{h}_{ij}) \in \zeta(p(\hat{h}(v_{ij}))), p(\hat{g}_{ij}) \in \zeta(p(\hat{g}(v_{ij}))) \right) \right\} \quad (46)$$

Step 5:

The decision maker's utility values are Θ_i , and the decision maker's view about personal frustration is Φ_i , as computed by the following equation. The wide majority utility ratings are then represented by Θ_i . The individual regret values are denoted by the letter Φ_i .

$$\Theta_j = \sum_{j=1}^n W_j \frac{(\tilde{V}_j^+ - \tilde{V}_{ij})}{(\tilde{V}_j^+ - \tilde{V}_j^-)}, \quad (47)$$

$$\Phi_j = \max \left\{ \frac{W_j (\tilde{V}_j^+ - \tilde{V}_{ij})}{(\tilde{V}_j^+ - \tilde{V}_j^-)} \right\} \quad (48)$$

Step 6:

Calculate the value of \aleph_i . Here \aleph_i represents the index value. The following equation is used for calculating the index value:

$$\aleph_i = v \frac{\Theta_i - \Theta^-}{\Theta^+ - \Theta^-} + (1 - v) \frac{\Phi_i - \Phi^-}{\Phi^+ - \Phi^-}, \quad (49)$$

$$\Theta^+ = \min \Theta_j, \quad \Theta^- = \max \Theta_j, \quad (50)$$

$$\Phi^+ = \min \Phi_j, \quad \Phi^- = \max \Phi_j, \quad (51)$$

Here, v is the maximum group utility compromise solution. The value, $v = (0.5)$.

Step 7:

The utility measure values and the regret measure are used to rank the options. The options are ordered by the index value. The descending order of each value in Θ , Φ and \aleph is an alternate ranking. The compromise solution $\aleph_{[i]}$ is used to pick alternatives, and the rules that follow are dependent on the compromise solution.

C₁: Acceptable advantage

The alternative advantages are calculated by using this equation $\aleph(A_2) - \aleph(A_1) \geq (\frac{1}{n-1})$, where $\frac{1}{n-1} = DG$. The alternative ranking lists are sorted. The first place is $\aleph(A_1)$, the second place is $\aleph(A_2)$ alternative.

C₂: Acceptable stability

When, the regret measure Φ and utility measure Θ ranking is based on v . Here the best value of $v = 0.5$. Every alternative value is stable.

If conditions C_1 do not satisfy the requirement, we have to move on to the following consolation solution:

- The regret measure R_2 is not satisfied the condition, if the alternative $A_{[1]}$ and alternative $A_{[2]}$.
- The regret measure R_1 does not satisfy the condition, if the alternative sequence is $A_{[1]}, \dots, A_{[n]}$.

Here, the equation $\aleph(A_n) - \aleph(A_1) \leq (\frac{1}{n-1})$ is $A_{[n]}$ evaluated.

7 Illustrative Example

Anti-aging therapy helps to make our appearance look younger. These treatments can cause a variety of side effects. So the treatment we choose should be tailored to the nature of the skin. Choosing a good treatment can fix the problems that occur in our skin. Here, we have selected five types of non-surgical anti-aging treatments and selected the best one of them. The five types of anti-aging treatments including microdermabrasion or dermabrasion, laser resurfacing anti-aging skin treatments, chemical peel, dermal fillers, and botox injections are considered for this proposed problem.

We choose the finest among these alternative types based on the attributes of the specified parameters. The best solutions are those that fulfill all of the safety and risk requirements, as well as the investment cost, customer satisfaction, and side effects criteria. The hierarchical tiers of the selected options, as well as the criterion, are depicted in the Fig. 2. For the proposed mathematical logical method, we provide results of the NWHPF combination of two different MCDM techniques.

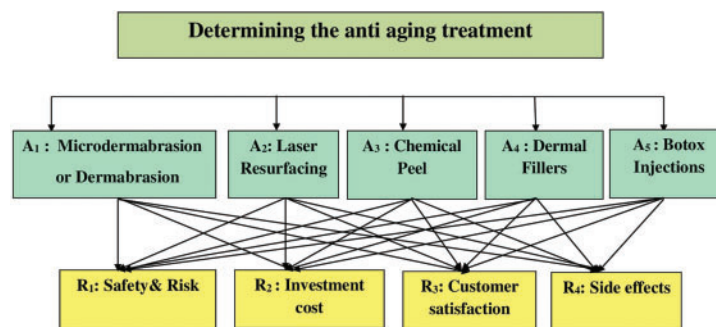


Figure 2: Hierarchical determination of the proposed problem

Using the MCDM process, we have now determined the value of the suggested set. We have incorporated the decision matrix values along with the criteria for the selected applications. The utility of such a matrix is determined by whether it allows the policymaker to remember the deep thoughts that come to mind. In this approach, the decision maker’s minor reservations are explained. Both

m.d. and n.m.d. are included in the NWHPFS matrix value. The Pythagorean set provides a concise answer by focusing just on membership and non-membership. The Table 4 displays the NWHPFDM values. The NWHPF matrices value must be computed using Eq. (22). The choice matrix is made up of $A_i(i = 1, 2, \dots, m)$, which stands for options, and $R_j(j = 1, 2, \dots, n)$, which stands for criteria.

Table 4: NWHPF decision matrix

	R_1	R_2	R_3	R_4
A_1	{(0.2, 0.4, 0.4, 0.3, 0.4, 0.5)}	{(0.5, 0.2, 0.3), (0.5, 0.5, 0.7)}	{(0.3, 0.2, 0.1), (0.7, 0.8, 0.8)}	{(0.5, 0.5, 0.6), (0.25, 0.4, 0.4)}
A_2	{(0.4, 0.5, 0.5), (0.2, 0.4, 0.5)}	{(0.2, 0.2, 0.4), (0.3, 0.35, 0.4)}	{(0.5, 0.25, 0.25), (0.5, 0.7, 0.7)}	{(0.15, 0.15, 0.1), (0.7, 0.8, 0.9)}
A_3	{(0.2, 0.25, 0.35), (0.75, 0.65, 0.6)}	{(0.15, 0.35, 0.5), (0.65, 0.55, 0.5)}	{(0.4, 0.25, 0.3), (0.55, 0.8, 0.7)}	{(0.15, 0.3, 0.5), (0.5, 0.65, 0.5)}
A_4	{(0.25, 0.2, 0.1), (0.75, 0.8, 0.9)}	{(0.55, 0.6, 0.7), (0.45, 0.3, 0.3)}	{(0.45, 0.25, 0.2), (0.5, 0.7, 0.8)}	{(0.6, 0.6, 0.5), (0.4, 0.4, 0.5)}
A_5	{(0.65, 0.6, 0.7), (0.25, 0.35, 0.25)}	{(0.1, 0.15, 0.25), (0.9, 0.8, 0.65)}	{(0.2, 0.3, 0.45), (0.75, 0.65, 0.5)}	{(0.1, 0.2, 0.2), (0.85, 0.7, 0.7)}

Eq. (23) is used to construct the score function of NWHPF m.d. and n.m.d., and the results are shown in the Table 5.

Table 5: NWHPF score matrix of membership and non-membership value

	R_1	R_2	R_3	R_4
A_1	(-0.0009, -0.0286)	(-0.0101, -0.0201)	(0.0068, -0.0116)	(-0.0108, -0.0504)
A_2	(0.0598, -0.0888)	(0.0068, -0.0425)	(-0.0096, -0.0189)	(-0.0031, -0.0122)
A_3	(0.0083, -0.0132)	(-0.0062, -0.0145)	(0.0514, -0.0291)	(0.0721, -0.0388)
A_4	(-0.0076, -0.0079)	(-0.0093, -0.0722)	(0.0338, -0.0242)	(-0.0131, -0.0144)
A_5	(0.1956, 0.0073)	(-0.0045, -0.0174)	(0.0765, -0.014)	(0.0076, -0.0112)

The NWHPF's unique score value is represented in the Table 6. This score value is utilized to determine the MCDM's additional techniques and the process of selecting the optimal anti-aging treatment. Fig. 3 depicts the NWHPF score value.

Table 6: Normal wiggly hesitant Pythagorean fuzzy score values

	R_1	R_2	R_3	R_4
A_1	0.0196	0.01	0.0184	0.0396
A_2	0.1486	0.0493	0.0093	0.0091
A_3	0.0215	0.0083	0.0805	0.1109
A_4	0.0003	0.0629	0.058	0.0013
A_5	0.1883	0.0129	0.0905	0.0188

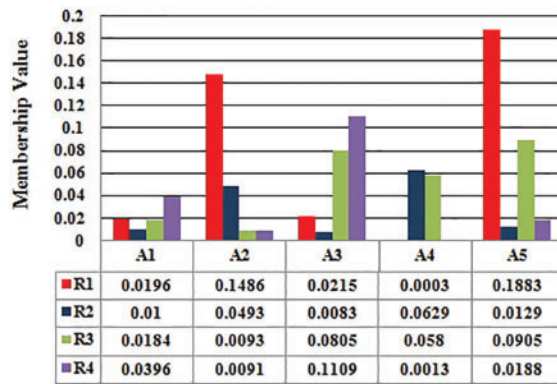


Figure 3: The score value of NWHPF

The normalized score value is calculated using score values. The Table 7 lists the normalized score values, which are seen in the Fig. 4.

Table 7: Normal wiggly hesitant Pythagorean fuzzy normalized values

	R_1	R_2	R_3	R_4
A_1	0.0518	0.0697	0.0716	0.2203
A_2	0.3928	0.3437	0.0362	0.0506
A_3	0.0568	0.0578	0.3135	0.6171
A_4	0.0008	0.4386	0.2259	0.0072
A_5	0.4977	0.0899	0.3525	0.1046

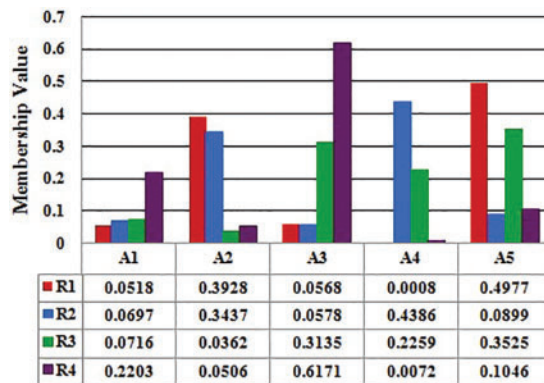


Figure 4: The normalized score value NWHPF

By using score values we have to determine the weighted entropy. By using Eq. (24) we determined the weighted entropy value. The Table 8 represents the weighted entropy values. The Fig. 5 represents the weighted criteria value of NWHPFs. The sum of the weighted criteria value is always 1.

Table 8: Entropy weights of criteria

Criteria	R_1	R_2	R_3	R_4
$(E_{j(NW)})$	0.2525	0.0656	0.0074	0.2401
$(W_{j(NW)})$	0.4464	0.1159	0.0131	0.4245

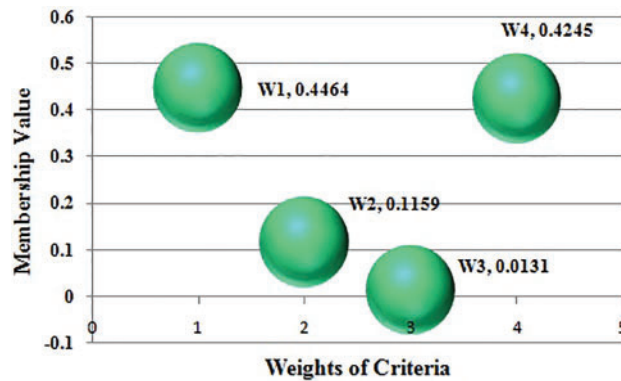


Figure 5: The weighted criteria value of NWHPF

By using the normalized score matrix, the PIS and NIS of (27) and (28) are calibrated and represented in Figs. 6 and 7.

$$\hat{V}_+ = \{0.1883, 0.0629, 0.0905, 0.1109\} \tag{52}$$

$$\hat{V}_- = \{0.0003, 0.0083, 0.0093, 0.0013\} \tag{53}$$

The utility measures matrix is calculated by using (29) and demonstrated in the Table 9.

Now we can calculate regret measures from (30). The Fig. 8 represents the result of utility and regret measure.

$$\Theta_1 = 0.8232, \Theta_2 = 0.5392, \Theta_3 = 0.5106, \Theta_4 = 0.5812, \Theta_5 = 0.2823. \tag{54}$$

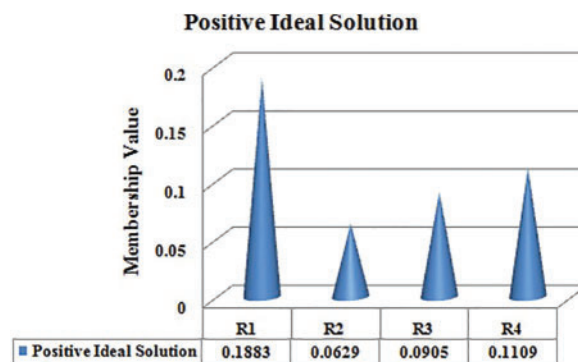


Figure 6: PIS of NWHPF

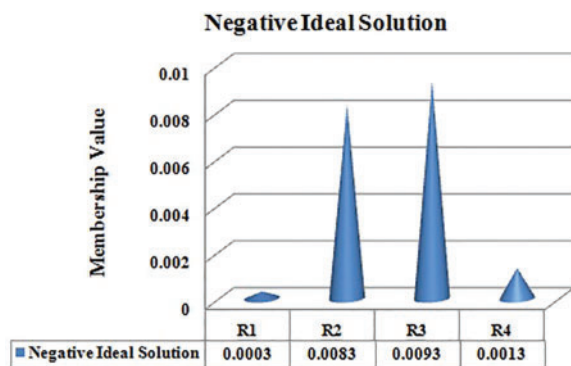


Figure 7: PIS of NWHPF

Table 9: The utility measures (Θ_{ij})

	R_1	R_2	R_3	R_4
A_1	0.3395	0.1389	0.2279	0.1169
A_2	0.0799	0.0357	0.2567	0.1669
A_3	0.3356	0.1434	0.0316	0
A_4	0.3783	0	0.0232	0.1797
A_5	0	0.1313	0	0.1510

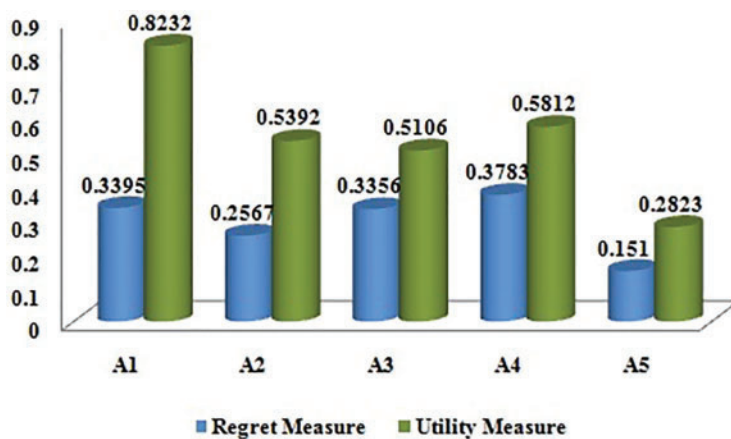


Figure 8: The result of utility and regret measure

Now regret measures (Φ) are calculated by using (23).

$$\Phi_1 = 0.3395, \Phi_2 = 0.2567, \Phi_3 = 0.3356, \Phi_4 = 0.3783, \Phi_5 = 0.1510. \tag{55}$$

Now for each alternative, index (\aleph_i) value been calculated by using Eq. (31).

$$\aleph_1 = 0.9150, \aleph_2 = 0.4703, \aleph_3 = 0.6172, \aleph_4 = 0.7766, \aleph_5 = 0. \tag{56}$$

Sort the \aleph values in decreasing order to rank the alternatives, which means,

$$A_5 > A_2 > A_3 > A_4 > A_1$$

Here, A_5 is best anti-aging treatment for skin. The final results of regret measure (Φ_i), utility measure (Θ_i) and index value (\aleph_i) are tabulated in the [Table 10](#) and shown in the [Fig. 9](#).

Table 10: The evaluation value of each alternative

	Regret measure Φ_i	Utility measure Θ_i	Index value \aleph_i	Rank
A_1	0.3395	0.8232	0.9150	V
A_2	0.2567	0.5392	0.4703	II
A_3	0.3356	0.5106	0.6172	III
A_4	0.3783	0.5812	0.7766	IV
A_5	0.1510	0.2823	0	I

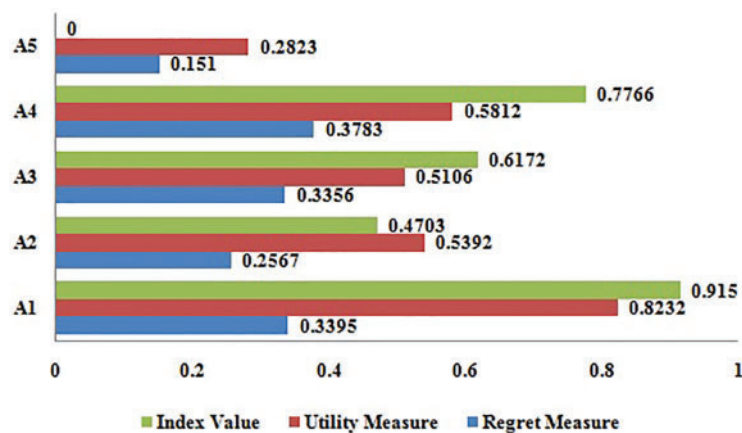


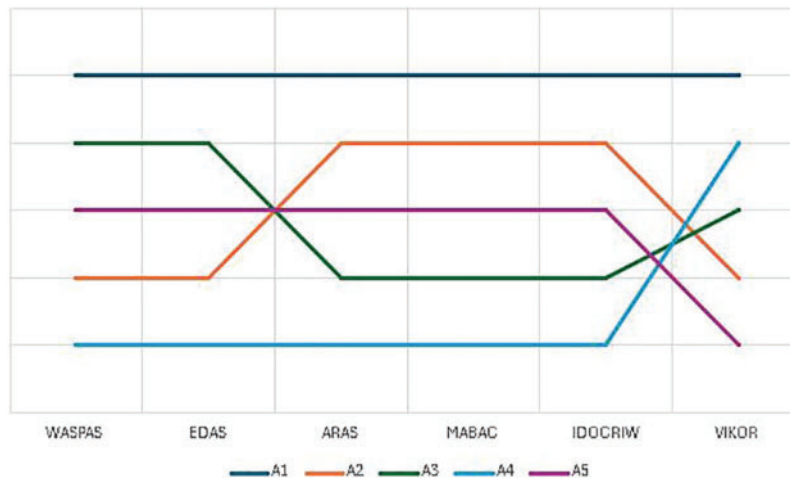
Figure 9: The result of VIKOR method

7.1 Comparative Analysis

Since MCDM is a vast and developing field, there many viable MCDM methods that can be applied to the discussed problem. A comparative analysis is performed to compare and contrast the proposed method with existing MCDM methods. The proposed method is compared with the other MCDM methods such as Weighted Aggregated Sum Product Assessment (WASPAS), Evaluation based on Distance from Average Solution (EDAS), Additive Ratio Assessment (ARAS), Multi-Attributive Border Approximation area Comparison (MABAC), Improved Deviation Objectivity based on Criteria Importance through Intercriteria Correlation (IDOCRIW). The ranking results of these methods are given in [Table 11](#). [Fig. 10](#) shows the results of the comparative analysis approaches in accordance with other existing MCDM methodologies.

Table 11: Comparative analysis

Alternatives	WASPAS	EDAS	ARAS	MABAC	IDOCRIW	VIKOR
A_1	5	5	5	5	5	5
A_2	2	2	4	4	4	2
A_3	4	4	2	2	2	3
A_4	1	1	1	1	1	4
A_5	3	3	3	3	3	1

**Figure 10:** Comparative analysis

Furthermore, the ranking outcomes of NWHPFS-MCDM approaches show minor deviations when compared to other techniques. The smallest difference is owing to the fact that criterion weights play an important role in MCDM problems. In this situation, the weighting of the criteria reflects the relative importance of the criterion.

Spearman's rank correlation analysis is performed to analyze the monotonicity of the results obtained from the proposed NWHPFS-VIKOR method. The decision matrix is formed based on expert opinions which could not be captured by generalized assumptions that are used in the other MCDM methods. This results in the low correlation of VIKOR with other methods as shown in the Fig. 11.

7.2 Sensitive Analysis

The robustness and reliability of any proposed model can be verified using the sensitive analysis. The sensitive analysis is performed by varying the weights of the criteria to check the performance of the model in each scenario. In this study, the criteria R1 and R3 are considered to be beneficial and the remaining are considered as cost criteria.

1. Case 1: Each criterion is assumed to have equal weights, thus each criterion assumes a weight of 0.25. The ranking of the alternatives is as follows: $A_5 > A_3 > A_1 > A_4 > A_2$.

- Case 2: The beneficial criteria is assumed to have 70 percent weightage and while the cost criteria is assumed to have 30 percent weightage. Thus the criteria R1 and R3 assume a value of 0.35 and R2 and R4 assume a value of 0.15, respectively. The preference order of the alternatives is given as: $A5 > A3 > A4 > A2 > A1$.

This implies that the change in weights of the criteria, i.e., the change in the influence exerted by the criteria in ranking the alternatives does not adversely affect the overall ranking. This shows the proposed model can perform well under different scenarios making it ideal for real-world applications.

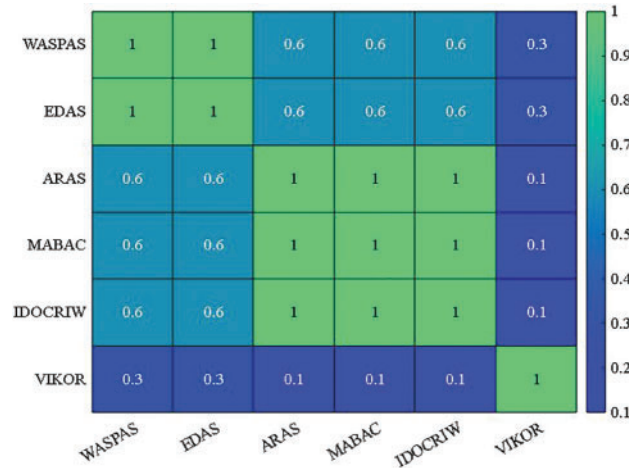


Figure 11: Spearman correlation analysis

8 Conclusion

Anti-aging medicine is defined as the early identification, prevention, and therapy of age-related disorders in the medical and commercial communities. It's not the same as treating the aging process, and there are a variety of procedures and treatments available right now. Based on performance, along with utility values, regret values, and index values, the VIKOR method offers a compromise option. This mathematical model is more suitable for evaluating anti-aging medicines in this regard. The HFS is used to deal with the unstable set theory's issue of uncertainty. HFS asked decision-makers for their thoughts on alternative criteria. We utilized the NWHFS as an expansion of the HFS. The greater information about the policymakers was delivered via a NWHFS. An MCDM is employed to an anti-aging medication in the usual wiggly reluctant fuzzy environment in this study work. Using VIKOR in a hesitant fuzzy environment, we have concluded that the optimum anti-aging treatment for the identified condition is based on our numerical evaluation. We conclude that botox injection is the best anti-aging therapy based on a ranking methodology. Further, the robustness and reliability of the method are analyzed using sensitive analysis. The comparison of the suggested methodology to current ranking systems revealed that it is consistent with other approaches. These offered procedures are the most effective anti-aging therapy options.

8.1 Limitations and Future Implications

There are a few limitations that the presented study must overcome. This study analyses five widely known anti-aging treatments based on expert opinion. While expert opinions offer insightful insights into the problem, the mindset and emotions toward these anti-aging therapies remain unknown. In

the future, the sentiments of people in selected cities can be conducted to ensure better accuracy in the present study. This proposed methodology analyzes the treatment techniques based on four major generalized criteria. This study could be further expanded by introducing sub-criteria to further scrutinize the treatment technologies. Due to the robustness of the presented method, this methodology can be applied to various fields such as robot selection, supply chain, site selection, and much more. Further, VIKOR is an objective method, a hybrid methodology combining VIKOR with a subjective method could bring a new perspective by analyzing both sides of the same coin. The NWHFS set can be combined with various other MCDM methods to accurately quantify the ambiguities and inconsistencies that often arise during the conversion of real-world problems into a mathematical model.

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