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Prioritizing Digital Health: Key Municipal Services Identified Through Fuzzy Methods

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Abstract

The integration of digital technologies into healthcare systems within municipalities has elicited a transformative change in health service delivery. This paper explores the importance of the digitalization of health services in municipalities and represents the most important services by employing fuzzy methods. The research evaluates the importance of digital transformation of several health services in municipalities by examining existing literature and employing a combination of qualitative and quantitative methods, including the Pythagorean Fuzzy CRITIC (PF-CRITIC) and Interval-Valued Pythagorean Fuzzy WASPAS (IVPF-WASPAS) methods. Key findings highlight that mobile health services and medical center services are the two most important municipal health activities regarding digital transformation. Additionally, we employed sensitivity analysis to assess the stability and reliability of the methods, thereby conducting a detailed analysis of the decision-making process. Through evidence-based strategies, municipalities can harness the power of digitalization to develop patient-centered, efficient, and responsive healthcare services. Therefore, this study contributes to a more inclusive approach to digitalization in healthcare, aiming to obtain the opinions of individuals who have experience with health activities in municipalities.

Keywords: healthcare services, municipalities, fuzzy, digitalization

1. Introduction

The convergence of digital technologies and healthcare has significantly transformed the delivery of health services in municipalities in recent years. This transition towards digitalization represents a transformative journey, promising enhanced efficiency, accessibility, and quality of healthcare provision. The integration of digital tools into health services, from electronic health records to telemedicine platforms and mobile health applications, holds immense potential to revolutionize the access, delivery, and experience of care for both patients and providers.

The emergence of digitalization faces both opportunities and challenges within the healthcare workforce. While digital technologies have the potential to streamline workflows, improve communication, and empower healthcare professionals, there is an

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obvious doubt about digital health solutions in the workforce. Addressing the concerns surrounding digital literacy, privacy, and data security is crucial to foster a culture of acceptance and readiness for digital transformation within the healthcare sector.

The digitalization of healthcare services in municipalities represents a comprehensive transformation that includes the integration of digital technologies and information systems into various aspects of healthcare. This paradigm shift varies from the digitization of medical records to include telemedicine platforms, mobile health applications, wearable devices, remote monitoring systems, and advanced analytics. Digitalization aims to improve communication between healthcare providers and individuals, improve access to care, optimize resource allocation, and improve health outcomes by streamlining processes. Accordingly, municipalities' adoption of digitalization offers the potential to improve healthcare services, making them more patient-focused, efficient, and responsive to the evolving needs of society.

This research has a combination of qualitative and quantitative approaches. The first phase comprises a literature review to synthesize existing knowledge for understanding the impact of digitalization on health services within municipalities. Subsequently, we employ the Pythagorean Fuzzy CRITIC (PF-CRITIC) method and the Interval-Valued Pythagorean Fuzzy WASPAS (IVPF-WASPAS) method to analyze data and evaluate the various aspects of digitalization in health service delivery. This integrated approach aims to provide insights for decision-making and technology development to improve health services by evaluating the digital transformation's impact on various health services in municipalities. Additionally, we used sensitivity analysis to evaluate the reliability of the model.

In light of these considerations, this research endeavors to explore the multifaceted impact of digitalization on health services within municipalities. Accordingly, by focusing on the needs and experiences of society, this paper aims to contribute to a more inclusive approach to digitalization in healthcare.

2. Literature Review

The digitalization of healthcare services in municipalities is a growing subject, focusing particularly on the impact of digitalization on public service delivery for socially disadvantaged individuals. Buchert et al. [1] emphasize the lack of empirical research examining the effects of digitalization on public health and social welfare services from the perspective of socially disadvantaged individuals and emphasize the need for more comprehensive studies in this field. So, Schou & Pors [2] discuss the shift towards self-service solutions in welfare services due to digitalization, which places the responsibility on citizens to actively seek services previously managed by professionals, raising concerns about the potential exclusion of disadvantaged individuals.

In the public sector domain, Lloyd & Payne [3] address the use of digitalization as a cost-effective method for delivering better care quality and more client-focused services, reflecting the ongoing efforts to leverage digitalization for improved public health services. Additionally, Collington [4] highlights the emergence of public sector digitalization strategies with the goal of improving services and enhancing efficiency, indicating a broader trend towards digital transformation in public service delivery.

The impact of digitalization on health care professionals and citizens is also a significant area of concern. Tiainen et al. [5] point out that digitalization poses challenges not only for health care and social welfare professionals but also for citizens, highlighting the need for comprehensive strategies to address the implications of digitalization in these sectors. Moreover, Baumgartner et al. [6] note a questioning attitude towards digital health among medical students, indicating the importance of addressing perceptions and preparedness for digitalization in the health care sector.

The literature on the digitalization of health services in municipalities is extensive and diverse, covering various aspects of digital transformation in healthcare, public health, and social welfare services. Gopal et al. [7] address the importance of digital transformation in healthcare, highlighting the integration of technologies like the Internet of Things, advanced analytics, Machine Learning, and Artificial Intelligence as key components to address challenges in healthcare. Scarano & Colfer [8] discuss the review of automated possibilities in linking active labor market policies to digitalization, considering the potential impact on employment and public services. Holm et al. [9] provide insights into the allocation of home care services by municipalities in Norway, indicating potential equity issues in the allocation system. Moreover, Collington [4] examines how digitization affects the capacity reduction of the public sector, emphasizing the need for more study on how governments might use technological advancement for the benefit of their population while keeping themselves functional during the process.

These studies provide a comprehensive overview of the multiple impacts of digitalization on health services in municipalities, addressing technological integration, service allocation, ethical considerations, and the broader implications for public sector capacity.

The implications of digitalization in the health services of municipalities have significant effects on various aspects of service delivery. Buchert et al. [1] highlight the reinforcement of social exclusion through the digitalization of public health and social welfare services, particularly for disadvantaged individuals. This underscores the need for comprehensive strategies to address the potential negative impact of digitalization on vulnerable populations. Additionally, Schou & Pors [2] emphasize the qualitative study of exclusion in digitalized welfare, shedding light on the impact of digitalization on welfare institutions and professional practices, particularly in the context of disadvantaged individuals. These findings underscore the complex interplay between digitalization, public sector capacity, and citizen welfare, emphasizing the need for careful consideration of the implications of digitalization in health services.

Additionally, Holm et al. [9] provide insights into the allocation of home care services by municipalities, indicating potential fairness issues in the allocation system. This highlights the need for equitable and transparent digitalized processes for service allocation to ensure fair access to health services. Furthermore, Shava & Vyas-Doorgapersad [10] highlight the need for comprehensive digital infrastructure to support effective service delivery, pointing out that municipalities are unable to foster digital innovations to improve public service delivery due to a lack of digital skills, infrastructure, accessibility, and connectivity.

The integration of qualitative and quantitative methods in studying the impact of digitalization on health services is well-supported by existing literature. O'cathain [24] used a mixed methods approach to evaluate the impact of health information systems in UK. Their use of both qualitative interviews and quantitative data analysis provided a comprehensive understanding of the system's effectiveness, similar to our approach.

Moreover, the application of multi-criteria decision-making (MCDM) methods, such as PF-CRITIC and IVPF-WASPAS, has been validated in various fields, including health services. Haktanir and Kahraman [25] utilized the CRITIC method to assess the performance of healthcare providers, and Wang et al. [26] applied PF-CRITIC method to select suppliers, while Gedikli and Cayir Ervural [27] applied the IVPF-WASPAS method to prioritize COVID-19 vaccine alternatives. These studies demonstrate the robustness and applicability of these methods, supporting our choice of methodology for evaluating digitalization impacts.

The literature underscores the need for more empirical research on the effects of digitalization on public health and social welfare services. There is also a growing focus on the challenges and implications of digitalization for health care professionals and citizens, highlighting the need for comprehensive strategies to address the impact of digitalization on health services in municipalities.

3. Preliminaries

3.1. Pythagorean Fuzzy Sets

Yager [11] proposed Pythagorean Fuzzy Sets (PFS) based on the logic of Intuitionistic Fuzzy Sets (IFS), which was developed by Atanassov [11], in 2013. In IFS, the sum of the degrees of membership (μ) and non-membership (υ) of an element in a set is in the range [0,1]. In the PFS, however, the sum of the squares of the degrees of membership and non-membership of an element cannot exceed 1. The PFS, as an extension of the IFS, allow experts to make evaluations on a wider scale [12] [13]

For example, a decision maker may determine the membership degree of an alternative to be √3/2 and the non-membership degree to be 1/2. In this case, since the sum of the membership and non-membership degrees exceeds 1, the use of IFS is not appropriate. However, since the condition $0 \leq (\frac{\sqrt{3}}{2})^2 + (\frac{1}{2})^2 \leq 1$ is satisfied, PFS can be used. In this regard, instead of asking decision makers to adjust their decisions to fit within the limits of IFS, PFS can be used. It is claimed that PFS have more capability than IFS in modeling uncertainty for decision-making problems [13].

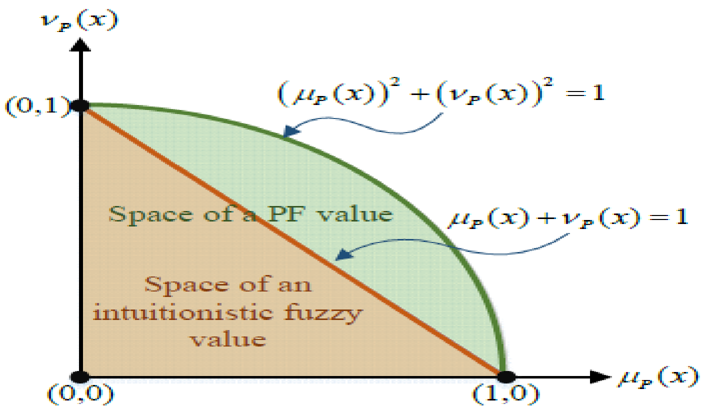

Figure 1. Comparison of PFS and IFS [12]

The comparison between IFS and PFS is provided in Figure 1. According to this figure, it is observed that PFS encompass IFS. PFS differ from IFS in that PFS allow the sum of membership and non-membership degrees to exceed 1, but the sum of their squares cannot exceed 1 [12].

Definition: Let X be the universal set and P be the Pythagorean fuzzy set object of this universal set. P object is defined as seen in Equation (1) [14]:

$$P = \left\{ < x, P\left(\mu_p(x), \upsilon_p(x)\right) > \mid x \in X \right\} \tag{1}$$

Here, $\mu_p(x): X \mapsto [0,1]$ represents the membership degree, and $v_p(x): X \mapsto [0,1]$ represents the non-membership degree.

The sum of the squares of the membership and non-membership degrees of an element x in the universal set X, belonging to the subset P, as seen in Equation (2), does not exceed 1 [14].

$$0 \leq \mu_p(x)^2 + \upsilon_p(x)^2 \leq 1 \tag{2}$$

3.1.1. Interval-Valued Pythagorean Fuzzy Sets

Peng and Yang [15] expressed fuzzy sets as Interval-Valued. Accordingly, membership and non-membership degrees are defined within lower and upper bound intervals. These sets are named as Interval-Valued Pythagorean Fuzzy Sets (IVPFS).

An Interval-Valued Pythagorean Fuzzy Set p̃ in the universe X is defined as follows: if x is an element, μ represents the membership degree, υ represents the non-membership degree, and L and U represent the lower and upper bounds of these degrees, respectively, as shown in Equation (3). The sum of the squares of membership and non-membership degrees does not exceed 1, as illustrated in Equation (4) [15] [16].

$$\tilde{p} = \left\{ \left(x, \left[\mu_{\tilde{p}}^{L}(x), \mu_{\tilde{p}}^{U}(x)\right], \left[\upsilon_{\tilde{p}}^{L}(x), \upsilon_{\tilde{p}}^{U}(x)\right]\right); x \in X \right\} \tag{3}$$

$$0 \leq \left(\mu_{\tilde{p}}(x)\right)^2 + \left(\upsilon_{\tilde{p}}(x)\right)^2 \leq 1 \tag{4}$$

4. Methodology

4.1. The Pythagorean Fuzzy CRITIC (PF-CRITIC) Method

The Pythagorean Fuzzy CRITIC (PF-CRITIC) method, introduced into the literature by Peng, Zhang, and Luo in 2020 [17], is an adaptation of the classical CRITIC method to the Pythagorean fuzzy numbers. The process flow diagram of the PF-CRITIC method is modeled in Figure 2.

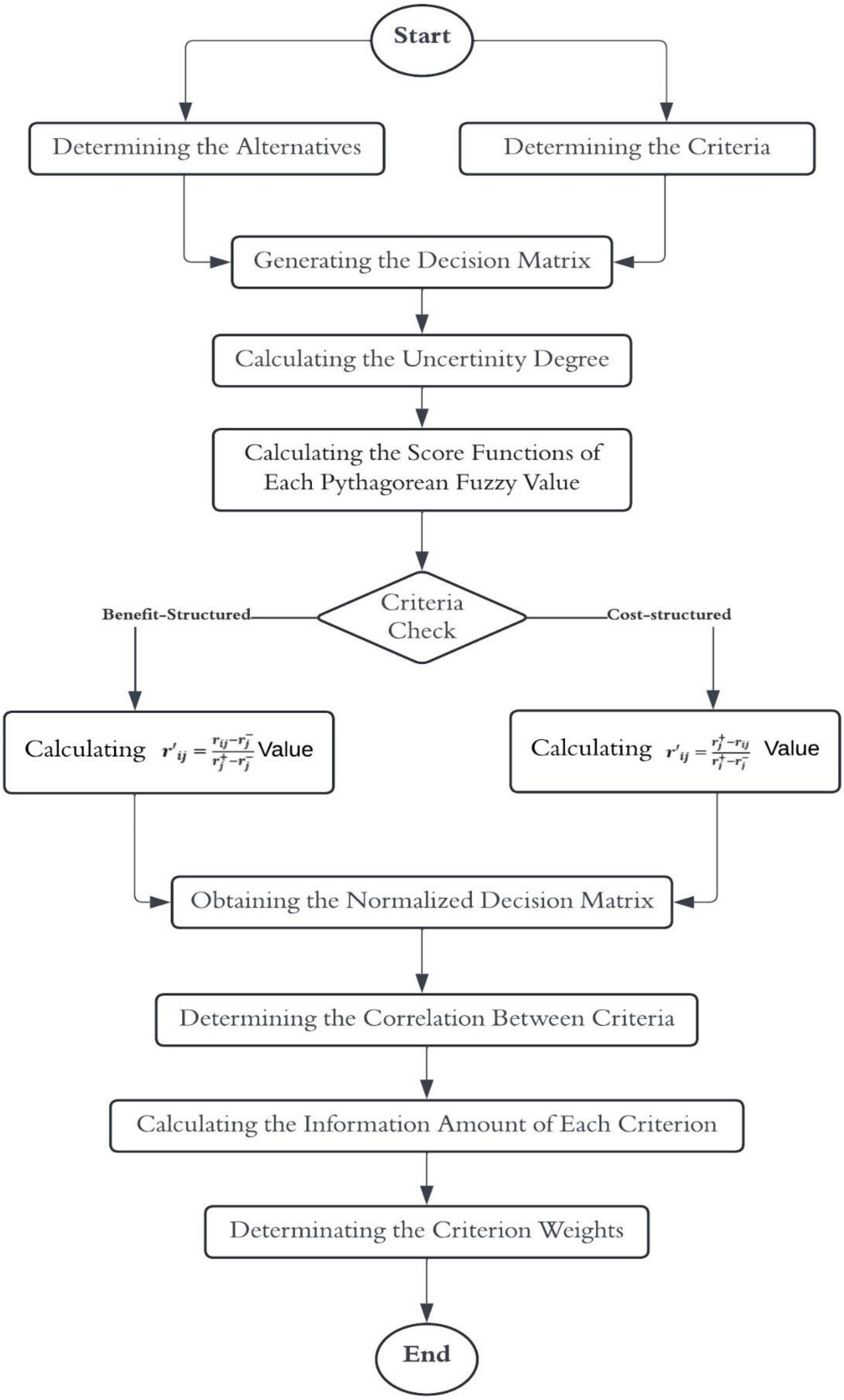

Figure 2. The Process Flow Diagram of the PF-CRITIC Method

The steps of the PF-CRITIC method are presented below [18]:

Step 1: Formation of the Decision Matrix: We construct the initial decision matrix according to Equation (5), where m denotes the number of candidate alternatives and n represents the number of evaluation criteria. Here, for i∈{1, 2,…,m} and j∈{1,2,…,n}), X_ij signifies the performance of the i-th alternative with respect to the j-th criterion.

$$X = [x_{ij}]_{mxn} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \quad (5)$$

Step 2: Calculation of Uncertainty Degree: The uncertainty degree of each fuzzy value, denoted as $p_{ij}(\mu_{ij}, \upsilon_{ij})$, representing the Pythagorean fuzzy value of the i-th alternative with respect to the j-th criterion, is calculated using Equation (6).

$$\prod_{ij} = \sqrt{1 - \mu_{ij}^2 - \upsilon_{ij}^2},\ (i = 1,2,\dots,m; j = 1,2,\dots,n)\ and\ 0 \leq (\mu_{ij})^2 + (\upsilon_{ij})^2 \leq 1 \quad (6)$$

Step 3: Calculation of Score Functions for Each Pythagorean Fuzzy Value: For a score matrix $R = (r_{ij})_{mxn}$, the score functions for each fuzzy value are calculated as shown in Equation (7).

$$r_{ij} = \mu_{ij}^2 - \upsilon_{ij}^2 - ln(1 + \prod_{ij}^2), \quad (i = 1,2,\dots,m;\ j = 1,2,\dots,n) \quad (7)$$

Step 4: Normalization Process (Conversion of the Score Matrix R to an Orthonormal Pythagorean Fuzzy Matrix): The transformation process, resulting in the matrix $R' = (r'_{ij})_{mxn}$, is conducted using Equation (8) for benefit criteria and Equation (9) for cost criteria.

For benefit criteria; $r'_{ij} = \frac{r_{ij} - r_j^-}{r_j^+ - r_j^-} \quad r_j^- = min_i r_{ij}\ ve\ r_j^+ = max_i r_{ij}$ (8)

For cost criteria; $r'_{ij} = \frac{r_j^+ - r_{ij}}{r_j^+ - r_j^-} \quad r_j^- = min_i r_{ij}\ ve\ r_j^+ = max_i r_{ij}$ (9)

Step 5: Calculation of Criterion Standard Deviations: The standard deviation calculation is determined using Equation (10).

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^m (r'_{ij} - \bar{r}_j)^2}{m}} \quad \text{Here } \bar{r}_j = \frac{\sum_{i=1}^m r'_{ij}}{m} \quad (10)$$

Step 6: Determination of Inter-Criteria Correlation: The correlation value between the j-th criterion and the k-th criterion is calculated using Equation (11).

$$p_{jk} = \frac{\sum_{i=1}^m (r'_{ij} - \bar{r}_j)(r'_{ik} - \bar{r}_k)}{\sqrt{\sum_{i=1}^m (r'_{ij} - \bar{r}_j)^2 \sum_{i=1}^m (r'_{ik} - \bar{r}_k)^2}} \quad (k, j = 1,2,\dots,n) \quad (11)$$

Step 7: Calculation of Information Amount for Each Criterion: The calculation of the information amount is performed using Equation (12).

$$C_j = \sigma_j \sum_{k=1}^n (1 - p_{jk}) \quad (k, j = 1,2,\dots,n) \quad (12)$$

The larger the value of C_j in Equation (12), the more information a specific criterion contains. Therefore, the weight of this evaluation criterion is greater than the weights of other criteria.

Step 8: Determination of Criterion Weights: Criterion weights are determined using Equation (13).

$$w_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \quad (j = 1,2,\ldots,n) \tag{13}$$

4.2. Interval-Valued Pythagorean Fuzzy WASPAS (IVPF-WASPAS) Method

Turskis, Zavadskas, and their colleagues integrated fuzzy logic with the WASPAS method for construction site selection, introducing the fuzzy WASPAS method to the literature in 2015 [19].

The Interval-Valued Pythagorean Fuzzy WASPAS (IVPF-WASPAS) method, introduced to the literature by Ilbahar and Kahraman in 2018, resulted from the adaptation of Pythagorean fuzzy numbers to the classical WASPAS method [20]. They [20] evaluated the performance of retail stores in their study. The process flow diagram of the IVPF-WASPAS method is modeled in Figure 3.

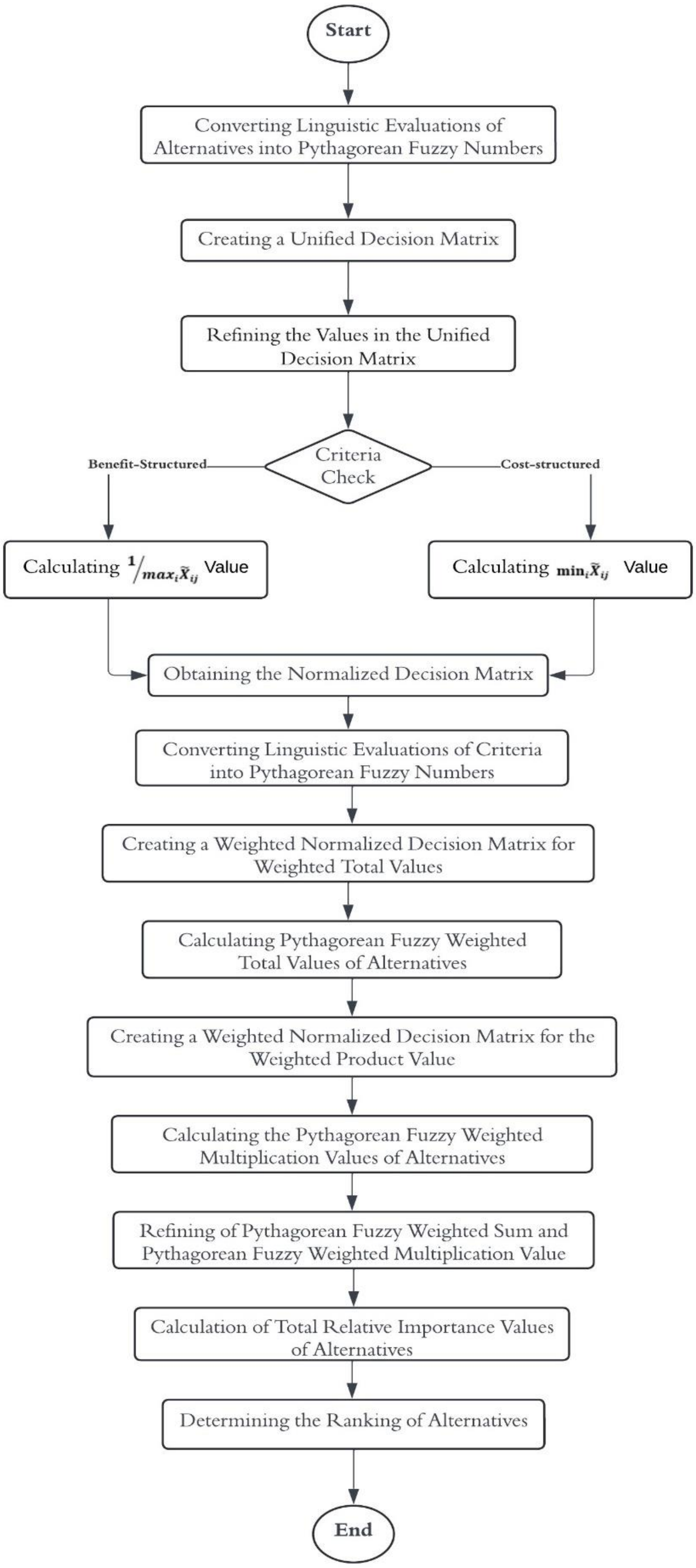

Figure 3. Process Flow Diagram of the IVPF-WASPAS Method

In the IVPF-WASPAS method, the implementation steps are as follows [18]:

Step 1: Formation of the Combined Decision Matrix: Decision-makers gather opinions about alternatives using linguistic expressions. These expressions are converted into Pythagorean fuzzy numbers. The arithmetic mean (IVPFWA) of matrices composed of Pythagorean fuzzy numbers from each expert is calculated using Equation (14), resulting in the creation of the combined decision matrix $\tilde{X}_{ij}$. Here,w_i represents the weight of the criterion.

$$IVPFWA(\tilde{p}_1, \tilde{p}_2, \dots, \tilde{p}_n) = \left(\left[\sum_{i=1}^{n} w_i \mu_i^L, \sum_{i=1}^{n} w_i \mu_i^U\right], \left[\sum_{i=1}^{n} w_i \upsilon_i^L, \sum_{i=1}^{n} w_i \upsilon_i^U\right]\right) \quad (14)$$

Step 2: Obtaining the Normalized Decision Matrix in the Form of Pythagorean Fuzzy Numbers: The defuzzification formula in Equation (15) defuzzifies the values in the resulting combined decision matrix. The "p" value in Equation (15) is an intermediate variable that clarifies the Pythagorean fuzzy number. This formula makes the calculations necessary for the defuzzification process and reduces the uncertainties in the decision matrix. If the criterion is benefit-based after the defuzzification process, Equation (16); If it is cost based, Equation (17) is used. Equation (18) is $1/_{max_i p_{ij}}$; for benefit-based criteria; for cost-based criteria, it is applied for all values in the combined decision matrix using $min_i p_{ij}$ .Thus, the normalized decision matrix ($\bar{\bar{X}}_{ij}$) is obtained.

$$p = \frac{\mu^L + \mu^U + \sqrt{1-(\upsilon^L)^2} + \sqrt{1-(\upsilon^U)^2} + \mu^L\mu^U - \sqrt{\sqrt{1-(\upsilon^L)^2}\sqrt{1-(\upsilon^U)^2}}}{4} \quad (15)$$

For benefit criteria; $\bar{\bar{X}}_{ij} = \frac{\tilde{X}_{ij}}{max_i p_{ij}}$ (16)

For cost criteria; $\bar{\bar{X}}_{ij} = \frac{\min_i . p_{ij}}{\tilde{X}_{ij}}$ (17)

$$\lambda\tilde{p} = \left(\left[\sqrt{1-(1-(\mu^L)^2)^\lambda}, \sqrt{1-(1-(\mu^U)^2)^\lambda}\right], \left[(\upsilon^L)^\lambda, (\upsilon^U)^\lambda\right]\right) \quad (18)$$

Equation (18) facilitates the transformation of Pythagorean fuzzy numbers using a specific λ coefficient. The λ coefficient is a parameter used during the defuzzification of Pythagorean fuzzy numbers. This transformation reduces uncertainty among the numbers and provides the necessary adjustment for normalization. Equations (16) and (17) then utilize these transformed values to normalize the decision matrix according to benefit and cost criteria. This process aims to make Pythagorean fuzzy numbers comparable and consistent within the decision-making framework.

In summary, the values of the combined decision matrix are defuzzified using Equation 15. Subsequently, Equation 16 is applied for benefit-based criteria using $1/_{max_i p_{ij}}$, and Equation 17 is used for cost-based criteria employing $min_i p_{ij}$. During this process, the p_{ij} values represent previously defuzzified values. The λ values specified in Equation 18 are based on $1/_{max_i p_{ij}}$ and $min_i p_{ij}$. μ^L, μ^U, υ^L, and υ^U denote the Pythagorean fuzzy number values in the combined decision matrix. These computational steps ensure the comparability and normalization of values in decision-making processes involving Pythagorean fuzzy numbers.

Step 3: Conversion of Linguistic Evaluations for Criteria into Pythagorean Fuzzy Numbers: The linguistic expressions regarding the importance levels of criteria provided by decision-makers are transformed into Pythagorean fuzzy numbers.

Step 4: Obtaining the Pythagorean Fuzzy Weighted Sum Values of Alternatives: The weighted sum matrix, which is the first part of the WASPAS method, is obtained through Equation (19). Here, w_j represents the weight of the criterion.

$$\tilde{Q}_i^{(1)} = \sum_{j=1}^{n} \bar{\bar{X}}_{ij} \, . \, w_j \tag{19}$$

Before Equation (19) can be applied, the values in the normalized decision matrix must first be multiplied by the criterion weights through Equation (20). These values are then summed with each other in Equation (21) to obtain the Pythagorean fuzzy weighted sum values of alternatives.

$$\tilde{p}_1 \otimes \tilde{p}_2 = \left([\mu_1^L \mu_2^L, \mu_1^U \mu_2^U], \left[\sqrt{(v_1^L)^2 + (v_2^L)^2 - (v_1^L)^2 (v_2^L)^2}, \sqrt{(v_1^U)^2 + (v_2^U)^2 - (v_1^U)^2 (v_2^U)^2}\right]\right) \tag{20}$$

$$\tilde{p}_1 \oplus \tilde{p}_1 = \left(\left[\sqrt{(\mu_1^L)^2 + (\mu_2^L)^2 - (\mu_1^L)^2 (\mu_2^L)^2}, \sqrt{(\mu_1^U)^2 + (\mu_2^U)^2 - (\mu_1^U)^2 (\mu_2^U)^2}\right], [v_1^L v_2^L, v_1^U v_2^U]\right) \tag{21}$$

Step 5: Obtaining the Pythagorean Fuzzy Weighted Product Values of Alternatives: The weighted product matrix of the WASPAS method is obtained using Equation (22). Before Equation (22) can be applied, Equation (23) is first applied to the values in the normalized decision matrix and the criterion weights. Then, by multiplying these values with each other in Equation (20), the Pythagorean fuzzy weighted product values of alternatives are obtained.

$$\tilde{Q}_i^{(2)} = \prod_{j=1}^{n} \left(\bar{\bar{X}}_{ij}\right)^{w_j} \tag{22}$$

$$p^{\lambda} = \left(\left[(\mu^L)^{\lambda}, (\mu^U)^{\lambda}\right], \left[\sqrt{1 - (1 - (v^L)^2)^{\lambda}}, \sqrt{1 - (1 - (v^U)^2)^{\lambda}}\right]\right) \tag{23}$$

Step 6: Determination of the Total Relative Importance Values of Alternatives: The Pythagorean fuzzy weighted sum and weighted product values are normalized using Equation (15). According to the WASPAS method, the weighted sum values and weighted product values of alternatives are integrated through Equation (24). Thus, the total relative importance value (Q_i) of alternatives is obtained, providing a single value for decision-making. Subsequently, the obtained values are weighted and summed using the λ coefficient. The λ coefficient represents the importance levels assigned to two values and should take a value between 0 and 1.

$$Q_i = \lambda Q_i^{(1)} + (1 - \lambda) Q_i^{(2)} = \lambda \sum_{j=1}^{n} \bar{X}_{ij} . w_j + (1 - \lambda) \prod_{j=1}^{n} (\bar{X}_{ij})^{w_j} \tag{24}$$

Step 7: Determination of Alternative Rankings: Alternatives are ranked based on their total relative importance values. The alternative with the highest total relative importance value is preferred.

5. Case Study

The study employed Fuzzy Multi-Criteria Decision Making (FMCDM) methods, specifically utilizing PF-CRITIC for criteria weighting and IVPF-WASPAS for simultaneous alternative ranking. Three decision-makers assessed the following alternatives: "Home Healthcare Services", "Medical Centers", "Psychological Counseling Centers", "Elderly Services", "Healthy Nutrition Support" and "Mobile Healthcare Services".

Five criteria were established to evaluate the digitization of healthcare services: "Urgency and Importance Level", "Social Needs and Demands", "Accessibility and Inclusivity", "Efficiency and Cost Effectiveness" and "Technological Infrastructure and Capabilities".

Some criteria considered in the decision-making process are benefit-oriented depending on the problem's nature, while others may focus on cost. Decision-makers aim to maximize benefit-oriented criteria and minimize cost-oriented ones.

The reason these criteria—"Urgency and Importance Level," "Social Needs and Demands", "Accessibility and Inclusivity", "Efficiency and Cost Effectiveness" and "Technological Infrastructure and Capabilities"—are benefit-oriented is due to the high demand from decision-makers in achieving their objectives. Essentially, decision-makers perceive these criteria as representing positive attributes and seek to maximize their value.

5.1 The Implementation of the PF-CRITIC Method

Step 1: Table 1 displays the Pythagorean Fuzzy values utilized for weighting the criteria in the PF-CRITIC method.

Table 1. The Nine-Point Pythagorean Fuzzy Linguistic Variables Scale Used to Evaluate Alternatives in Terms of Criteria [23]

Language Terms	The Corresponding Pythagorean Fuzzy Number $(\boldsymbol{u}.\boldsymbol{v})$
Extremely Low (EL)	(0.10,0.99)
Very Little (VL)	(0.10,0.97)
Little (L)	(0.25,0.92)
Middle Little (ML)	(0.40,0.87)
Middle (M)	(0.50,0.80)
Middle High (MH)	(0.60,0.71)
Big (B)	(0.70,0.60)
Very Tall (VT)	(0.80,0.44)
Tremendously High (TH)	(0.10,0.00)

Utilizing Equation (5), Tables 2, 3, and 4 present the fuzzy decision matrices created for each decision-maker.

Table 2. Fuzzy Decision Matrix for Decision Maker-1

Alternatives	Criteria				
	Urgency and Importance Level	Social Needs and Demands	Accessibility and Inclusivity	Efficiency and Cost Effectiveness	Technological Infrastructure and Capabilities
Home Health Services	M	B	B	B	MH
Medical Centers	B	TH	VT	B	VT
Psychological Counseling Centers	MH	B	VT	VT	MH
Elderly Services	MH	B	B	B	M
Healthy Nutrition Support	M	M	B	VT	B
Mobile Health Services	VT	VT	TH	TH	TH

Table 3. Fuzzy Decision Matrix for Decision Maker-2

Alternatives	Criteria				
	Urgency and Importance Level	Social Needs and Demands	Accessibility and Inclusivity	Efficiency and Cost Effectiveness	Technological Infrastructure and Capabilities
Home Health Services	L	B	VL	M	VL
Medical Centers	M	ML	VT	ML	L
Psychological Counseling Centers	M	B	VL	VT	L
Elderly Services	M	VT	L	MH	M
Healthy Nutrition Support	MH	B	MH	B	ML
Mobile Health Services	B	MH	EL	VT	TH

Table 4. Fuzzy Decision Matrix for Decision Maker-3

Alternatives	Criteria				
	Urgency and Importance Level	Social Needs and Demands	Accessibility and Inclusivity	Efficiency and Cost Effectiveness	Technological Infrastructure and Capabilities
Home Health Services	EL	ML	M	VL	TH
Medical Centers	EL	VT	MH	ML	M
Psychological Counseling Centers	EL	VL	B	EL	ML
Elderly Services	EL	B	VT	VT	MH
Healthy Nutrition Support	EL	MH	EL	B	VT
Mobile Health Services	VL	M	ML	MH	B

In Table 5, the Pythagorean fuzzy number versions of the linguistic terms used in the fuzzy decision matrix for decision maker-1 in Table 2 have been presented. Similar procedures were applied for decision maker-2 and decision maker-3 using Tables 3 and 4 respectively.

Table 5. The Pythagorean Fuzzy Number Counterparts of The Fuzzy Decision Matrix for Decision Maker-1

Alternatives	Criteria									
	Urgency and Importance Level		Social Needs and Demands		Accessibility and Inclusivity		Efficiency and Cost Effectiveness		Technological Infrastructure and Capabilities	
Home Health Services	0.5	0.8	0.7	0.6	0.7	0.6	0.7	0.6	0.6	0.71
Medical Centers	0.7	0.6	0.1	0	0.8	0.44	0.7	0.6	0.8	0.44
Psychological Counseling Centers	0.6	0.71	0.7	0.6	0.8	0.44	0.8	0.44	0.6	0.71
Elderly Services	0.6	0.71	0.7	0.6	0.7	0.6	0.7	0.6	0.5	0.8
Healthy Nutrition Support	0.5	0.8	0.5	0.8	0.7	0.6	0.8	0.44	0.7	0.6
Mobile Health Services	0.8	0.44	0.8	0.44	0.1	0	0.1	0	0.1	0

Step 2: The uncertainty degree of each Pythagorean fuzzy value has been calculated using Equation (6). The uncertainty matrix calculated for decision maker-1 is presented in Table 6. Similar procedures have been applied for decision makers 2 and 3 as well.

Table 6. Uncertainty Matrix for Decision Maker-1

Alternatives	Criteria				
	Urgency and Importance Level	Social Needs and Demands	Accessibility and Inclusivity	Efficiency and Cost Effectiveness	Technological Infrastructure and Capabilities
Home Health Services	0.332	0.387	0.387	0.387	0.369
Medical Centers	0.387	0.995	0.408	0.387	0.408
Psychological Counseling Centers	0.369	0.387	0.408	0.408	0.369
Elderly Services	0.369	0.387	0.387	0.387	0.332
Healthy Nutrition Support	0.332	0.332	0.387	0.408	0.387
Mobile Health Services	0.408	0.408	0.995	0.995	0.995

Step 3: The score function of each Pythagorean fuzzy value has been found using Equation (7). The score matrix for decision maker-1 is presented in Table 7. Similar procedures have been applied for decision makers 2 and 3 as well.

Table 7. Score Matrix for Decision Maker-1

Alternatives	**Criteria**				
	Urgency and Importance Level	Social Needs and Demands	Accessibility and Inclusivity	Efficiency and Cost Effectiveness	Technological Infrastructure and Capabilities
Home Health Services	-0.494	-0.010	-0.010	-0.010	-0.272
Medical Centers	-0.010	-0.678	0.292	-0.010	0.292
Psychological Counseling Centers	-0.272	-0.010	0.292	0.292	-0.272
Elderly Services	-0.272	-0.010	-0.010	-0.010	-0.494
Healthy Nutrition Support	-0.494	-0.494	-0.010	0.292	-0.010
Mobile Health Services	0.292	0.292	-0.678	-0.678	-0.678
Maximum	0.292	0.292	0.292	0.292	0.292
Minimum	-0.494	-0.678	-0.678	-0.678	-0.678

Step 4: The score matrix has been transformed into an orthonormal Pythagorean fuzzy matrix for the benefit-oriented criteria using Equation (8). The orthonormal Pythagorean fuzzy matrix (normalization matrix) for decision maker-1 is presented in Table 8. Similar procedures have been applied for decision makers 2 and 3 as well.

Table 8. Orthonormal Pythagorean Fuzzy Matrix for Decision Maker-1 (Normalization matrix)

Alternatives	**Criteria**				
	Urgency and Importance Level	Social Needs and Demands	Accessibility and Inclusivity	Efficiency and Cost Effectiveness	Technological Infrastructure and Capabilities
Home Health Services	0.000	0.689	0.689	0.689	0.419
Medical Centers	0.616	0.000	1.000	0.689	1.000
Psychological Counseling Centers	0.283	0.689	1.000	1.000	0.419
Elderly Services	0.283	0.689	0.689	0.689	0.189
Healthy Nutrition Support	0.000	0.189	0.689	1.000	0.689
Mobile Health Services	1.000	1.000	0.000	0.000	0.000

Step 5: According to the values in Table 8, the standard deviations of the criteria for decision maker-1 are determined using Equation (10). In Table 9, the standard deviation values for decision maker-1 were calculated using the "STDEV ()" function in Excel. Similar procedures have been applied for decision makers 2 and 3 as well.

Table 9. The Standard Deviation Values of The Criteria for Decision Maker-1

Criteria	Urgency and Importance Level	Social Needs and Demands	Accessibility and Inclusivity	Efficiency and Cost Effectiveness	Technological Infrastructure and Capabilities
σ	0.353	0.340	0.334	0.334	0.324

Step 6: The correlation value between criteria is calculated using Equation (11). To apply Equation (11), the correlation matrix for decision maker-1 was created using the "CORREL ()" function in Excel, and it is presented in Table 10. Similar procedures have been applied for decision makers 2 and 3 as well.

Table 10. Correlation Matrix for Decision Maker-1

Criteria	Urgency and Importance Level	Social Needs and Demands	Accessibility and Inclusivity	Efficiency and Cost Effectiveness	Technological Infrastructure and Capabilities
Urgency and Importance Level	1.000	0.287	-0.545	-0.817	-0.291
ocial Needs and Demands	0.287	1.000	-0.645	-0.558	-0.961
Accessibility and Inclusivity	-0.545	-0.645	1.000	0.855	0.726
Efficiency and Cost Effectiveness	-0.817	-0.558	0.855	1.000	0.577
Technological Infrastructure and Capabilities	-0.291	-0.961	0.726	0.577	1.000

Step 7: The amount of information provided by each criterion (useful information value) is calculated using Equation (12). The information amount of the criteria for decision maker-1 is presented in Table 11. Similar procedures have been applied for decision makers 2 and 3 as well.

Table 11. Information Value of Criteria for Decision Maker-1

Criteria	Urgency and Importance Level	Social Needs and Demands	Accessibility and Inclusivity	Efficiency and Cost Effectiveness	Technological Infrastructure and Capabilities
c	1.892	1.997	1.204	1.315	1.281

Step 8: The weights of the criteria for each decision-maker are calculated using Equation (13). The weights of the criteria for decision maker-1 have been presented in Table 12 using Equation (13). Similar procedures have been applied for decision makers 2 and 3 as well.

Table 12. Weights of Criteria for Decision Maker-1

Criteria	Urgency and Importance Level	Social Needs and Demands	Accessibility and Inclusivity	Efficiency and Cost Effectiveness	Technological Infrastructure and Capabilities
w	0.246	0.260	0.157	0.171	0.167
Prioritization	2	1	5	3	4

Upon examining the results obtained from the PF-CRITIC method:

For decision maker-1, the importance ranking of criteria is as follows: "Social Needs and Demands" > "Urgency and Importance Level" > "Efficiency and Cost Effectiveness" > "Technological Infrastructure and Capabilities" > "Accessibility and Inclusivity".

For decision maker-2, the importance ranking of criteria is as follows: "Accessibility and Inclusivity" > "Social Needs and Demands" > "Efficiency and Cost Effectiveness" > "Technological Infrastructure and Capabilities" > "Urgency and Importance Level".

For decision maker-3, the importance ranking of criteria is as follows: "Accessibility and Inclusivity" > "Urgency and Importance Level" > "Technological Infrastructure and Capabilities" > "Social Needs and Demands" > "Efficiency and Cost Effectiveness".

As observed, for decision maker-2 and decision maker-3, the "Accessibility and Inclusivity" criterion is the most important factor, while for decision maker-1, this criterion is determined as the least prioritized factor. For decision maker-1 and decision maker-3, the second priority factor is "Urgency and Importance Level", whereas for decision maker-2, this criterion is determined as the least prioritized factor. For decision maker-1 and decision maker-2, the third priority factor is "Efficiency and Cost Effectiveness", while for decision maker-3, this criterion is determined as the least prioritized factor. For decision maker-1 and decision maker-2, the fourth priority factor is "Technological Infrastructure and Capabilities".

5.2 The Implementation of the IVPF-WASPAS Method

Step 1: The comparison scale used in linguistic evaluations about alternatives in the IVPF-WASPAS method is provided in Table 13.

Table 13. Comparison Scale for Evaluating Alternatives [17]

Linguistic Terms		**IVPF Numbers**			
		μ^L	μ^U	v^L	v^U
CCI	Extremely good	0.8	0.9	0.1	0.2
CI	Very good	0.7	0.8	0.2	0.3
I	Good	0.6	0.7	0.3	0.4
O	Fair	0.5	0.6	0.3	0.5
K	Poor	0.3	0.4	0.6	0.7
CK	Very poor	0.2	0.3	0.7	0.8
CCK	Extremely poor	0.1	0.2	0.8	0.9

Decision maker-1, decision maker-2, and decision maker-3 provided their opinions regarding the alternatives using linguistic expressions. Tables 14, 15, and 16 present the relevant information for each decision maker, respectively.

Table 14. Linguistic Terms Used by Decision Maker-1 to Rank The Importance of Alternatives

Alternatives	**Criteria**				
	Urgency and Importance Level	Social Needs and Demands	Accessibility and Inclusivity	Efficiency and Cost Effectiveness	Technological Infrastructure and Capabilities
Home Health Services	I	CI	CCI	CI	CCI
Medical Centers	CI	CCI	CI	CI	CCI
Psychological Counseling Centers	I	I	CI	O	I
Elderly Services	CI	CI	I	O	CI
Healthy Nutrition Support	I	O	CI	O	I
Mobile Health Services	CCI	CI	CCI	CCI	CCI

Table 15. Linguistic Terms Used by Decision Maker-2 to Rank the Importance of Alternatives

Alternatives	**Criteria**				
	Urgency and Importance Level	Social Needs and Demands	Accessibility and Inclusivity	Efficiency and Cost Effectiveness	Technological Infrastructure and Capabilities
Home Health Services	CI	I	O	K	CK
Medical Centers	CCI	CCI	CI	CCK	O
Psychological Counseling Centers	O	I	CI	I	CK
Elderly Services	CI	CI	CI	O	CK
Healthy Nutrition Support	O	O	O	CI	I
Mobile Health Services	CCI	CI	CCI	CCI	CCI

Table 16. Linguistic Terms Used by Decision Maker-3 to Rank the Importance of Alternatives

Alternatives	Criteria				
	Urgency and Importance Level	Social Needs and Demands	Accessibility and Inclusivity	Efficiency and Cost Effectiveness	Technological Infrastructure and Capabilities
Home Health Services	CCK	CI	CK	CCI	CI
Medical Centers	CK	CCI	CCI	CI	CK
Psychological Counseling Centers	CI	K	CK	CK	CCI
Elderly Services	CI	CK	CCI	CCI	CI
Healthy Nutrition Support	CK	CI	CI	CK	CCK
Mobile Health Services	CK	I	CK	CI	K

The linguistic expressions in Tables 14, 15 and 16 should be converted into Pythagorean fuzzy numbers. The linguistic expressions' Pythagorean fuzzy counterparts for decision maker-1 are presented in Table 17. Table 18 presents the combined decision matrix values $\tilde{X}_{ij}$ for decision makers using Equation (14).

Table 17. Pythagorean Fuzzy Number Equivalents of Linguistic Expressions for Decision Maker-1

Criteria	Urgency and Importance Level				Social Needs and Demands				Accessibility and Inclusivity				Efficiency and Cost Effectiveness				Technological Infrastructure and Capabilities			
Alternatives	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U
Home Health Services	0.6	0.7	0.3	0.4	0.7	0.8	0.2	0.3	0.8	0.9	0.1	0.2	0.7	0.8	0.2	0.3	0.8	0.9	0.1	0.2
Medical Centers	0.7	0.8	0.2	0.3	0.8	0.9	0.1	0.2	0.7	0.8	0.2	0.3	0.7	0.8	0.2	0.3	0.8	0.9	0.1	0.2
Psychological Counseling Centers	0.6	0.7	0.3	0.4	0.6	0.7	0.3	0.4	0.7	0.8	0.2	0.3	0.5	0.6	0.3	0.5	0.6	0.7	0.3	0.4
Elderly Services	0.7	0.8	0.2	0.3	0.7	0.8	0.2	0.3	0.6	0.7	0.3	0.4	0.5	0.6	0.3	0.5	0.7	0.8	0.2	0.3
Healthy Nutrition Support	0.6	0.7	0.3	0.4	0.5	0.6	0.3	0.5	0.7	0.8	0.2	0.3	0.5	0.6	0.3	0.5	0.6	0.7	0.3	0.4
Mobile Health Services	0.8	0.9	0.1	0.2	0.7	0.8	0.2	0.3	0.8	0.9	0.1	0.2	0.8	0.9	0.1	0.2	0.8	0.9	0.1	0.2

Table 18. Combined Decision Matrix

Criteria	Urgency and Importance Level				Social Needs and Demands				Accessibility and Inclusivity				Efficiency and Cost Effectiveness				Technological Infrastructure and Capabilities			
Alternatives	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U
Home Health Services	0.269	0.331	0.290	0.352	0.422	0.485	0.146	0.209	0.333	0.406	0.288	0.392	0.302	0.355	0.169	0.221	0.293	0.343	0.157	0.207
Medical Centers	0.331	0.393	0.228	0.290	0.505	0.568	0.063	0.126	0.533	0.606	0.120	0.192	0.247	0.300	0.224	0.276	0.244	0.294	0.191	0.256
Psychological Counseling Centers	0.382	0.444	0.163	0.239	0.327	0.390	0.241	0.304	0.381	0.453	0.272	0.345	0.236	0.288	0.219	0.288	0.278	0.328	0.172	0.222
Elderly Services	0.434	0.496	0.124	0.186	0.356	0.419	0.212	0.275	0.517	0.590	0.135	0.208	0.308	0.360	0.126	0.216	0.276	0.326	0.173	0.223
Healthy Nutrition Support	0.264	0.326	0.280	0.356	0.350	0.413	0.172	0.281	0.445	0.517	0.177	0.281	0.255	0.308	0.199	0.268	0.207	0.257	0.243	0.293
Mobile Health Services	0.355	0.417	0.203	0.265	0.424	0.488	0.143	0.206	0.428	0.501	0.225	0.297	0.404	0.456	0.068	0.120	0.307	0.357	0.143	0.193

Step 2: The formula that provides Equation (15) defused the values in the integrated decision matrix. After the defuzzification process, Equation (16) was used since all criteria are utility-based. The defuzzified values obtained are presented in Table 19. Equation (18) was applied to all values $1/max_i\tilde{X}_{ij}$ in the combined decision matrix for benefit-based criteria. Thus, we obtained the normalized decision matrix ($\bar{\bar{X}}_{ij}$) for decision makers, which is presented in Table 20.

Table 19. Defuzzified Values

Alternatives	Urgency and Importance Level	Social Needs and Demands	Accessibility and Inclusivity	Efficiency and Cost Effectiveness	Technological Infrastructure and Capabilities
Home Health Services	0.409	0.524	0.453	0.436	0.430
Medical Centers	0.455	0.589	0.612	0.397	0.396
Psychological Counseling Centers	0.493	0.452	0.489	0.390	0.419
Elderly Services	0.533	0.473	0.599	0.441	0.418
Healthy Nutrition Support	0.406	0.470	0.541	0.403	0.370
Mobile Health Services	0.473	0.526	0.527	0.510	0.440
1/Maximum	1.875	1.699	1.633	1.962	2.275

Table 20. Normalized Decision Matrix in Pythagorean Fuzzy Numbers

Criteria	Urgency and Importance Level				Social Needs and Demands				Accessibility and Inclusivity				Efficiency and Cost Effectiveness				Technological Infrastructure and Capabilities			
Alternatives	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U
Home Health Services	0.362	0.442	0.098	0.141	0.532	0.605	0.038	0.070	0.419	0.505	0.131	0.216	0.414	0.482	0.031	0.052	0.430	0.498	0.015	0.028
Medical Centers	0.442	0.519	0.062	0.098	0.627	0.696	0.009	0.030	0.649	0.725	0.031	0.068	0.341	0.411	0.053	0.080	0.361	0.431	0.023	0.045
Psychological Counseling Centers	0.506	0.581	0.033	0.068	0.418	0.495	0.089	0.132	0.475	0.560	0.119	0.175	0.326	0.395	0.051	0.087	0.409	0.478	0.018	0.032
Elderly Services	0.569	0.641	0.020	0.043	0.453	0.529	0.072	0.111	0.632	0.709	0.038	0.077	0.421	0.489	0.017	0.049	0.407	0.475	0.019	0.033
Healthy Nutrition Support	0.356	0.436	0.092	0.144	0.446	0.522	0.050	0.116	0.550	0.631	0.059	0.125	0.352	0.421	0.042	0.076	0.308	0.379	0.040	0.061
Mobile Health Services	0.473	0.549	0.050	0.083	0.535	0.608	0.037	0.068	0.530	0.613	0.087	0.138	0.543	0.606	0.005	0.016	0.449	0.516	0.012	0.024

Step 3: Utilizing the comparison scale in Table 21, the joint linguistic assessments of decision makers regarding the importance levels of the criteria are presented in Table 22. The combined criterion weights for decision makers, expressed as Pythagorean fuzzy numbers, are provided in Table 23.

Table 21. Linguistic Terms for Rating the Importance of Criteria [21]

Linguistic Terms	$\boldsymbol{\mu^L}$	$\boldsymbol{\mu^U}$	$\boldsymbol{\upsilon^L}$	$\boldsymbol{\upsilon^U}$
Very important (VI)	0.70	0.90	0.06	0.26
Important (I)	0.54	0.74	0.22	0.42
Medium (M)	0.38	0.58	0.38	0.58
Unimportant (U)	0.22	0.42	0.54	0.74
Very unimportant (VU)	0.06	0.26	0.70	0.90

Table 22. Linguistic Terms Used by Decision Makers to Rate the Importance of Criteria

Criteria	**Linguistic Terms**
Urgency and Importance Level	I
Social Needs and Demands	I
Accessibility and Inclusivity	M
Efficiency and Cost Effectiveness	I
Technological Infrastructure and Capabilities	VI

Table 23. Criterion Weights in The Form of Pythagorean Numbers

Criteria				
Urgency and Importance Level	0.54	0.74	0.22	0.42
Social Needs and Demands	0.54	0.74	0.22	0.42
Accessibility and Inclusivity	0.38	0.58	0.38	0.58
Efficiency and Cost Effectiveness	0.54	0.74	0.22	0.42
Technological Infrastructure and Capabilities	0.7	0.9	0.06	0.26

Step 4: The values in the normalized decision matrix have been multiplied by the criteria weights using Equation (20). Table 24 provides the resulting weighted normalized decision matrix for the weighted total value. Subsequently, we obtained the Pythagorean fuzzy weighted total values of the alternatives by summing these values using Equation (21), as shown in Table 25.

Table 24. Weighted Normalized Decision Matrix for Weighted Total Value

Criteria	Urgency and Importance Level				Social Needs and Demands				Accessibility and Inclusivity				Efficiency and Cost Effectiveness				Technological Infrastructure and Capabilities			
Alternatives	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U
Home Health Services	0.195	0.327	0.240	0.439	0.287	0.447	0.223	0.425	0.159	0.293	0.399	0.606	0.224	0.356	0.222	0.423	0.301	0.448	0.062	0.261
Medical Centers	0.239	0.384	0.228	0.429	0.339	0.515	0.220	0.421	0.247	0.421	0.381	0.583	0.184	0.304	0.226	0.426	0.253	0.388	0.064	0.264
Psychological Counseling Centers	0.273	0.430	0.222	0.425	0.226	0.366	0.236	0.437	0.181	0.325	0.396	0.597	0.176	0.292	0.225	0.427	0.286	0.430	0.063	0.262
Elderly Services	0.307	0.475	0.221	0.422	0.245	0.391	0.231	0.432	0.240	0.411	0.382	0.583	0.228	0.362	0.221	0.422	0.285	0.428	0.063	0.262
Healthy Nutrition Support	0.192	0.323	0.238	0.440	0.241	0.386	0.225	0.433	0.209	0.366	0.384	0.589	0.190	0.312	0.224	0.426	0.215	0.341	0.072	0.267
Mobile Health Services	0.255	0.406	0.225	0.427	0.289	0.450	0.223	0.425	0.202	0.355	0.388	0.591	0.293	0.448	0.220	0.420	0.314	0.464	0.061	0.261

Table 25. Pythagorean Fuzzy Weighted Total Values of The Alternatives

Alternatives	μ^L	μ^U	υ^L	υ^U
Home Health Services	0.535	0.849	0.000	0.012
Medical Centers	0.575	0.912	0.000	0.012
Psychological Counseling Centers	0.521	0.833	0.000	0.012
Elderly Services	0.587	0.928	0.000	0.012
Healthy Nutrition Support	0.470	0.775	0.000	0.013
Mobile Health Services	0.611	0.954	0.000	0.012

Step 5: Equation (23) calculated the weighted normalized decision matrix using the values from the normalized decision matrix and the criterion weights. Table 26 displays the resulting weighted normalized decision matrix for the weighted product value.

Subsequently, Table 27 presents the Pythagorean fuzzy weighted product values of the alternatives obtained by multiplying these values together through Equation (20).

Table 26. Weighted Normalized Decision Matrix for The Weighted Product Value

Criteria	Urgency and Importance Level				Social Needs and Demands				Accessibility and Inclusivity				Efficiency and Cost Effectiveness				Technological Infrastructure and Capabilities			
Alternatives	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U	μ^L	μ^U	υ^L	υ^U
Home Health Services	0.578	0.546	0.046	0.092	0.711	0.689	0.018	0.045	0.718	0.673	0.081	0.166	0.621	0.582	0.014	0.034	0.554	0.534	0.004	0.014
Medical Centers	0.643	0.616	0.029	0.064	0.777	0.764	0.004	0.019	0.848	0.830	0.019	0.052	0.560	0.518	0.025	0.052	0.490	0.469	0.006	0.023
Psychological Counseling Centers	0.692	0.669	0.016	0.044	0.625	0.594	0.042	0.086	0.754	0.714	0.074	0.134	0.546	0.503	0.024	0.056	0.535	0.515	0.004	0.017
Elderly Services	0.738	0.720	0.009	0.028	0.652	0.624	0.034	0.072	0.840	0.819	0.024	0.059	0.627	0.589	0.008	0.032	0.533	0.512	0.005	0.017
Healthy Nutrition Support	0.573	0.541	0.043	0.094	0.647	0.618	0.024	0.075	0.797	0.766	0.036	0.096	0.569	0.527	0.020	0.049	0.438	0.418	0.010	0.031
Mobile Health Services	0.667	0.642	0.024	0.054	0.714	0.692	0.017	0.044	0.786	0.753	0.054	0.105	0.719	0.690	0.002	0.010	0.571	0.551	0.003	0.012

Table 27. Pythagorean Fuzzy Weighted Product Values of Alternatives

Alternatives	μ^L	μ^U	υ^L	υ^U
Home Health Services	0.101	0.079	0.096	0.198
Medical Centers	0.116	0.095	0.044	0.101
Psychological Counseling Centers	0.095	0.073	0.089	0.175
Elderly Services	0.135	0.111	0.043	0.104
Healthy Nutrition Support	0.074	0.056	0.065	0.164
Mobile Health Services	0.154	0.127	0.061	0.127

Step 6: Equation (15) defuzzifies the Pythagorean fuzzy weighted sum and the Pythagorean fuzzy weighted product. Table 28 presents the defuzzified weighted sum values, and Table 29 shows the defuzzified weighted product values. According to the WASPAS method, Equation (24) integrates the weighted sum values of the alternatives with the weighted product values, and Table 30 presents the total relative importance values of the alternatives. A λ coefficient value of 0.5 is assigned at this stage.

Table 28. Defuzzified Weighted Sum Values

Alternatives	**Weighted Sum Value**
Home Health Services	0.710
Medical Centers	0.753
Psychological Counseling Centers	0.697
Elderly Services	0.765
Healthy Nutrition Support	0.653
Mobile Health Services	0.787

Table 29. Defuzzified Weighted Product Values

Alternatives	Weighted Product Value
Home Health Services	0.294
Medical Centers	0.305
Psychological Counseling Centers	0.291
Elderly Services	0.314
Healthy Nutrition Support	0.282
Mobile Health Services	0.324

Table 30. Total Relative Importance Values of Alternatives

Alternatives	Total Relative Importance Value	Ranking
Home Health Services	0.502	4
Medical Centers	0.529	3
Psychological Counseling Centers	0.494	5
Elderly Services	0.540	2
Healthy Nutrition Support	0.467	6
Mobile Health Services	0.556	1

Step 7: The alternatives have been ranked considering their total relative importance values. The alternative with the highest total relative importance value is considered the most suitable candidate. The rankings of digitalization alternatives for decision makers are presented in Figure 4.

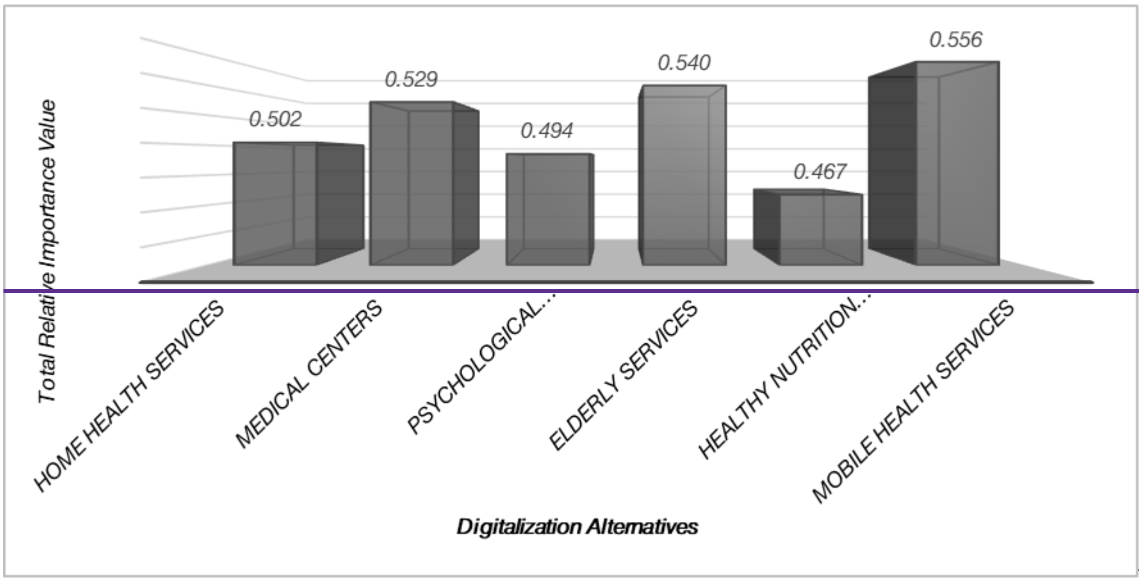

Figure 4. The Rankings of Digitalization Alternatives

Upon examining Figure 4, the importance ranking of alternatives for decision makers is as follows: "Mobile Health Services" > "Elderly Services" > "Medical Centers" > "Home Health Services" > "Psychological Counseling Centers" > "Healthy Nutrition Support".

5.3. The Implementation of the Sensitivity Analysis

To test the validity of the proposed integrated model, a comprehensive sensitivity analysis examined the impact of variations in different criteria weights on the ranking results. This analysis involved creating 50 scenarios to analyze how modifications in criterion weights affected the new ranking of alternatives. Each scenario adjusted the weight of a specific criterion by 10%, while the weights of the remaining criteria were adjusted to maintain a total sum of 1, as recommended by Görçün et al. [22]. The new weight values for each criterion were calculated using Equations (25), (26), and (27) respectively.

$$w_{nv}^{1} = w_{pv}^{1} - \left(w_{pv}^{1} . \varsigma_{v}\right) \tag{25}$$

$$w_{rfv}^{2} = \frac{\left(w_{pv}^{1} - w_{nv}^{1}\right)}{n-1} + w_{pv}^{2} \tag{26}$$

$$w_{nv}^{1} + \sum w_{rfv}^{2} = 1 \tag{27}$$

In Equation (25), w_{pv}^{1}, denotes the original value of the criterion to be reduced in weight; ς_{v} represents the degree of change in percentage terms (10%, 20%...100%); and w_{nv}^{1} signifies the new value of the modified weight of the factor. In Equation (26), w_{pv}^{2} symbolizes the original value of the remaining criterion; n denotes the number of criteria; and w_{rfv}^{2} represents the new value of the remaining criterion. Equation (27) expresses the constraint that the sum of the modified criterion weights must equal 1.

Within the study's scope, we systematically reduced the weights of each factor obtained from the PF-CRITIC method by 10% increments until each factor's weight reached 0, while ensuring the total weight sum of all factors remained at 1. For instance, starting with the "Urgency and Importance Level" criterion, we decreased its weight from 100% to 0% in increments of 10%, redistributing the reduced weight among the remaining criteria. This procedure was applied to each criterion, maintaining the constraint that the cumulative weight equals 1. Subsequently, we iterated the IVPF-WASPAS method using these adjusted criterion weights. The impact of these weight adjustments on the ranking performance of alternatives for each decision maker is depicted in Figures 5, 6 and 7 respectively.

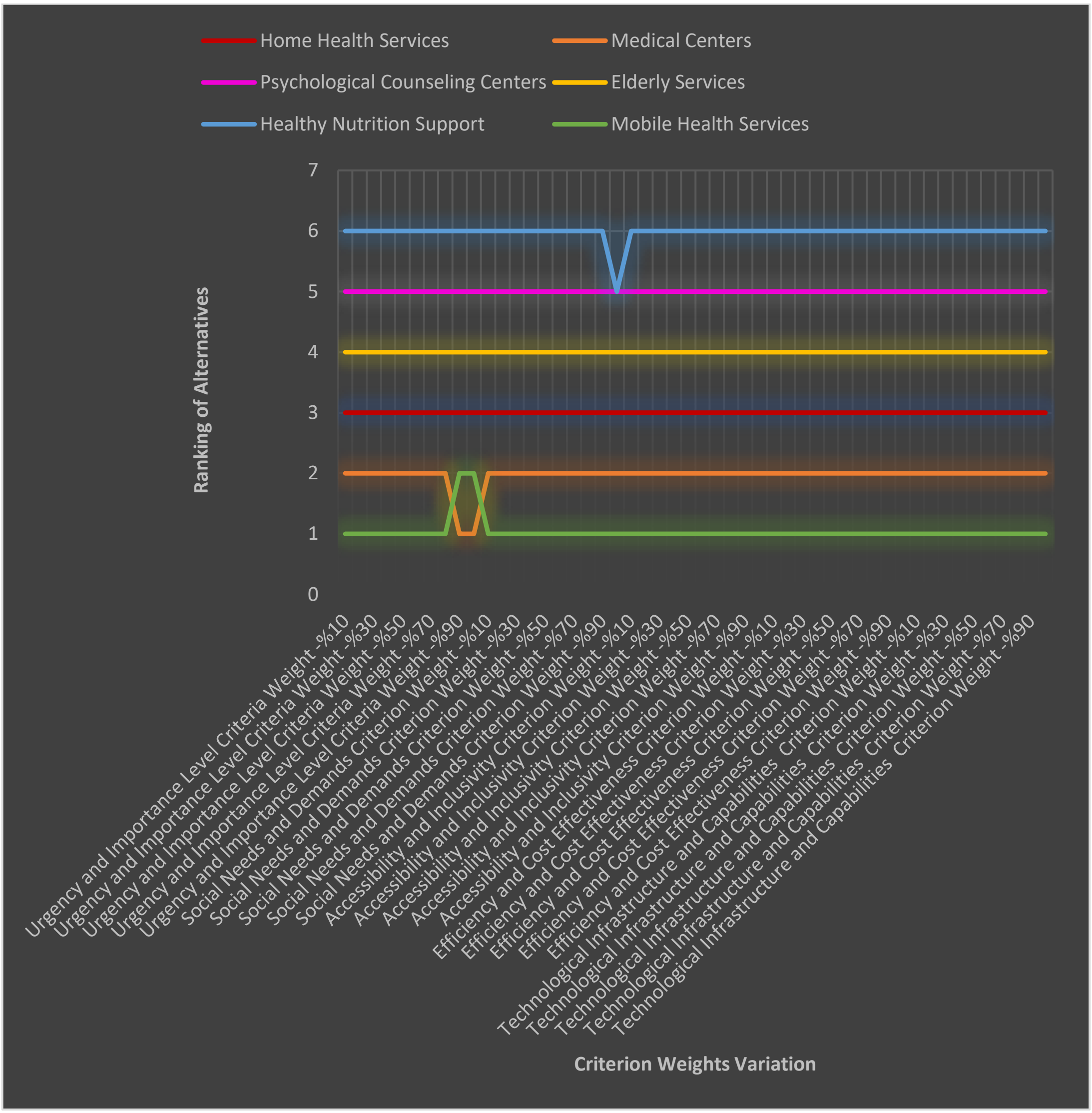

Figure 5. Effects Of Changes in Criterion Weights on The Ranking Performance of Alternatives for Decision Maker-1

Examining Figure 5 reveals the following results:

Reducing the weight of the "Urgency and Importance Level" criterion by 90% and 100% causes the "Mobile Health Services" alternative, initially in the first position, to fall to the second position.

Conversely, the "Medical Centers" alternative, which is initially in the second position, rises to the first position when the weight of the "Urgency and Importance Level" criterion is reduced by 90% and 100%.

The rankings of the "Home Health Services" in the third position, "Elderly Services" in the fourth position, and "Psychological Counseling Centers" in the fifth position remain unchanged regardless of any variations in criterion weights.

The "Healthy Nutrition Support" alternative, which is initially in the sixth position, moves to the fifth position when the weight of the "Social Needs and Demands" criterion is reduced by 100%.

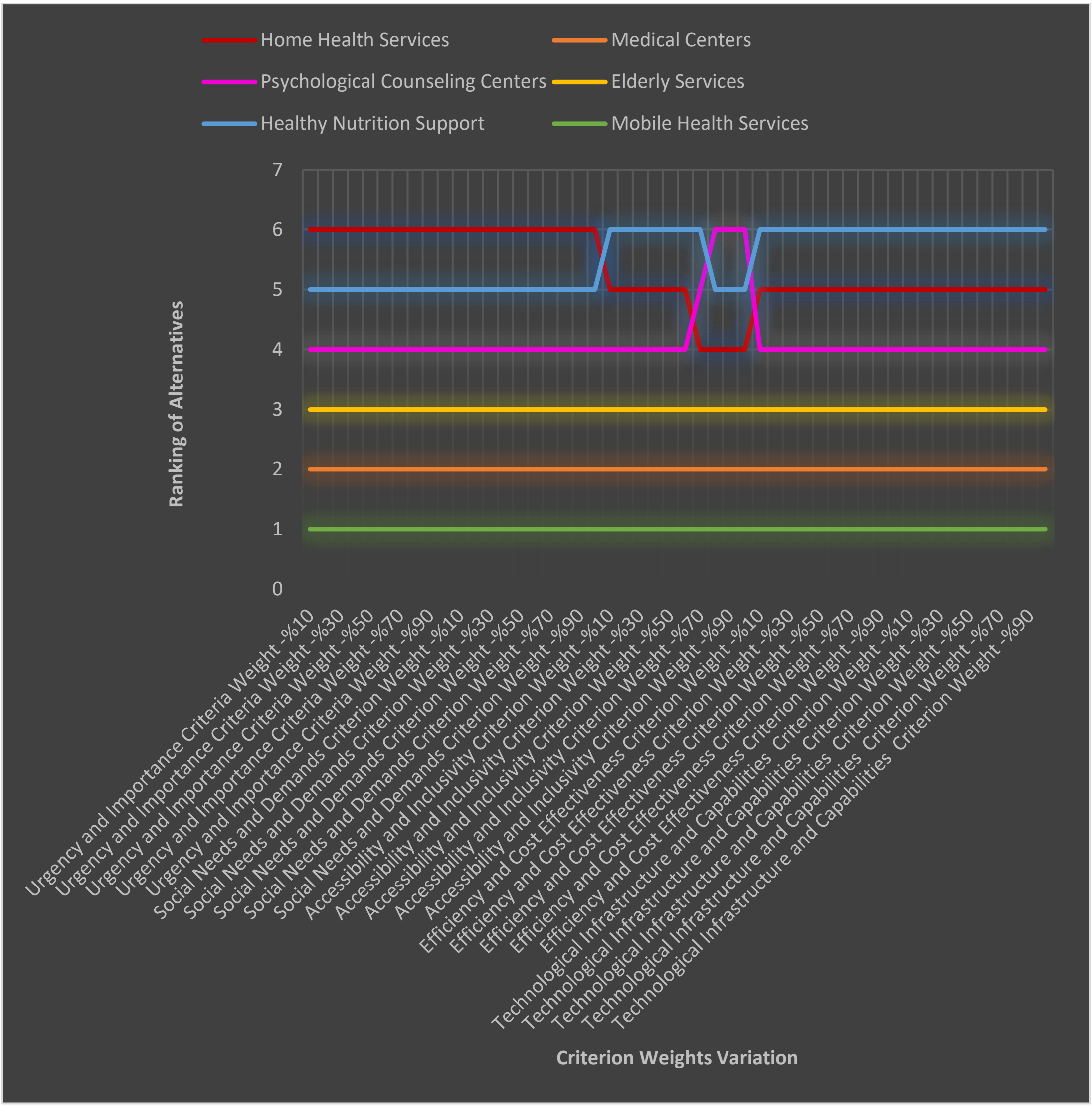

Figure 6. Effects Of Changes in Criterion Weights On The Ranking Performance Of Alternatives For Decision Maker-2

Examining Figure 6 reveals the following results:

The rankings of the alternatives "Mobile Health Services" in the first position, "Medical Centers" in the second position and "Elderly Services" in the third position did not change with any variation in criterion weights.

Reducing the "Accessibility and Inclusivity" criterion weight by 70% moves the "Psychological Counseling Centers" alternative from the fourth to the fifth position, and reducing this criterion weight by 80%, 90%, and 100% moves it to the sixth position.

The "Healthy Nutrition Support" alternative, which is in the fifth position, moved to the sixth position when the criterion weight of "Accessibility and Inclusivity" was reduced by 10%, 20%, 30%, 40%, 50%, 60% and 70%, as well as when the criterion weight of "Efficiency and Cost Effectiveness" was reduced by 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%, and when the criterion weight of "Technological Infrastructure and Capabilities" was reduced by 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%.

The "Home Health Services" alternative, which is in the sixth position, moved to the fifth position when the criterion weight of "Accessibility and Inclusivity" was reduced by 10%, 20%, 30%, 40%, 50% and 60%, and when the criterion weight of "Efficiency and Cost Effectiveness" was reduced by 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%, and when the criterion weight of "Technological Infrastructure and Capabilities" was reduced by 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%; it moved to the fourth position when the criterion weight of "Accessibility and Inclusivity" was reduced by 70%, 80%, 90% and 100%.

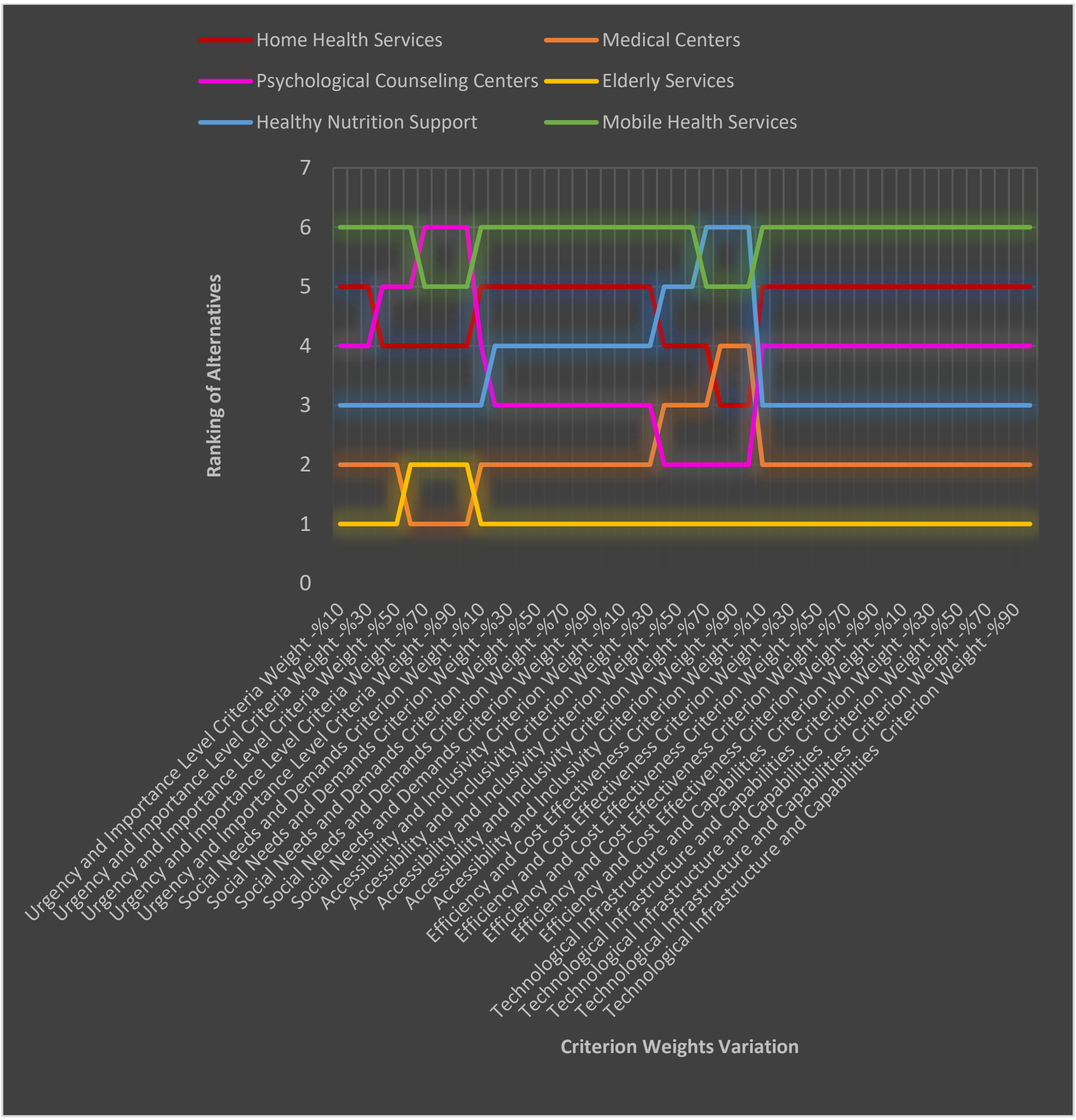

Figure 7. Effects of Changes in Criterion Weights on The Ranking Performance of Alternatives for Decision Maker-3

Examining Figure 7 reveals the following results:

The "Elderly Services" alternative, which was ranked first, dropped to the second position when the "Urgency and Importance Level" criterion weight was reduced by 60%, 70%, 80%, 90% and 100%.

The "Medical Centers" alternative, which was ranked second, rose to the first position when the "Urgency and Importance Level" criterion weight was reduced by 60%, 70%, 80% and 90%; dropped to the third position when the "Accessibility and Inclusivity" criterion weight was reduced by 40%, 50%, 60% and 70%; and further dropped to the fourth position when the "Accessibility and Inclusivity" criterion weight was reduced by 80%, 90% and 100%.

The "Healthy Nutrition Support" alternative, which was ranked third, dropped to the fourth position when the "Social Needs and Demands" criterion weight was reduced by 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%, and when the "Accessibility and Inclusivity" criterion weight was reduced by 10%, 20% and 30%; dropped to the fifth position when the "Accessibility and Inclusivity" criterion weight was reduced by 40%, 50% and 60%; and further dropped to the sixth position when the "Accessibility and Inclusivity" criterion weight was reduced by 70%, 80%, 90% and 100%.

The "Psychological Counseling Centers" alternative, which was ranked fourth, dropped to the fifth position when the "Urgency and Importance Level" criterion weight was reduced by 40%, 50% and 60%; further dropped to the sixth position when the "Urgency and Importance Level" criterion weight was reduced by 70%, 80%, 90% and 100%; rose to the third position when the "Social Needs and Demands" criterion weight was reduced by 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%, and when the "Accessibility and Inclusivity" criterion weight was reduced by 10%, 20% and 30%; and further rose to the second position when the "Accessibility and Inclusivity" criterion weight was reduced by 40%, 50%, 60%, 70%, 80%, 90% and 100%.

The "Home Health Services" alternative, which was ranked fifth, rose to the fourth position when the "Urgency and Importance Level" criterion weight was reduced by 40%, 50%, 60%, 70%, 80%, 90% and 100%, and when the "Accessibility and Inclusivity" criterion weight was reduced by 40%, 50%, 60% and 70%; and further rose to the third position when the "Accessibility and Inclusivity" criterion weight was reduced by 80%, 90% and 100%.

The "Mobile Health Services" alternative, which was ranked sixth, rose to the fifth position when the "Urgency and Importance Level" criterion weight was reduced by 70%, 80%, 90% and 100%, and when the "Accessibility and Inclusivity" criterion weight was reduced by 70%, 80%, 90% and 100%.

Overall evaluation of the sensitivity analysis results shows minor changes in the preference rankings of alternatives due to modifications in criterion weights, indicating that these changes do not significantly alter the general outcomes. Despite modifications in criterion weights, the results obtained demonstrate that the proposed integrated approach is a robust, accurate, realistic, and reasonable technique that yields strong outcomes.

6. Conclusion and Discussion

In this research, three decision-makers evaluated six alternatives within the framework of five criteria: "Urgency and Importance Level", "Social Needs and Demands", "Accessibility and Inclusivity", "Efficiency and Cost Effectiveness" and "Technological Infrastructure and Capabilities". The PF-CRITIC method determined the weights of the selection criteria. Subsequently, we inputted the obtained criterion weights into the IVPF-WASPAS method to rank the alternatives. The conducted study demonstrated the feasibility of the proposed framework.

The decision-making process involved aggregating different criteria or preferences to make an overall assessment. According to the PF-CRITIC method, decision maker-1 prioritized "Social Needs and Demands" as the most important criterion, while decision makers 2 and 3 prioritized "Accessibility and Inclusivity". In contrast, the IVPF-WASPAS method identified "Mobile Health Services" as the most important alternative in the shared importance ranking, with "Healthy Nutrition Support" deemed the least important.

We conducted a comprehensive sensitivity analysis based on variations in criterion weights to test the validity of the proposed integrated model. The results indicate that the proposed integrated approach is a robust, accurate, reasonable, and realistic technique that yields strong outcomes.

We believe that the integrated method used in the study contributes by providing practitioners with a methodological framework, thereby offering comprehensive insights into the study and its methods, which can guide researchers intending to undertake similar studies. The proposed hybrid approach can also be applied to solve decision-making problems encountered in various fields. The presented framework can serve as an exemplary model and lay the groundwork for future research. Below, we delineate the limitations of the study.

To obtain reasonable and realistic results, researchers should carefully select experts. In the coming years, those conducting research in this field may benefit from collaborating with highly knowledgeable, experienced, and authoritative experts, as demonstrated in the study. Moreover, while selecting the correct and appropriate criteria is crucial, relying solely on a literature review may not suffice for determining these criteria. Therefore, conducting fieldwork in collaboration with experts, as practiced in this study, can help define suitable selection criteria.

Future research could employ the methodology used in this document to address issues through diverse evaluations using various FMCDM methods. Additionally, expanding the number of experts in the decision-making group can enhance the robustness of outcomes.

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