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An Interval-Valued Intuitionistic Fuzzy Model Based on Extended VIKOR and MARCOS for Sustainable Supplier Selection in Organ Transplantation Networks for Healthcare Devices

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Abstract: The selection of proper healthcare device suppliers in sustainable organ transplantation networks has become an essential topic of increasing life expectancy. Assessment of sustainable healthcare device suppliers can be regarded as a complex multi-criteria decision-making (MCDM) problem that consists of multiple alternative solutions with sustainable criteria. For this reason, this paper proposes a new integrated MCDM model based on combining an extended vlsekriterijuska optimizacija i komoromisno resenje (E-VIKOR) and measurement alternatives and ranking according to the compromise solution (MARCOS) approaches under interval-valued intuitionistic fuzzy sets (IVIFSs). The aggregating technique of the E-VIKOR method is a strong point of this method compared to the original approach. The IVIFS is taken to cope with the uncertain situation of real-world applications. In this regard, an IVIF-similarity measure is introduced to compute weights of the decision-makers (DMs). The IVIF-Shannon entropy method is utilized to calculate the criteria weights, and a new hybrid proposed model is developed by presenting the IVIF-E-VIKOR method and IVIF-MARCOS, to calculate the ranking of sustainable supplier alternatives in organ transplantation networks to supply the surgery devices. Afterward, an illustrative example is introduced to evaluate the performance of the proposed model, and a comparative analysis is presented to confirm and validate the proposed approach. Moreover, sensitivity analysis for essential parameters of the proposed model is performed to assess their effects on outcomes.

Keywords: supply chain management; sustainable organ transplantation networks; interval-valued intuitionistic fuzzy sets (IVIFSs); IVIF-similarity measure; IVIF-Shannon entropy approach; IVIF-E-VIKOR method; IVIF-MARCOS method

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1. Introduction

Supply chain management (SCM) is generally provided as a flow of planning, executing, and controlling the activities of the chain based on an efficient foundation [1]. The SCM is the combination of presented operations via improved supply chain associations to gain a sustainable situation [2]. Sustainability can be regarded as the grade to which actual decisions of associations affect the future status of environmental, societal, and economic viability [3]. The healthcare supply chain (HSC) is an execution of the service supply chain into healthcare industries. The HSC execution motivates healthcare service providers to cooperate with supply chain performers to consider stakeholder satisfaction with respect to economic, environmental, and social requirement conditions [4,5].

Organ transplantation, one of the most significant subsets of healthcare systems, has become a favored therapy for many conditions [6]. The transplant surgical action consists of a donor person and a recipient individual. This network includes donor hospitals, recipients' regions, transportation systems, and transplant centers (TCs). Donor people are maintained in donor hospitals, where some essential investigations are done, and organs are harvested from the whole body. Furthermore, recipient regions are populated places where people receiving organs are located [7]. After receiving the organ by TC, one of the main concern issues is related to starting the surgery of the transplant process. In this regard, the modernization of surgery process and the usage of new surgery equipment has an important position. Hence, the transplantation manager is to determine the operation of supplier selection in the medical device manufacturing industry where there are restricted scholarly research actions presented [8].

Several approaches have been utilized for solving issues in the dimensions of healthcare transplantation sustainability. Multiple criteria decision making (MCDM) can be a crucial approach that has been used in different regions of sustainable engineering. Many previous papers have operated MCDM techniques in various areas of sustainable engineering [9–11]. Moreover, various previous articles have examined the applications of MCDM and fuzzy sets theory in several domains of engineering and sustainability to take an appropriate decision in uncertain situations. In this regard, healthcare device sustainable supplier selection is a complex issue that is caused by the use of uncertain handling techniques, such as fuzzy sets. Fuzzy sets theory has been extended in a wide range, and diverse transformations and generalizations have been emerged [12–14]. In this regard, intuitionistic fuzzy sets (IFSs) are one of their new concepts [15].

The IFS is represented by a membership function and a non-membership function that is related to the advantage of IFS over fuzzy theory in the lack of knowledge about the membership values. According to this point, the IFS has received more and more considerations since its formation. Given that, sometimes, it is not imprecise to assume, which membership degrees for specific segments of an IFS are exactly described, but a range of degrees can be provided. In this regard, interval-valued intuitionistic fuzzy set (IVIFS) is a diverse conception of the IFSs; the fundamental element of the IVIF is that the values of its membership degree and non-membership degree are intervals rather than exact digits [16]. Accordingly, vague and incomplete information can be handled better by employing IVIFSs in comparison with IFSs. By developing IFSs to IVIFSs, controlling ambiguous and unclear data evolves more successfully due to the fact that the vague, membership and non-membership degrees are represented as ranges of degrees instead of actual values [17]. Hayat et al. [18] introduced two new aggregations IF operators, such as generalized group-based weighted averaging and geometric operators, that were used to evaluate the multi-attribute group decision making (MAGDM) problem based on soft sets. Hayat et al. [19] presented a hybrid method according to assessed selection problems based on generalized intuitionistic fuzzy soft sets with regard to combining soft sets and IFS.

Based on the literature, Bolturk and Kahraman [20] proposed the MCDM method based on the combinative distance assessment (CODAS) approach to select facility location problem under IVIF situations. Liu et al. [21] adopted the MCDM approach to choose a sustainable supplier under IVIF conditions with linguistic terms via judgments. Abdullah et al. [22] introduced a combined MCDM method based on decision-making trial and evaluation laboratory (DEMATEL) and Choquet integral under fuzzy environments to manage sustainable solid waste. Roy et al. [23] developed the CODAS method to select sustainable material for construction projects under fuzzy uncertainty conditions. Davoudabadi et al. [24] proposed a hybrid MCDM method based on the TODIM technique for order of preference by similarity to ideal solution (TOPSIS), and the weighted aggregated sum product assessment (WASPAS) approaches under IVIF conditions. Davoudabadi et al. [25] developed a decision-making structure to select the resilience and sustainable supplier under IVIF situations. Afterward, Mao et al. [26] regarded an IVIF-TODIM approach to evaluate and choose sustainable suppliers with a heterogenous MCDM structure. Seker et al. [27] evaluated a sustainable public transportation system with an IVIF-analytical hierarchy process (AHP) and CODAS approaches. Liu et al. [28] proposed a new ranking MADM method under incomplete data. Furthermore, the approach used some optimization models, such as simulation annealing, to rank. Zhang et al. [29] proposed an effective decision model, social network group decision-making (SNGDM), that was conducted based on the social trust relationships among the DMs. Qi et al. [30] introduced a hybrid MCDM method based on DEMATEL and vlsekriterijumska optimizacija i kompromisno resenje (VIKOR) approaches to create sustainability in the energy industry by considering an economic requirement under IVIF conditions. Davoudabadi et al. [31] proposed a decision model based on simulation and DEA to assess the renewable energy project with IVIFSs. Bolturk et al. [32] adopted the MCDM method to select an energy with a sustainable condition under an IVIF environment.

Alrasheedi et al. [33] considered a combined compromise solution (CoCoSo) MCDM approach under IVIF situations to assess green growth criteria to attain sustainable extensions. Alimohammadlou and Khoshsepehr [34] introduced an integrated method based on the AHP and WASPAS approaches under IVIF conditions to develop a sustainable situation. Chen et al. [35] presented the MCDM approach to select and evaluate providers of the sustainable third-party logistic system under an IVIF situation. Furthermore, Mishra et al. [36] proposed the MCDM method based on a similarity measure with an IVIF condition to evaluate and select a suitable low-carbon tourism strategy. This method was extended based on the additive ratio assessment (ARAS) approach. Ayyildiz [37] proposed an IVIF-AHP method for assessing a sustainable resilience green supply chain in a post coronavirus disease 2019 (COVID-19) condition. Tumsekcali et al. [38] adopted the MCDM method based on integrating AHP and WASPAS approaches to evaluate sustainable public urban transportation quality under IVIF conditions. Perçin [39] introduced the MCDM method to select a circular supplier with IVIF requirements. Tavana et al. [40] proposed a fuzzy MCDM method to evaluate a suitable supplier in reverse supply chains with regard to applying the BWM and CoCoSo approaches. Furthermore, this paper used Bonferroni functions to capture the inter-relationships among the decision criteria and remove the impact of extreme data. Sun et al. [41] proposed a mixed-integer nonlinear programming for order splitting formulation to select the suitable supplier. Jiang et al. [42] introduced the financing problem by analyzing two main alternatives, such as bank financing and trade credit. This paper investigated a supply chain by considering a well-funded supplier and one small-sized retailer with capital constraints. Chen et al. [43] proposed a multi-perspective multi-attribute decision making (MPMADM) method to select the best logistic provider in the third-party reverse problem. This paper used linguistic terms to assess the main alternative values by judging the DMs and applied hesitant fuzzy to handle uncertain situations.

The literature review determines that sustainable evaluation and selection with the MCDM approach under IVIF conditions and, mainly, sustainable device supplier selection in organ transplantation networks are limited to the current years. According to this gap, the selection of sustainable suppliers for healthcare devices in organ transplantation networks has a high value to evaluate with a newly developed MCDM approach under IVIF conditions. This paper proposes a new hybrid MCDM model to compute criteria weights and decision makers (DMs) weights with a Shannon entropy and similarity measure, respectively. Moreover, a combination of new methods is proposed to rank the alternatives based on measurement alternatives and ranking according to the compromise solution (MARCOS) and extended VIKOR (E-VIKOR). This model is proposed under IVIF requirements to deal with an uncertain condition that helps healthcare managers to make suitable decisions in real-world situations. This concept is given in Table 1. Table 1 determines the evaluation by considering the linguistic terms, which is a common practice as shown in several previous works, but identifying the DMs weights and criteria weights concurrently is a necessary work that is not highly determined in the literature. Furthermore, new hybrid or extended ranking methods do not exist enough in the literature. According to this table, this paper proposes a new hybrid MCDM method based on a group of DMs' opinions considering linguistic terms to evaluate the DMs weights and criteria weights, and compute the ranking of the alternatives with a new integration approach. The main innovations of this paper are represented below:

- Developing an IVIF-similarity measure to compute weights of DMs. The similarity measure method is conducted based on the distance from the ideal decision matrix under IVIF conditions that considers membership and non-membership degrees to control vagueness and uncertain conditions.
- Extending an IVIF-Shannon entropy method to obtain the weights of the criteria. This method calculates the criteria weights with respecting entropy measures under IVIF situations.
- Developing an IVIF-E-VIKOR method for ranking the alternatives. In the IVIF-E-VIKOR method, a new indicator is presented for evaluating the alternatives under IVIF conditions by considering membership and non-membership degrees closer to the outcomes of real-world problems.
- Extending an IVIF-MARCOS approach to rank the alternatives. This method obtains the alternative ranking based on the utility function that is computed based on the utility degree by respecting membership and non-membership values to handle uncertain situations.
- Proposing a new hybrid ranking model to concurrently appraise alternatives based on two IVIF-E-VIKOR and IVIF-MARCOS approaches.

Table 1. Literature review of supplier selection problem.

References	Method Features					
	Applying Linguistic Terms	IVIF	DM Weights	Criteria Weights	Hybrid/New Ranking Method	Group Decision Making
[20]		*				
[21]	*	*		*		
[23]	*	*		*		
[25]	*	*	*	*	*	*
[30]	*	*		*		*
[32]	*			*		*
[33]		*		*		*
[36]	*	*		*		
[38]	*	*		*		
[43]	*	*	*	*		*
This paper	*	*	*	*	*	*

Moreover, this study provides an illustrative example to validate the performance of the proposed soft computing model.

The remainder of this study is as follows: the basic essential examinations of IVIFS are introduced in Section 2; Section 3 proposes a new hybrid soft computing method based on the similarity measure, Shannon entropy method, and combination MARCOS and E-VIKOR methods under the IVIF situation; Section 4 regards an illustrative example to validate the performance of the introduced method with a comparative and sensitivity analyses sub-section; and Section 5 is related to the conclusion and future research suggestions.

2. Preliminaries

In this section, basic definitions of IVIFSs and operators on IVIFSs are presented.

Definition 1. *Let $P = \{p_1,\ p_2, \ldots, p_n\}$ be a universe. An IVIFS $\widetilde{Y}$ in P is described by Equation (1) [15].*

$$\widetilde{Y} = \{p_i, \mu_{\widetilde{Y}}(p_i), v_{\widetilde{Y}}(p_i) | p_i \in P\} \tag{1}$$

where $\mu_{\widetilde{Y}}(p_i) = \left[\mu^l_{\widetilde{Y}}(p_i),\ \mu^u_{\widetilde{Y}}(p_i)\right], v_{\widetilde{Y}}(p_i) = \left[v^l_{\widetilde{Y}}(p_i),\ v^u_{\widetilde{Y}}(p_i)\right]$ and $\mu_{\widetilde{Y}}(p_i), v_{\widetilde{Y}}(p_i) \in [0,1]$. In these equations, $\mu^l_{\widetilde{Y}}(p_i)$ is the infimum of the $\mu_{\widetilde{Y}}(p_i)$ and $\mu^u_{\widetilde{Y}}(p_i)$ is the supremum of the $\mu_{\widetilde{Y}}(p_i)$. Afterward, this situation exists for $v_{\widetilde{Y}}(p_i)$ simultaneously.

$$\mu^u_{\widetilde{Y}}(p_i) + v^u_{\widetilde{Y}}(p_i) \leq 1\ \forall p_i \in P \tag{2}$$

$$\pi_{\widetilde{Y}}(p_i) = \left[\pi^l_{\widetilde{Y}}(p_i),\ \pi^u_{\widetilde{Y}}(p_i)\right] \tag{3}$$

where $\pi^l_{\widetilde{Y}}(p_i) = 1 - \mu^u_{\widetilde{Y}}(p_i) - v^u_{\widetilde{Y}}(p_i)$ and $\pi^u_{\widetilde{Y}}(p_i) = 1 - \mu^l_{\widetilde{Y}}(p_i) - v^l_{\widetilde{Y}}(p_i)$ for $p_i \in P$. Moreover, if $\mu_{\widetilde{Y}}(p_i) = \mu^u_{\widetilde{Y}}(p_i) = \mu^l_{\widetilde{Y}}(p_i)$ and $v_{\widetilde{Y}}(p_i) = v^u_{\widetilde{Y}}(p_i) = v^l_{\widetilde{Y}}(p_i)$, the IVFS changes to the IFS.

Definition 2. *Let $\widetilde{Y}_1 = \left(\left[\mu^l_{\widetilde{Y}_1},\ \mu^u_{\widetilde{Y}_1}\right], \left[v^l_{\widetilde{Y}_1},\ v^u_{\widetilde{Y}_1}\right]\right)$, $\widetilde{Y}_2 = \left(\left[\mu^l_{\widetilde{Y}_2},\ \mu^u_{\widetilde{Y}_2}\right], \left[v^l_{\widetilde{Y}_2},\ v^u_{\widetilde{Y}_2}\right]\right)$, $\widetilde{Y} = \left[\mu^l_{\widetilde{Y}},\ \mu^u_{\widetilde{Y}}\right], \left[v^l_{\widetilde{Y}},\ v^u_{\widetilde{Y}}\right]$. The mathematical operations are presented in Equations (4)–(7), where $\varnothing$ is a coefficient value number [16].*

$$\widetilde{Y}_1 \oplus \widetilde{Y}_2 = \left(\left[\mu^l_{\widetilde{Y}_1} + \mu^l_{\widetilde{Y}_2} - \mu^l_{\widetilde{Y}_1}\mu^l_{\widetilde{Y}_2}, \mu^u_{\widetilde{Y}_1} + \mu^u_{\widetilde{Y}_2} - \mu^u_{\widetilde{Y}_1}\mu^u_{\widetilde{Y}_2}\right], \left[v^l_{\widetilde{Y}_1}v^l_{\widetilde{Y}_2}, v^u_{\widetilde{Y}_1}v^u_{\widetilde{Y}_2}\right]\right) \tag{4}$$

$$\widetilde{Y}_1 \otimes \widetilde{Y}_2 = \left(\left[\mu^l_{\widetilde{Y}_1}\mu^l_{\widetilde{Y}_2}, \mu^u_{\widetilde{Y}_1}\mu^u_{\widetilde{Y}_2}\right], \left[v^l_{\widetilde{Y}_1} + v^l_{\widetilde{Y}_2} - v^l_{\widetilde{Y}_1}v^l_{\widetilde{Y}_2}, v^u_{\widetilde{Y}_1} + v^u_{\widetilde{Y}_2} - v^u_{\widetilde{Y}_1}v^u_{\widetilde{Y}_2}\right]\right) \tag{5}$$

$$\varnothing\widetilde{Y} = \left(\left[1 - \left(1 - \mu^l_{\widetilde{Y}}\right)^{\varnothing}, 1 - \left(1 - \mu^u_{\widetilde{Y}}\right)^{\varnothing}\right], \left[v^{l\,\varnothing}_{\widetilde{Y}}, v^{u\,\varnothing}_{\widetilde{Y}}\right]\right) \tag{6}$$

$$\widetilde{Y}^{\varnothing} = \left(\left[\mu^{l\,\varnothing}_{\widetilde{Y}}, \mu^{u\,\varnothing}_{\widetilde{Y}}\right]\left[1 - \left(1 - v^l_{\widetilde{Y}}\right)^{\varnothing}, 1 - \left(1 - v^v_{\widetilde{Y}}\right)^{\varnothing}\right]\right) \tag{7}$$

Definition 3. *Euclidean distance is obtained from Equation (8) [44].*

$$DIS_R\left(\widetilde{Y}_1, \widetilde{Y}_2\right) = \sqrt{\frac{1}{4}\left(\left(\mu^l_{\widetilde{Y}_1} - \mu^l_{\widetilde{Y}_2}\right)^2 + \left(\mu^u_{\widetilde{Y}_1} - \mu^u_{\widetilde{Y}_2}\right)^2 + \left(v^l_{\widetilde{Y}_1} - v^l_{\widetilde{Y}_2}\right)^2 + \left(v^u_{\widetilde{Y}_1} - v^u_{\widetilde{Y}_2}\right)^2\right)} \tag{8}$$

Definition 4. *Normalized decision matrix is calculated with Equations (9)–(16). Eqauations (9)–(12) have the benefit nature and Equations (13)–(16) have the cost nature. In these formulations, i and j are regarded as alternatives and criteria sets in MCDM problems, respectively [45].*

$$\mu^l_{ij} = \frac{\mu^l_{ij}}{\sqrt{\sum_{i=1}^m \left(2 - v^l_{ij} - v^u_{ij}\right)^2}} \tag{9}$$

$$\mu^u_{ij} = \frac{\mu^u_{ij}}{\sqrt{\sum_{i=1}^m \left(2 - v^l_{ij} - v^u_{ij}\right)^2}} \tag{10}$$

$$v^l_{ij} = 1 - \frac{\left(1 - v^l_{ij}\right)}{\sqrt{\sum_{i=1}^m \left(\mu^l_{ij} + \mu^u_{ij}\right)^2}} \tag{11}$$

$$v_{ij}^{u}=1-\frac{\left(1-v_{ij}^{u}\right)}{\sqrt{\sum_{i=1}^{m}\left(\mu_{ij}^{l}+\mu_{ij}^{u}\right)^{2}}} \quad (12)$$

$$\mu_{ij}^{l}=\frac{\left(1-v_{ij}^{l}\right)^{-1}}{\sqrt{\sum_{i=1}^{m}\left(\left(\mu_{ij}^{l}\right)^{-1}+\left(\mu_{ij}^{u}\right)^{-1}\right)^{2}}} \quad (13)$$

$$\mu_{ij}^{u}=\frac{\left(1-v_{ij}^{u}\right)^{-1}}{\sqrt{\sum_{i=1}^{m}\left(\left(\mu_{ij}^{l}\right)^{-1}+\left(\mu_{ij}^{u}\right)^{-1}\right)^{2}}} \quad (14)$$

$$v_{ij}^{l}=1-\frac{\left(\mu_{ij}^{l}\right)^{-1}}{\sqrt{\sum_{i=1}^{m}\left(\left(1-v_{ij}^{l}\right)^{-1}+\left(1-v_{ij}^{u}\right)^{-1}\right)^{2}}} \quad (15)$$

$$v_{ij}^{u}=1-\frac{\left(\mu_{ij}^{u}\right)^{-1}}{\sqrt{\sum_{i=1}^{m}\left(\left(1-v_{ij}^{l}\right)^{-1}+\left(1-v_{ij}^{u}\right)^{-1}\right)^{2}}} \quad (16)$$

Definition 5. *An IVIF weighted geometric (IVIFWG) is computed from Equation (17) [46].*

$$IVIFWG\left(\widetilde{Y}_{1},\widetilde{Y}_{2},\ldots,\widetilde{Y}_{n}\right)=\left(\widetilde{Y}_{1}\otimes\widetilde{Y}_{2}\otimes\ldots\otimes\widetilde{Y}_{n}\right)^{\frac{1}{n}} \quad (17)$$

Definition 6. *Computing the score function with Equation (18) [47].*

$$Score\left(\widetilde{Y}_{ij}\right)=\frac{1}{2}\left(\mu_{ij}^{l}+\mu_{ij}^{l}\left(1-\mu_{ij}^{l}-v_{ij}^{l}\right)+\mu_{ij}^{u}+\mu_{ij}^{u}\left(1-\mu_{ij}^{u}-v_{ij}^{u}\right)\right) \quad (18)$$

Definition 7. *Computing the IVIF averaging (IVIFA) function with Equation (19) [48].*

$$\begin{aligned} IVIFWA\left(\widetilde{Y}_{1},\widetilde{Y}_{2},\ldots,\quad\widetilde{Y}_{n}\right) &= \tfrac{1}{n}\sum_{j=1}^{n}\widetilde{Y}_{j} \\ &= \left(\left[1-\prod_{j=1}^{n}\left(1-\mu_{\widetilde{Y}_{j}}^{l}\right)^{\frac{1}{n}},1\right.\right. \\ &\left.\left.-\prod_{j=1}^{n}\left(1-\mu_{\widetilde{Y}_{j}}^{u}\right)^{\frac{1}{n}}\right],\left[\prod_{j=1}^{n}\left(v_{\widetilde{Y}_{j}}^{l}\right)^{\frac{1}{n}},\prod_{j=1}^{n}\left(v_{\widetilde{Y}_{j}}^{l}\right)^{\frac{1}{n}}\right]\right) \end{aligned} \quad (19)$$

3. Proposed Soft Computing Model

This paper develops a new structure to assess and choose suitable surgery device suppliers for TCs in the organ transplantation networks. In this respect, firstly, the corresponding literature has been observed to recognize the challenges of supplier selection for supplying surgery devices in healthcare industries, especially organ transplantation. Afterward, several DMs are introduced to judge the relations among criteria and alternatives with linguistic terms. Thereafter, a new IVIF-hybrid soft computing model has been proposed based on a similarity measure, the Shannon entropy method, and integrating the E-VIKOR and MARCOS approaches to obtain the weights of DMs and the weights of criteria, and rank the main alternatives, respectively. The main advantage of IVIFSs is concerned with the ability to manage membership and non-membership degrees together with regarding fuzzy values, which is a strength point of this study over traditional fuzzy sets [25,49]. Moreover, IVIFS applies interval values to depict the degrees rather than employing crisp. Likewise, uncertain data can be handled sufficiently by operating IVIFSs in comparison with other fuzzy types approaches. Furthermore, IVIFs, by considering membership and non-membership degrees, are represented as ranges of values instead of exact values [31]. The IVIF-similarity measure is one of the methods that is employed based on the distance from IVIF membership and non-membership values. This method is detailed and easy for applications. Furthermore, it not only can fulfill all the necessities of the metric, but also can avoid the limited outcomes assembled by an applied computing distance method in useful applications [50]. The main benefit of using the fuzzy Shannon entropy method is, as it is one of the most typically employing measures of variety within probability distributions, it computes the average value of uncertainty current in a given probability distribution. Furthermore, this method is able to compute the criteria weights under high complexity conditions [51]. The VIKOR method is one of the common ranking approaches by considering an advantage that involves a solution closest to the ideal solution containing an adequate compromise of conflicting and non-commensurable criteria [52]. Another obtaining ranking approach is the MARCOS method, which is constructed according to calculating utility functions. Hence, this method has an important benefit when it is utilized under fuzzy conditions. The advantage of using the fuzzy-MARCOS approach, considering fuzzy relation issues through fuzzy ideal and fuzzy anti-ideal from the beginning of model construction, is this can be a more accurate decision of the degree of utility concerning both set functions, the suggestion of a new way of specifying utility functions and its aggregation, and a possible way to view multiple sets of criteria and alternatives [53]. This paper introduces a new extended IVIF-hybrid model by applying the similarity measure and Shannon entropy methods under IVIF conditions to obtain the DMs weights and criteria weights, respectively. The organ transplant supply chain needs to select the best supplier whilst choosing a suitable expert within them. The distance-based similarity measure method has created this possibility to select a suitable DM by computing the distance from IVIF values. The IVIF-Shannon entropy approach enables us to obtain the criteria weights with a simple and accurate procedure and to select the essential criteria in less time to solve the surgery device supplier selection problem for organ transplantation networks. Moreover, this study proposes a new integration ranking method based on two new extended VIKOR methods and the MARCOS approach under IVIF situations. This method has the advantages of using the VIKOR and MARCOS approaches by combining their benefits to rank the surgery device supplier alternatives in transplant supply chain problems. It is important to consider the essential requirements of an organ transplant supply chain, such as using the freshest products with regard to the lowest impact on cold ischemia time, shelf life of the organs, and using high-quality organs to increase the satisfaction degree in a recipient person by demanding the surgery devices with a suitable supplier in less time. The healthcare managers or DMs should take note of these essential points by making an appropriate decision. This type of decision needs to consider the uncertain condition of the real-world application and compare the several alternatives with the ideal points. The E-VIKOR approach and MARCOS method compute the ranking of the alternatives by taking the ideal point and its closer degree by evaluating under IVIF conditions. The IVIF handles the uncertain situation by respecting membership and non-membership degrees closer to real-world applications. Furthermore, the IVIF-MARCOS approach ranks the main alternatives by involving the utility degree that selects the best alternative from the others. For this purpose, this model is capable of assessing surgery device suppliers in organ transplant networks under IVIF conditions. In this study, the criteria are related to sustainability segments, and the alternatives are respected healthcare device supplier organizations.

Step 1. Constructing the decision matrix (N_E) based on the experts' opinions (E) from Equation (20).

$$N_E = \left(\widetilde{N}_{ij}^E\right)_{m\times n} = \begin{pmatrix} \widetilde{N}_{11}^E & \cdots & \widetilde{N}_{1n}^E \\ \vdots & \ddots & \vdots \\ \widetilde{N}_{m1}^E & \cdots & \widetilde{N}_{mn}^E \end{pmatrix}_{m\times n} = \begin{pmatrix} \left(\left[\mu_{\widetilde{N}_{11}}^{El}, \mu_{\widetilde{N}_{11}}^{Eu}\right], \left[v_{\widetilde{N}_{11}}^{El}, v_{\widetilde{N}_{11}}^{Eu}\right]\right) & \cdots & \left(\left[\mu_{\widetilde{N}_{1n}}^{El}, \mu_{\widetilde{N}_{1n}}^{Eu}\right], \left[v_{\widetilde{N}_{1n}}^{El}, v_{\widetilde{N}_{1n}}^{Eu}\right]\right) \\ \vdots & \ddots & \vdots \\ \left(\left[\mu_{\widetilde{N}_{m1}}^{El}, \mu_{\widetilde{N}_{m1}}^{Eu}\right], \left[v_{\widetilde{N}_{m1}}^{El}, v_{\widetilde{N}_{m1}}^{Eu}\right]\right) & \cdots & \left(\left[\mu_{\widetilde{N}_{mn}}^{El}, \mu_{\widetilde{N}_{mn}}^{Eu}\right], \left[v_{\widetilde{N}_{mn}}^{El}, v_{\widetilde{N}_{mn}}^{Eu}\right]\right) \end{pmatrix}_{m\times n} \quad (20)$$

Step 2. Calculating the DMs weights with an IVIF-similarity measure.

Sub-step 2.1. [54]. Obtaining the ideal decision matrix (N^*) with Equation (21).

$$N^* = \left(\widetilde{N}_{ij}^*\right)_{m\times n} = \begin{pmatrix} \left(\left[\mu_{\widetilde{N}_{11}}^{*l}, \mu_{\widetilde{N}_{11}}^{*u}\right], \left[v_{\widetilde{N}_{11}}^{*l}, v_{\widetilde{N}_{11}}^{*u}\right]\right) & \cdots & \left(\left[\mu_{\widetilde{N}_{1n}}^{*l}, \mu_{\widetilde{N}_{1n}}^{*u}\right], \left[v_{\widetilde{N}_{1n}}^{*l}, v_{\widetilde{N}_{1n}}^{*u}\right]\right) \\ \vdots & \ddots & \vdots \\ \left(\left[\mu_{\widetilde{N}_{m1}}^{*l}, \mu_{\widetilde{N}_{m1}}^{*u}\right], \left[v_{\widetilde{N}_{m1}}^{*l}, v_{\widetilde{N}_{m1}}^{*u}\right]\right) & \cdots & \left(\left[\mu_{\widetilde{N}_{mn}}^{*l}, \mu_{\widetilde{N}_{mn}}^{*u}\right], \left[v_{\widetilde{N}_{mn}}^{*l}, v_{\widetilde{N}_{mn}}^{*u}\right]\right) \end{pmatrix}_{m\times n} \quad (21)$$

where $\mu_{\widetilde{N}_{ij}}^{*l} = 1 - \prod_{E=1}^{e}\left(1 - \mu_{\widetilde{N}_{ij}}^{El}\right)^{\frac{1}{e}}$, $\mu_{\widetilde{N}_{ij}}^{*u} = 1 - \prod_{E=1}^{e}\left(1 - \mu_{\widetilde{N}_{ij}}^{Eu}\right)^{\frac{1}{e}}$, $v_{\widetilde{N}_{ij}}^{*l} = \prod_{E=1}^{e}\left(v_{\widetilde{N}_{ij}}^{El}\right)^{\frac{1}{e}}$, $v_{\widetilde{N}_{ij}}^{*u} = \prod_{E=1}^{e}\left(\mu_{\widetilde{N}_{ij}}^{Eu}\right)^{\frac{1}{e}}$, and $\widetilde{N}_{ij}^* = \left(\left[\mu_{\widetilde{N}_{ij}}^{*l}, \mu_{\widetilde{N}_{ij}}^{*u}\right], \left[v_{\widetilde{N}_{ij}}^{*l}, v_{\widetilde{N}_{ij}}^{*u}\right]\right)$. This procedure is done based on IVIFA operator that is introduced on Definition 7.

Sub-step 2.2. Obtaining the similarity measure (SM) with Equation (22).

$$SM(N_E, N^*) = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} DIS\left(\widetilde{N}_{ij}^E, \widetilde{N}_{ij}^{*c}\right)}{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(DIS\left(\widetilde{N}_{ij}^E, \widetilde{N}_{ij}^*\right) + DIS\left(\widetilde{N}_{ij}^E, \widetilde{N}_{ij}^{*c}\right)\right)} \quad (22)$$

In this equation, $\widetilde{N}_{ij}^{*c} = \left(\left[v_{\widetilde{N}_{ij}}^{*l}, v_{\widetilde{N}_{ij}}^{*u}\right], \left[\mu_{\widetilde{N}_{ij}}^{*l}, \mu_{\widetilde{N}_{ij}}^{*u}\right]\right)$ and $DIS\left(\widetilde{N}_{ij}^E, \widetilde{N}_{ij}^{*c}\right) = \sqrt{\frac{1}{4}\left(\left(\mu_{\widetilde{N}_{ij}^E}^l - \mu_{\widetilde{N}_{ij}^{*c}}^l\right)^2 + \left(\mu_{\widetilde{N}_{ij}^E}^u - \mu_{\widetilde{N}_{ij}^{*c}}^u\right)^2 + \left(v_{\widetilde{N}_{ij}^E}^l - v_{\widetilde{N}_{ij}^{*c}}^l\right)^2 + \left(v_{\widetilde{N}_{ij}^E}^u - v_{\widetilde{N}_{ij}^{*c}}^u\right)^2\right)}$.

Sub-step 2.3. Calculating the weight of eth $(e \in E)$ DM from Equation (23).

$$W_e = \frac{SM(N_E, N^*)}{\sum_{E=1}^{e} SM(N_E, N^*)} \; \forall e \quad (23)$$

Step 3. Calculating the criteria weights with the Shannon entropy approach.

Sub-step 3.1. Computing the entropy measure with Equation (24).

$$\varsigma_j^e = -\frac{1}{m \ln 2}\sum_{i=1}^{m}\left[\mu_{ij}^{el}\ln\mu_{ij}^{el} + \mu_{ij}^{eu}\ln\mu_{ij}^{eu} + v_{ij}^{el}\ln v_{ij}^{el} + v_{ij}^{eu}\ln v_{ij}^{eu}\right] \forall e, j \quad (24)$$

Sub-step 3.2. Obtaining the criteria weights with Equation (25).

$$w_j^e = \frac{\left(1 - \varsigma_j^e\right)}{\sum_{j=1}^{n}\left(1 - \varsigma_j^e\right)} \quad (25)$$

Sub-step 3.3. Aggregating the criteria weights using the IVIFWG method with Definition 5.

$$\varpi^j = \prod_e \left(w_j^e\right)^{W_e} \tag{26}$$

In Equation (25), the DM weight is used from the previous step to compute the criteria weights.

Step 4. Calculating the ranking of alternatives with proposed IVIF-integrating model.

Sub-step 4.1. Obtaining the normalized ideal decision matrix $\left(\psi_{ij}\right)$ with Definition 4 from sub-step 2.1. by Equation (27).

$$\psi = \left(\widetilde{\psi}_{ij}\right)_{m\times n} = \\ = \begin{pmatrix} \left(\left[\mu^l_{\widetilde{I_{11}}}, \mu^u_{\widetilde{I_{11}}}\right], \left[v^l_{\widetilde{I_{11}}}, v^u_{\widetilde{I_{11}}}\right]\right) & \cdots & \left(\left[\mu^l_{\widetilde{I_{1n}}}, \mu^u_{\widetilde{I_{1n}}}\right], \left[v^l_{\widetilde{I_{1n}}}, v^u_{\widetilde{I_{1n}}}\right]\right) \\ \vdots & \ddots & \vdots \\ \left(\left[\mu^l_{\widetilde{I_{m1}}}, \mu^{*u}_{\widetilde{I_{m1}}}\right], \left[v^l_{\widetilde{I_{m1}}}, v^u_{\widetilde{I_{m1}}}\right]\right) & \cdots & \left(\left[\mu^l_{\widetilde{I_{mn}}}, \mu^u_{\widetilde{I_{mn}}}\right], \left[v^l_{\widetilde{I_{mn}}}, v^u_{\widetilde{I_{mn}}}\right]\right) \end{pmatrix}_{m\times n} \tag{27}$$

Sub-step 4.2. Computing positive ideal solutions and negative ideal solutions with Equations (28) and (29).

$$\psi_j^+ = \max_i\left(\psi_{ij}\right)\ \forall e, j \tag{28}$$

$$\psi_j^- = \min_i\left(\psi_{ij}\right) \tag{29}$$

Sub-step 4.3. Computing S_i and R_i from Equations (30) and (31).

$$S_i = \sum_j \frac{\varpi^j\left(\psi_j^+ - \psi_{ij}\right)}{\left(\psi_j^+ - \psi_j^-\right)}\ \forall e, j \tag{30}$$

$$R_i = \max_j \frac{\varpi^j\left(\psi_j^+ - \psi_{ij}\right)}{\left(\psi_j^+ - \psi_j^-\right)} \tag{31}$$

Equations (29) and (30) are utilized criteria weights to obtain S_i and R_i from step 3.

Sub-step 4.4. Computing the indices values of λ^i with Equation (32).

$$\lambda^i = \left(\frac{S_i + R_i}{2}\right)\left(\frac{S_i - S^+}{S^- - S^+}\right) + \left(\frac{2 - (S_i + R_i)}{2}\right)\left(\frac{R_i - R^+}{R^- - R^+}\right) \tag{32}$$

In these formulations, $S^+ = \min_i S_i$, $S^- = \max_i S_i$, $R^+ = \min_i R_i$, and $R^- = \max_i R_i$. Furthermore, Equation (31) computes the distance rate from the ideal value and expresses the distance rate from the anti-ideal degree. In this formula, $\left(\frac{S_i+R_i}{2}\right)$ is the average value between group utility and individual regret degrees, and $\frac{2-(S_i+R_i)}{2}$ is equal to $1 - \frac{(S_i+R_i)}{2}$, which is used to compute the indices values. These computational coefficient values are caused by indices that are calculation values independent of the DMs opinions.

Step 5. Obtaining the alternatives weights with IVIF-MARCOS method.

Sub-step 5.1. Calculating the weighted normalized decision matrix based on the ideal decision matrix with Equation (33).

$$\varsigma_{ij} = \varpi^j \psi_{ij}^* \tag{33}$$

In this respect, criteria weights $\left(\varpi^j\right)$ are obtained from step 3.

Sub-step 5.2. Creating the Q_i matrix with Equation (34).

$$Q_i = \sum_i \varsigma_{ij} \tag{34}$$

Sub-step 5.3. Computing the utility degree from Equations (35) and (36).

$$U_i^+ = \frac{Q_i}{Q_{ai}} \tag{35}$$

$$U_i^- = \frac{Q_i}{Q_{id}} \tag{36}$$

where, $Q_{ai} = \sum_{i=1}^{m} \Delta_i$, $Q_{id} = \sum_{i=1}^{m} \nabla_i$, $\Delta_i = \max_i \varsigma_{ij}$, and $\nabla_i = \min_i \varsigma_{ij}$.

Sub-step 5.4. Obtaining the utility functions of alternatives from Equations (37)–(39). Alternative ranking occurs based on the final values of utility functions.

$$f(U_i^+) = \frac{U_i^-}{U_i^- + U_i^+} \tag{37}$$

$$f(U_i^-) = \frac{U_i^+}{U_i^- + U_i^+} \tag{38}$$

$$f(U_i) = \frac{U_i^- + U_i^+}{1 + \frac{1 - f(U_i^+)}{f(U_i^+)} + \frac{1 - f(U_i^-)}{f(U_i^-)}} \tag{39}$$

Step 6. Computing alternative final ranking based on a new integration method with Equation (40).

$$C^i = \Gamma \lambda^i + (1 - \Gamma) f(U_i) \tag{40}$$

Γ is one coefficient value between 0 and 1. The proposed framework is illustrated in Figure 1.

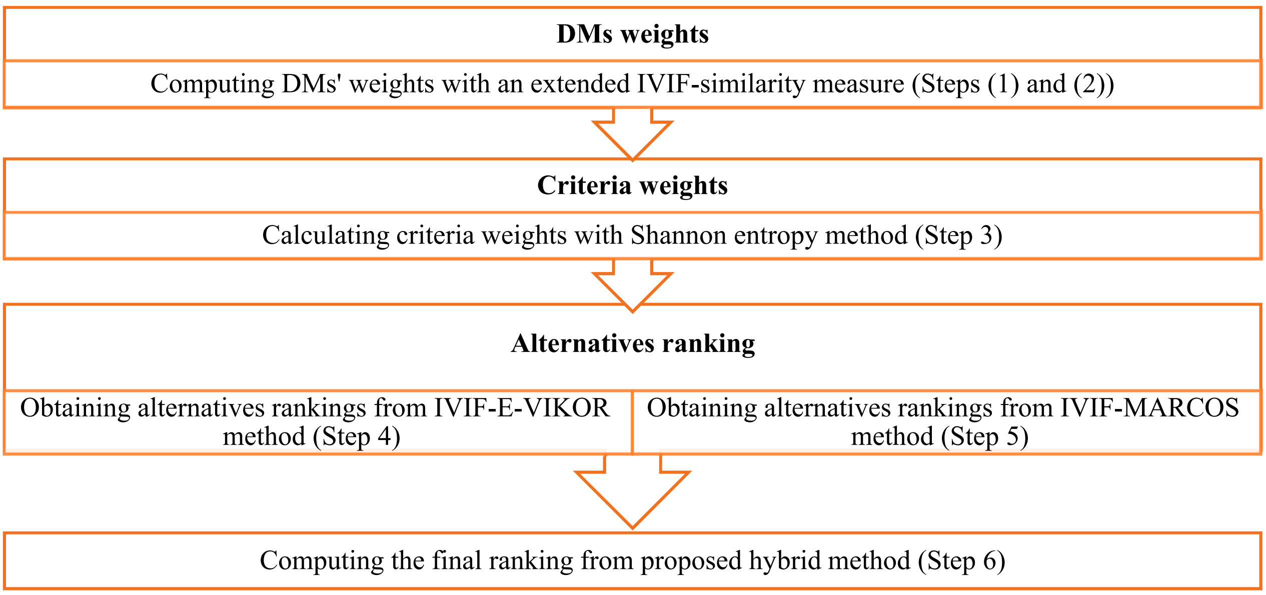

Figure 1. Structure of the proposed model.

4. Illustrative Example

This section is provided to validate the performance of the proposed model with an illustrative example. This example is considered based on supplying new devices of healthcare surgery for TC in the transplant networks for updating the technology of transplantation. In this respect, three experts ($DM_E = DM_1, DM_2, DM_3$) are utilized to evaluate 17 criteria ($Cr_j = Cr_1, Cr_2, \ldots, Cr_n$) that are related to three principal criteria, i.e., economic, social, and environmental. The criteria list is determined in Table 2 that is selected based on the related literature [55–60].

Table 2. Introducing criteria for the evaluation.

Segments	Criteria	Definition
Economic	C_1	Price
	C_2	Quality
	C_3	Delivery on time
	C_4	Contributions
	C_5	Management
	C_6	Reliability
Social	C_7	Credibility
	C_8	Safety
	C_9	Information revelation
	C_{10}	Employee benefits and rights
	C_{11}	Security acts
	C_{12}	Education
	C_{13}	Policies
Environmental	C_{14}	Environmental suitability
	C_{15}	Management systems of environment
	C_{16}	Pollution control
	C_{17}	Consider the requirements of ISO

Afterward, four suppliers as the main alternatives ($A_i = A_1, A_2, A_3, A_4$) are described in order to be evaluated and selected in organ transplantation networks. The first alternative (A_1) is related to the foreign companies of medical items that supply the equipment and medical devices. The second alternative (A_2) is regarded as the laboratory and surgery supplier. Moreover, the third alternative (A_3) is a distributor of the surgery equipment. Finally, the fourth alternative (A_4) is related to a supplier of surgery instruments.

This paper has decided to obtain new equipment and selected a sustainable supplier. In order to meet the special requirements of healthcare industries in using the equipment, a sustainable supplier selection can be applied. The issue of sustainability is based on the segment of economic, social, and environmental criteria. Firstly, the DMs were selected to assess the appropriate suppliers with a linguistic judgment that is recognized from Table 3 [61].

Table 3. Linguistic IVIF values [61].

Linguistic Terms	IVIF Values
Absolutely low (AL)	([0.1,0.25],[0.65,0.75])
Very low (VL)	([0.15,0.30],[0.60,0.70])
Low (L)	([0.20,0.35],[0.55,0.65])
Medium low (ML)	([0.25,0.40],[0.50,0.60])
Equal (E)	([0.45,0.55],[0.30,0.45])
Medium high (MH)	([0.50,0.60],[0.25,0.40])
High (H)	([0.55,0.65],[0.20,0.35])
Very high (VH)	([0.60,0.70],[0.15,0.30])
Absolutely high (AH)	([0.65,0.75],[0.10,0.25])

Later, this work has recognized which criteria of sustainability would be applied for three major segments. Thus, a proposed new hybrid soft computing approach is presented to obtain weights of the DMs and criteria with an extended IVIF-similarity measure and IVIF-Shannon entropy, respectively. Afterward, a new combination ranking method is proposed to rank the main alternatives by integrating the IVIF-E-VIKOR and IVIF-MARCOS (Γ = 0.5).

The linguistic comparison among criteria and alternatives with the DMs opinion matrix is shown in Table 4.

Table 4. Decision matrix.

Criteria	DMs	Alternatives			
		A_1	A_2	A_3	A_4
C_1	DM_1	E	MH	VH	AH
	DM_2	AH	E	AH	MH
	DM_3	MH	ML	VH	E
C_2	DM_1	MH	MH	ML	MH
	DM_2	VH	VH	AH	H
	DM_3	MH	MH	ML	ML
C_3	DM_1	ML	E	MH	E
	DM_2	MH	VH	MH	H
	DM_3	MH	AH	MH	MH
C_4	DM_1	E	MH	MH	MH
	DM_2	AH	MH	AH	MH
	DM_3	VH	MH	MH	H
C_5	DM_1	MH	VH	MH	VH
	DM_2	VH	AH	VH	AH
	DM_3	AH	VH	MH	MH
C_6	DM_1	MH	ML	MH	ML
	DM_2	E	AH	ML	E
	DM_3	ML	ML	H	ML
C_7	DM_1	MH	MH	MH	VH
	DM_2	VH	MH	E	AH
	DM_3	MH	MH	MH	VH
C_8	DM_1	E	MH	VH	MH
	DM_2	VH	AH	VH	AH
	DM_3	AH	MH	VH	MH
C_9	DM_1	MH	MH	VH	MH
	DM_2	MH	VH	AH	MH
	DM_3	MH	MH	VH	MH
C_{10}	DM_1	VH	MH	ML	MH
	DM_2	AH	ML	AH	AH
	DM_3	VH	H	ML	MH

Table 4. *Cont.*

Criteria	DMs	Alternatives			
		A_1	A_2	A_3	A_4
C_{11}	DM_1	ML	L	E	MH
	DM_2	AH	MH	AH	VH
	DM_3	ML	MH	MH	MH
C_{12}	DM_1	MH	MH	MH	MH
	DM_2	MH	H	VH	ML
	DM_3	MH	VH	MH	H
C_{13}	DM_1	MH	AH	ML	MH
	DM_2	AH	E	MH	E
	DM_3	MH	VH	MH	MH
C_{14}	DM_1	MH	AH	E	VH
	DM_2	VH	VH	AH	VH
	DM_3	MH	H	VH	VH
C_{15}	DM_1	MH	E	MH	VH
	DM_2	ML	MH	VH	AH
	DM_3	H	AH	AH	VH
C_{16}	DM_1	MH	H	MH	ML
	DM_2	E	E	E	AH
	DM_3	MH	MH	E	H
C_{17}	DM_1	VH	MH	MH	MH
	DM_2	VH	H	VH	MH
	DM_3	VH	MH	MH	MH

4.1. Computational Results

This section considers the outcomes of the proposed model. The similarity measure is used to compute the weights of the DMs. This method is organized based on obtaining the similarity measure degree ($SM(N_E, N^*)$) from Equation (22). This value is provided in Table 5. Afterward, the DM weight (W_e) is computed from Equation (23), of which the final values are determined in Table 5.

Table 5. Similarity measure computation results.

DMs	$SM(N_E, N^*)$	W_e
DM_1	0.630	0.337
DM_2	0.617	0.330
DM_3	0.623	0.333

Furthermore, the criteria weights are computed in Step 3 by the IVIF-Shannon entropy approach. In this respect, the entropy measure (ς_j^e) is computed from Equation (23), which is demonstrated in Table 6. The criteria weights with the DMs' opinions (W_j^e) are obtained by Equation (25), and the final aggregated criteria weights (ϖ^j) are computed from Equation (26), which are reported in Tables 7 and 8, respectively.

Table 6. Entropy measure.

DMs	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}
DM_1	0.429	0.464	0.471	0.467	0.436	0.464	0.450	0.453	0.450	0.450	0.462	0.464	0.444	0.429	0.453	0.458	0.450
DM_2	0.418	0.405	0.444	0.414	0.386	0.446	0.429	0.386	0.425	0.389	0.400	0.444	0.446	0.397	0.425	0.450	0.430
DM_3	0.453	0.464	0.439	0.444	0.425	0.458	0.450	0.425	0.450	0.444	0.464	0.444	0.450	0.430	0.394	0.462	0.450

Table 7. Criteria weights.

DMs	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}
DM_1	0.046	0.050	0.051	0.050	0.047	0.050	0.048	0.049	0.048	0.048	0.050	0.050	0.048	0.046	0.049	0.049	0.048
DM_2	0.042	0.041	0.045	0.042	0.039	0.045	0.043	0.039	0.043	0.039	0.041	0.045	0.045	0.040	0.043	0.046	0.044
DM_3	0.048	0.049	0.046	0.047	0.045	0.048	0.048	0.045	0.048	0.047	0.049	0.047	0.048	0.045	0.042	0.049	0.048

Table 8. Final aggregation criteria weights.

Criteria	**Weights**
C_1	0.045
C_2	0.127
C_3	0.047
C_4	0.046
C_5	0.044
C_6	0.048
C_7	0.046
C_8	0.044
C_9	0.046
C_{10}	0.045
C_{11}	0.046
C_{12}	0.047
C_{13}	0.047
C_{14}	0.044
C_{15}	0.044
C_{16}	0.048
C_{17}	0.046

Moreover, a proposed integrated ranking method is created based on two separate methods that consists of the IVIF-E-VIKOR method and IVIF-MARCOS. In this regard, the IVIF-E-VIKOR method is done by computing S_i in sub-steps 3.3 and 3.4. Furthermore, the final results of R_i, the final ranking values (λ^i), and the score function are given in Table 9. Furthermore, the amounts of S^+, S^-, R^+, and R^- are determined in Table 10.

The IVIF-MARCOS method result is shown in Table 11. These results consist of U_i^+, U_i^-, $f(U_i^+)$, $f(U_i^-)$, $f(U_i)$, and score function values.

Table 9. Ranking results of the IVIF-E-VIKOR method.

Alternatives	S_i	R_i	λ^i	Final Score Values
A_1	([0.379,0.391], [0.462,0.455])	([0.047,0.047], [0.127,0.127])	([0.032,0.030], [1.000,0.991])	0.030
A_2	([0.369,0.381], [0.458,0.458])	([0.046,0.046], [0.127,0.127])	([0.010,0.010], [0.987,1.000])	0.010
A_3	([0.443,0.460], [0.406,0.399])	([0.127,0.127], [0.048,0.048])	([0.198,0.192], [0.828,0.824])	0.191
A_4	([0.465,0.492], [0.375,0.370])	([0.096,0.112], [0.046,0.046])	([0.266,0.279], [0.749,0.752])	0.266

Table 10. Ideal and anti-ideal values.

S^+	S^-	R^+	R^-
([0.369,0.381], [0.375,0.370])	([0.465,0.492], [0.462,0.458])	([0.046,0.046], [0.046,0.046])	([0.127,0.127], [0.127,0.127])

Table 11. Final values of the IVIF-MARCOS method.

Alternatives	U_i^+	U_i^-	$f(U_i^+)$	$f(U_i^-)$	$f(U_i)$
A_1	([0.588,0.592], [0.226,0.363])	([2.222,2.237], [0.855,1.374])	([0.791,0.791], [0.791,0.791])	([0.209,0.209], [0.209,0.209])	([0.557,0.561], [0.214,0.344])
A_2	([0.490,0.590], [0.229,0.366])	([1.852,2.228], [0.865,1.384])	([0.791,0.791], [0.791,0.791])	([0.209,0.209], [0.209,0.209])	([0.464,0.559], [0.217,0.347])
A_3	([0.483,0.586], [0.242,0.375])	([1.824,2.215], [0.915,1.419])	([0.791,0.791], [0.791,0.791])	([0.209,0.209], [0.209,0.209])	([0.457,0.555], [0.229,0.356])
A_4	([0.484,0.584], [0.235,0.371])	([1.824,2.209], [0.889,1.402])	([0.791,0.791], [0.791,0.791])	([0.209,0.209], [0.209,0.209])	([0.458,0.554], [0.223,0.351])

The final outcomes of the proposed integrated model are determined in Table 12. The fourth alternative has higher priority than others with a high-ranking value with a proposed model. This alternative is related to the supplier of surgery instruments.

Table 12. Final proposed method ranking results.

Alternatives	Final Score Values	Final Ranking Results
A_1	0.340	3
A_2	0.311	4
A_3	0.397	2
A_4	0.436	1

4.2. Comparative Analysis

This section analyses the performance of the proposed approach via other methods. In this respect, the proposed model is compared with the IVIF-VIKOR and IVIF-TOPSIS methods based on the studies of Park et al. [62] and Park et al. [63], and the final outcomes are demonstrated in Table 13. Table 13 determines that the proposed approach has a high performance from the related literature study. The final results show that the fourth alternative has a higher priority than the other ones; the comparison determines that the hybrid proposed approach is validated to rank the main alternatives of the MCDM problems.

Table 13. Comparing the performance of the proposed model.

Alternatives	IVIF-VIKOR [62]	IVIF-VIKOR Ranking	IVIF-TOPSIS [63]	IVIF-TOPSIS Ranking	IVIF-Hybrid Proposed Model	Proposed Model Ranking
A_1	0.052	3	0.522	3	0.340	3
A_2	0.006	4	0.496	4	0.311	4
A_3	0.359	2	0.524	2	0.397	2
A_4	0.461	1	0.653	1	0.436	1

According to Table 13, the final ranking outcomes are similar to three types of methods, but the proposed model has various advantages over other approaches. The introduced method has the features of the IVIF-E-VIKOR process that is because of independent solutions to the DMs opinions. This instance is not common in a traditional VIKOR approach, which is the strong point of the proposed model. The alternatives' utility functions are displayed according to the relationships described in the IVIF-MARCOS approach, which is a straightforward and efficient multi-criteria procedure by considering handling technique of uncertain conditions. Furthermore, this method is constructed based on specifying the relationship between ideal and anti-ideal alternatives. An agreement ranking is then recognized regarding ideal and non-ideal solutions. The proposed model is more efficient than the IVIF-TOPSIS method and IVIF-VIKOR approach concerning the previous descriptions.

4.3. Sensitivity Analysis

This section provides an analysis of the essential and efficient parameters that have an impact on the final decisions. For this reason, the impact of DMs weights on criteria weights are discussed by changing the weights of DMs among each other in Figure 2. This figure shows that the second criterion has a higher value than other criteria by changing DMs weights. Furthermore, this point shows that the criteria weights are independent of the DMs' weight effects.

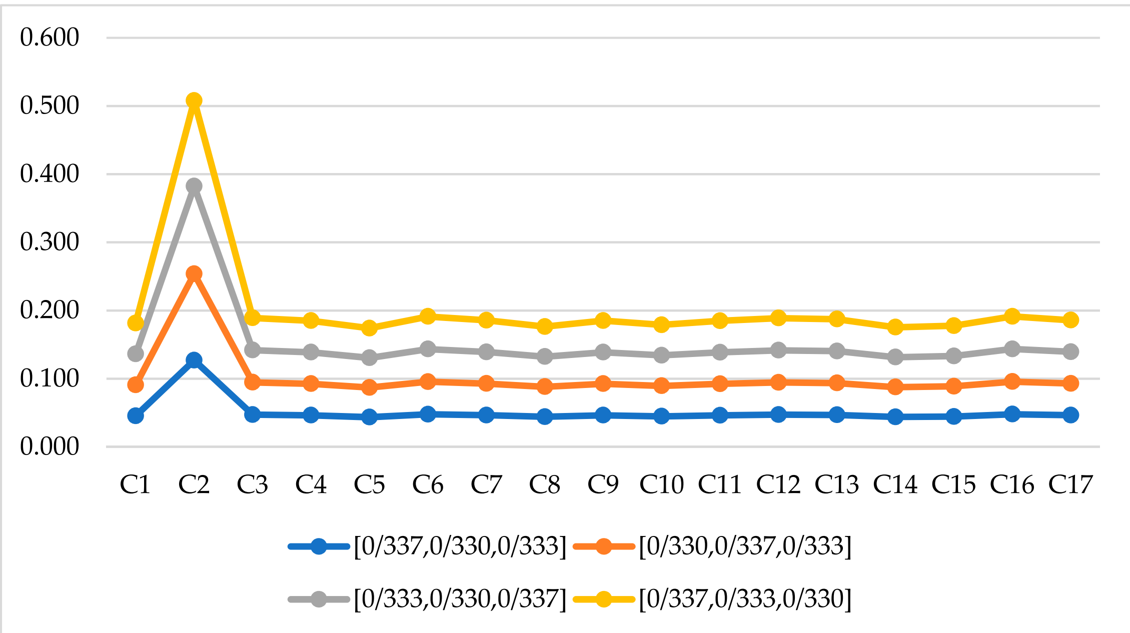

Figure 2. Effect of DMs weights on criteria weights.

Moreover, the effect of criteria weights on the final ranking results is an important issue that is discussed in this part. For this reason, the criteria weights change among each other, and their effectiveness on the final ranking results are presented in Figure 3. In this regard, the changing of criteria weights between two criteria, *i* and *j*, is shown by CC_{ij}. Furthermore, this figure determines the changing of criteria weights in 10 different situations to depict the effectiveness of criteria weights on the final ranking results. This figure demonstrates that the fourth alternative has higher priority than others by changing the criteria weights, and the proposed ranking model is independent of their weights.

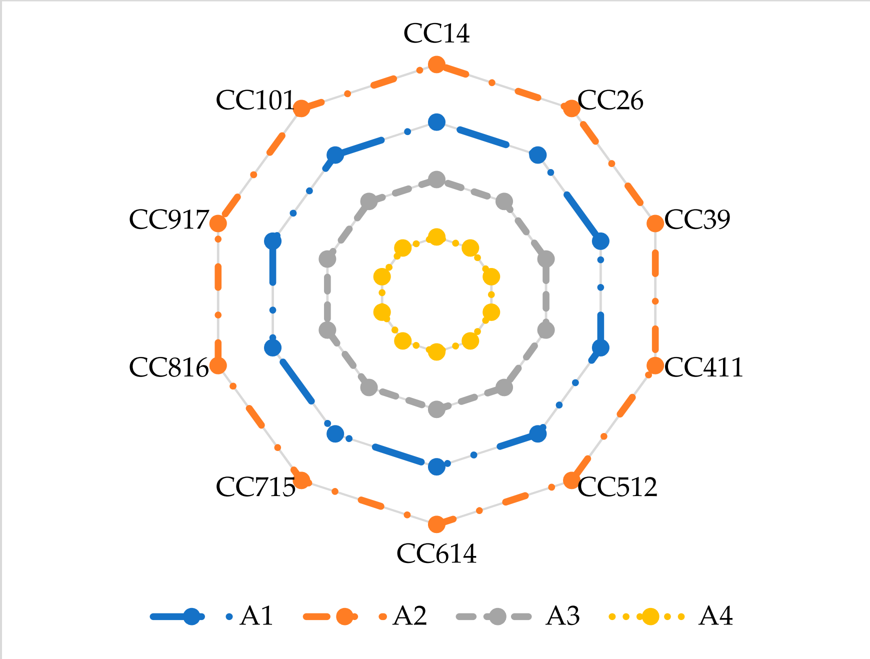

Figure 3. Impact of criteria weights on final ranking results.

Finally, the impact of Γ value in the proposed integrated approach is analyzed in this section. In this respect, the value of Γ changes between [0.1,0.9], and the final ranking consequences are represented in Table 14. In more cases, the fourth alternative has higher priority than others, and in one case, this alternative changes its position with the first alternative.

Table 14. Impact of *M* value on final ranking results.

Γ	1 − Γ	Ranking Results
0.100	0.900	$A_4 > A_3 > A_1 > A_2$
0.200	0.800	$A_4 > A_3 > A_1 > A_2$
0.300	0.700	$A_4 > A_3 > A_1 > A_2$
0.400	0.600	$A_4 > A_3 > A_1 > A_2$
0.500	0.500	$A_4 > A_3 > A_1 > A_2$
0.600	0.400	$A_4 > A_3 > A_1 > A_2$
0.700	0.300	$A_4 > A_3 > A_1 > A_2$
0.800	0.200	$A_4 > A_1 > A_3 > A_2$
0.900	0.100	$A_1 > A_4 > A_3 > A_2$

5. Conclusions

Selecting the suitable supplier of medical devices in sustainable healthcare networks, especially organ transplantation networks, plays a critical role in operating and transplanting. In this regard, the aim of this paper is to analyze the impact of appropriate surgery device suppliers and select them to increase and improve surgery technology for transplantation operations under the sustainability requirement. This paper has provided a new multi-criteria decision-making (MCDM) approach by a hybrid extended vlsekriterijuska optimizacija i komoromisno resenje (E-VIKOR) and measurement alternatives and ranking according to the compromise solution (MARCOS) methods with interval-valued intuitionistic fuzzy sets (IVIFSs). The strength point of the E-VIKOR method is related to aggregating the final value procedure. The proposed model has included the technique of computing decision-makers (DMs) weights, criteria weights, and alternative ranking for healthcare device supplier selection problems in transplantation networks based on the IVIF-similarity measure, the IVIF-Shannon entropy method, and a new hybrid proposed soft computing method that included an extended IVIF-E-VIKOR method and IVIF-MARCOS approach, respectively. Furthermore, the managers and DMs need to cope with the uncertain condition of the real-world applications; in this paper, in this respect, the IVIFSs were utilized. Therefore, this study considered an empirical example to evaluate the performance of the proposed approach in the supplier selection for the transplantation sustainable networks problem. For this reason, the sustainability criteria were provided to assess the impact of the sustainability concept, based on three aspects, i.e., economic, social, and environmental issues, under four main alternatives. Hence, the fourth alternative had a higher priority than others that was related to the supplier of surgery instruments. Moreover, the proposed model was compared with the IVIF-VIKOR and IVIF-TOPSIS approaches; these methods confirmed the performance and validation of the introduced approach. Furthermore, the sensitivity analysis on the impact of the DMs weights on the criteria weights, and the criteria weights on the final ranking results were investigated. All of them determined that the criteria weights and the final ranking results were independent of the DMs weights and criteria weights, respectively. Furthermore, the sensitive analysis occurred on the Γ parameter in the final ranking proposed approach that determined the impact of the IVIF-E-VIKOR approach more than the IVIF-MARCOS method in hybrid proposed model outcomes.

For future research suggestions, other aspects of organ transplantation network requirements can be focused on increasing the surgery level. Furthermore, future studies can regard one side of sustainability conditions. Afterward, other well-known MCDM techniques can be applied, in the related literature of MCDM [64–69], to compare with the proposed method or increase the suitability of the selected supplier.

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