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An IVIF-Distance Measure and Relative Closeness Coefficient-Based Model for Assessing the Sustainable Development Barriers to Biofuel Enterprises in India

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Abstract: Biofuel can become a favorable sustainable energy resource in India by relieving conventional fossil fuels. However, biofuel enterprises (BEs) are still in the preliminary phase because of sustainable development barriers (SDBs) in environmental, technological, economic, social, and regulatory aspects. In the paper, nineteen SDBs to biofuels are identified by studying the literature and decision experts' (DEs') views. Considering the involvement of multiple tangible and non-tangible barriers, the assessment of SDBs to BEs can be taken as a multi-attribute decision-analysis (MADA) problem. Since ambiguity and imprecision generally ensue in the assessment of SDBs to BEs, the doctrine of interval-valued intuitionistic fuzzy sets (IVIFSs) has been recognized as a more sensible and proficient way to tackle uncertain MADA problems. Then, an integrated approach with IVIF-distance measure and IVIF-relative closeness coefficient models is presented to form associations between the SDBs to recognize the most important SDBs. The outcomes of this study show that four SDBs, i.e., "lack of effective storage facilities (EC-2), lack of investors (EC-3), technical issues associated with conversion technologies (T-2), and lack of trust between local societies, agencies, and developers (S-4)" are the leading obstacles. The paper also discusses some policies that can be utilized as a managing stage by the DEs to articulate guidelines for the operational exclusion of SDBs to biofuel enterprises.

Keywords: interval-valued intuitionistic fuzzy sets; distance measure; closeness coefficient; sustainability; barriers; MADA; biofuel sector

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1. Introduction

Nowadays, people are relentlessly concerned about global warming because of the increase in the world population, the diminution of customary "fossil fuels (FFs)", and pollution produced by automobiles [1]. Henceforth, conventional fuels need to be replaced by "renewable energy resources (RESs)". As an RES, biomass can represent a solution that contributes to supplying the electricity demands and producing high-density fuels. However, biomass is an inadequate RES and can only complement variable RESs for electricity generation and electrification of transportation sectors [2,3]. Biomass-based fuel blends as an alternative can play an important part in achieving "sustainable development (SD)" and improving energy safety. Biofuels and electric vehicles have started to be used to reach the targets of "sustainable development goals (SDGs)" [4]. At present, biodiesel is the major biofuel utilized in the European Union for transport [5]. Moreover, ethanol is usually utilized as a blend with a low proportion of fossil fuels. Consequently, scientists and governments have started to pay attention to hydrocarbon fuels as the target product of biomass refinement technology.

Since India is a huge agricultural nation, the growth of the biofuel economy would cause savings in traditional fuels and support the alleviation of pollution concerns to a certain level. The utilization of biomass considerably supports the reduction of carbon emissions and allows the growth of rural regions because biofuels can be utilized for manufacturing transportation fuel, electricity, and heat [6–8]. The agriculture of biomass delivers rural progress prospects and agriculture variation, and the energy achieved from biomass will have further social recognition, as it is associated with the diverse practices of RESs [9]. Biofuels are a promising energy resource produced from different plant oils, waste oils, microbial lipids, food crops, agricultural residues, and animal fats, and have a massive possibility to meet more than a quarter of the world demand for transportation fuels by 2050, especially in developing countries such as India. India has around 500 MTs of biomass produced per year, out of which 120 to 150 MTs are additional. Additionally, 12.83% of the whole RE production is funded by biofuels only [10]. Furthermore, advanced adaptation efficiencies and minor costs are the noteworthy drivers of bioenergy abstraction [11].

India is the fourth-place net importer and user of crude oil and petroleum goods behind the USA, China, and Japan [12]. Moreover, India is the fourth-place emitter of "greenhouse gases (GHGs)", and the nation's transportation field produces 13% of CO_2 emissions [8,13]. These emissions owing to transportation can be minimized using sustainable methods, for example, the practice of public transit, more and more use of biofuels, and refining vehicle proficiencies. Since oil is the second-biggest energy source next to coal with a share of 30.5% of prime energy consumption in India [12], the growth of RESs or other alternatives needs to be produced successfully and resourcefully to replace or enhance petrol family oils. Biofuels are evolving as the most favorable energy choices to conventional fuels. Biofuels have momentous benefits for national energy safety, alleviation of GHGs, and rural growth [14]. Biomass-based energy can address several concerns associated with energy safety and organization [15]. This produces an important barrier for biofuel energy abstraction policies. It is noticed that energy abstraction from biomass should not be taken as an economic or technological issue. Additionally, it comprises public views about the risks elaborated in the procedure of growth. Additionally, it is claimed that the utilization of comestible biomass for making fuel may have an adversative impact on food safety and inflate food costs [7,12]. Furthermore, agriculture imitative biofuels are related to ecological damage and they are less efficient as compared to traditional fuel oils, which raises biofuel consumption [16].

Sustainability mobility raises a certain number of questions. Over the last decades, most industrialized countries have introduced strict regulations limiting the environmental impact produced by combustion engines. Governments pressing the car industry to electrify their products in order to assure the ecological transition of mobility. This has forced car manufacturers to invest heavily in research and development into alternative fuels and new propulsion systems. To encourage this transition, governments offer incentives and benefits, such as tax exemption (ownership tax) or free access to restricted traffic zones (ZTLs). As argued by D'Adamo et al. [17], the real weight of this transition is charged to the customers that are stimulated to change their traditional vehicles but at the same time, they have to buy hybrid/electric cars with high costs. Ecological benefits could, of course, be obtained by considering alternative fuels, but also by considering the "end of life" strategies based on the circular economy approach [18]. The sustainable transition also needs an original social approach involving citizens in the decision-making activity. Moreover, incentives and economic measures should be provided to stimulate the dissemination of small-scale plants in the territory and the creation of energy communities [17].

It may be seen that the "biofuel enterprise (BE)" is in its initial phase in India because of numerous "sustainable development barriers (SDBs)" in different aspects of sustainability. The SDBs are inter-reliant, and there exists a cause-and-influence association with the SDBs. Assessment of SDB pillars considers several barriers in the biofuel industry. Since the assessment of SDBs involves diverse aspects and uncertainty, it can be considered a "multi-attribute decision analysis (MADA)" issue with uncertainty. The "interval-valued intuitionistic fuzzy sets (IVIFSs)" [19] can treat imprecise and uncertain data in numerous realistic settings. As the generalization of the fuzzy set, the theory of IVIFS is characterized by the membership grade (MG) and non-membership grade (NG), expressed in the form of intervals rather than exact numbers. As IVIFSs can effectively deal with the MADA concern with ambiguity and fuzziness, some extant studies have applied IVIFS-based models from the perspective of SD [20–22].

In this research, the precarious SDBs to BEs in India are recognized and demonstrated using an integrated MADA procedure for identifying the limitations and their cause-influence association, which is missing in earlier studies. This paper also plans to offer a few policies, which may be utilized by "decision experts (DEs)" and executives to articulate appropriate strategies for the operative eradication of recognized SDBs. We present the notable research contributions of the paper as follows:

- This study classifies the crucial SDBs to the biofuel industry in India and assesses the association between the recognized barriers. However, existing methods given by [1,23–25] are not able to identify and assess the SDBs in the biofuel industry.
- Distance measure, as one of the important information measures, plays a vital role in real-life problems such as decision-making, pattern recognition, texture recognition, and so forth. In this study, we propose a new IVIF-distance measure with enviable properties to measure the degree of discrimination between IVIFSs.
- Direct assumption of decision experts' (DEs') weights results in loss of information while making decisions. Thus, it is very important to determine the weights of DEs during the process of decision-making. In this paper, we propose a new IVIF-score value and rank sum (RS) model-based weighting approach to derive the DEs' weights within the IVIFS context.
- In order to consider the relative closeness coefficient of barriers, this paper presents a new IVIF-distance-based model and uses it to find the objective and subjective weight of barriers to prioritize the SDBs in the biofuel industry.

2. Literature Review

2.1. Studies on the Biofuel Sector

This section entails a review of the biofuel sector. With the use of the gray DEMATEL approach, Liang et al. [1] identified the critical success factors for enhancing the sustainability of China's biofuel sector. That study has effectively recognized the success factors but does not consider the barriers to SD in China's biofuel sector. Jernstrom et al. [23] identified the opportunities and analyzed the barriers to entry for small/medium enterprises in biofuel-based sectors. However, their study is unable to express the uncertainty and vagueness of real-life problems, while practical decision-making problems usually involve uncertainty due to time limitations and the subjectivity of the human mind. Saravanan et al. [24] studied strategy barriers to biofuel marketing from an Indian perspective and they underlined the efforts of the public and government to overcome these barriers. That study only considers an empirical study but does not provide any tool to identify the strategy barriers. In addition, their study is not able to handle the biofuel marketing decision-making problems from an uncertainty perspective. Malode et al. [25] provided the theoretical aspects of recent advances and the possibility of biofuel production in the biofuel sector. Unfortunately, there is no study that identifies the critical SDBs to the biofuel industry in India from an uncertainty perspective.

2.2. Review on IVIFSs and MADA

The theory of IVIFS has been given by Atanassov and Gargov [19] for treating uncertain information in realistic MADA problems. Numerous scholars have employed IVIFSs to develop MADA models for handling realistic issues with uncertain settings [26]. Firstly, Xu [27] discussed diverse basic "aggregation operators (AOs)" to aggregate the information and score and accuracy functions to rank the IVIFNs. Wang and Mendel [28] proposed a decision-making method based on the Lukasiewicz triangular norm. Moreover, their study presented the drawbacks of existing studies on IVIFSs. In a study, Hu et al. [29] developed a novel entropy-weighted TOPSIS methodology with interval-valued intuitionistic fuzzy information. Their application presented the assessment of technology portfolios of clean energy-driven desalination-irrigation systems. Mishra et al. [30] introduced a divergence and entropy measure-based decision support system for assessing the service quality problem. For this purpose, they proposed some divergence measures to quantify the degree of discrimination between IVIFSs and entropy measures to quantify the uncertainty of IVIFSs. Oraki et al. [31] defined some frank t-norm and t-conorm operations on IVIFNs. Further, they proposed a list of frank AOs by analyzing the limitations of existing AOs under the IVIFS context. Bharati [32] studied a new ranking method by means of the law of trichotomy. In addition, their applicability has been tested on a transportation problem under an interval-valued intuitionistic fuzzy environment. As per our investigation, no study has used the theory of IVIFS for assessing SDBs in the biofuel industry.

3. IVIF-Distance Measure

3.1. Preliminaries

Here, some essential concepts of IVIFSs are discussed.

Atanassov and Gargov [19] extended IVIFSs based on IFSs to handle the uncertainty, which is exemplified by the "membership grade (MG)" and "non-membership grade (NG)" in interval form.

Definition 1 [19]. *Let* $\Omega = \{x_1, x_2, \ldots, x_n\}$ *be a fixed set. An IVIFS P on* Ω *is described as* $P = \{\langle x_i, \mu_P(x_i), \nu_P(x_i)\rangle : x_i \in \Omega\}$, *where* $\mu_P(x_i) = \left[\mu_P^-(x_i), \mu_P^+(x_i)\right] : \Omega \to [0, 1]$ *and* $\nu_P = \left[\nu_P^-(x_i), \nu_P^+(x_i)\right] : \Omega \to [0, 1]$ *hold* $\sup(\mu_P(x_i)) + \sup(\nu_P(x_i)) \leq 1$. *The intervals* $\mu_P(x_i)$ *and* $\nu_P(x_i)$ *indicate the MG and NG of the variable* x_i *in* Ω, *respectively.*

The interval $\pi_P(x_i) = \left[\pi_P^-(x_i), \pi_P^+(x_i)\right] = \left[1 - \mu_P^+(x_i) - \nu_P^+(x_i), 1 - \mu_P^-(x_i) - \nu_P^-(x_i)\right]$ signifies the "hesitancy grade (HG)" of x_i to P. The pair $\left(\left[\mu_P^-(x_i), \mu_P^+(x_i)\right], \left[\nu_P^-(x_i), \nu_P^+(x_i)\right]\right)$ is termed an IVIFN [27] and is commonly denoted by $\theta = ([p, q], [0, 1])$, where $[p, q] \subset [0, 1]$, $[r, s] \subset [0, 1]$, and $q + s \leq 1$.

Definition 2 [17]. *Let* $P, Q \in IVIFSs(\Omega)$. *Some basic operations on IVIFSs are defined as*

(a) $P \subseteq Q$ if and only if $\mu_P^-(x_i) \leq \mu_Q^-(x_i)$, $\mu_P^+(x_i) \leq \mu_Q^+(x_i)$, $\nu_P^-(x_i) \geq \nu_Q^-(x_i)$ and $\nu_P^+(x_i) \geq \nu_Q^+(x_i), \forall x_i \in \Omega$,

(b) $P = Q$ if and only if $P \subseteq Q$ and $P \supseteq Q$,

(c) $P^c = \left\{\left\langle \alpha_i, \left[\nu_P^-(\alpha_i), \nu_P^+(\alpha_i)\right], \left[\mu_P^-(\alpha_i), \mu_P^+(\alpha_i)\right]\right\rangle \middle| \alpha_i \in \alpha\right\}$,

(d) $P \cup Q = \left\{\left\langle \begin{array}{c} \alpha_i, \left[\mu_P^-(\alpha_i) \vee \mu_Q^-(\alpha_i), \mu_P^+(\alpha_i) \vee \mu_Q^+(\alpha_i)\right], \\ \left[\nu_P^-(\alpha_i) \wedge \nu_Q^-(\alpha_i), \nu_P^+(\alpha_i) \wedge \nu_Q^+(\alpha_i)\right] \end{array} \right\rangle \middle| \alpha_i \in \alpha \right\}$,

(e) $P \cap Q = \left\{\left\langle \begin{array}{c} \alpha_i, \left[\mu_P^-(\alpha_i) \wedge \mu_Q^-(\alpha_i), \mu_P^+(\alpha_i) \wedge \mu_Q^+(\alpha_i)\right], \\ \left[\nu_P^-(\alpha_i) \vee \nu_Q^-(\alpha_i), \nu_P^+(\alpha_i) \vee \nu_Q^+(\alpha_i)\right] \end{array} \right\rangle \middle| \alpha_i \in \alpha \right\}$.

Definition 3 [27]. *Consider* $\theta = ([p, q], [r, s])$ *be an IVIFN, then* $\mathbb{S}(\theta) = \frac{1}{2}(p + q - r - s)$ *and* $\hbar(\theta) = \frac{1}{2}(p + q + r + s)$ *are said to be IVIF-score and IVIF-accuracy values of* θ, *respectively.*

Bai [33] pioneered the improved score value using the HD between the BD and ND of IVIFNs.

Definition 4 [33]. *Let* $\theta = ([p, q], [r, s])$ *be an IVIFN. Then,*

$$\mathbb{S}^*(\theta) = \frac{p + p(1 - p - r) + q + q(1 - q - s)}{2} \tag{1}$$

is known as an improved score function, where $\mathbb{S}^*(\theta) \in [0,1]$.

Definition 5 [27]. *For a set of IVIFNs* $P = \{P_1, P_2, \ldots, P_\ell\}$, *where* $P_k = ([p_k, q_k], [r_k, s_k])$, $k = 1, 2, \ldots, \ell$, *the IVIFWA operator is given*

$$\overset{\ell}{\underset{k=1}{\oplus}} \xi_k P_k = \left(\left[1 - \prod_{k=1}^{\ell} (1 - p_k)^{\xi_k}, 1 - \prod_{k=1}^{\ell} (1 - q_k)^{\xi_k} \right], \left[\prod_{k=1}^{\ell} (r_k)^{\xi_k}, \prod_{k=1}^{\ell} (s_k)^{\xi_k} \right] \right). \quad (2)$$

Along a similar line, the IVIFWG operator is given by

$$\overset{\ell}{\underset{k=1}{\otimes}} \xi_k P_k = \left(\left[\prod_{k=1}^{\ell} (p_k)^{\xi_k}, \prod_{k=1}^{\ell} (q_k)^{\xi_k} \right], \left[1 - \prod_{k=1}^{\ell} (1 - r_k)^{\xi_k}, 1 - \prod_{k=1}^{\ell} (1 - s_k)^{\xi_k} \right] \right). \quad (3)$$

Definition 6 [34]. *An IVIF-distance measure* $d : IVIFSs(\Omega) \times IVIFSs(\Omega) \to [0, 1]$ *is a real-valued mapping that holds*

(C_1). $0 \le d(P, Q) \le 1$,
(C_2). $d(P, Q) = 0 \Leftrightarrow P = Q$,
(C_3). $d(P, Q) = 1 \Leftrightarrow Q = P^c$,
(C_4). $d(P, Q) = d(Q, P)$,
(C_5). If $P \subseteq Q \subseteq H$, then $d(P, H) \ge d(P, Q)$ and $d(P, H) \ge d(Q, H)$, for all $F, G, H \in IVIFSs(\Omega)$.

3.2. Proposed IVIF-Distance Measure

The objective of the section is to develop new IVIF-distance measures and then employ them to originate the attribute weight in the next section. Based on Tripathi et al. [35], a distance measure is developed for IVIFSs.

For $P, Q \in IVIFSs(\Omega)$, we develop a new IVIF-distance measure for estimating the discrimination between two IVIFSs, given as

$$d_1(P, Q) = \frac{1 - \exp\left[-\frac{1}{2} \left(\sum_{i=1}^{t} \left(\begin{array}{c} \left|\mu_P^-(x_i) - \mu_Q^-(x_i)\right|^\gamma + \left|\mu_P^+(x_i) - \mu_Q^+(x_i)\right|^\gamma + \left|\nu_P^-(x_i) - \nu_Q^-(x_i)\right|^\gamma \\ + \left|\nu_P^+(x_i) - \nu_Q^+(x_i)\right|^\gamma + \left|\pi_P^-(x_i) - \pi_Q^-(x_i)\right|^\gamma + \left|\pi_P^+(x_i) - \pi_Q^+(x_i)\right|^\gamma \end{array} \right) \right)^{1/\gamma} \right]}{1 - \exp\left(-(t)^{1/\gamma} \right)}, \quad (4)$$

where $\gamma > 0$, $\gamma \neq 1$.

Lemma 1. *If* $h(\lambda) = 1 - \frac{1 - \exp(-\lambda)}{1 - \exp\left(-(t)^{1/\gamma}\right)}$, *then*

$$\min_{\lambda \in [0, t]} h(\lambda) = h(0) = 0 \text{ and } \max_{\lambda \in [0, t]} h(\lambda) = h(t) = 1.$$

Proof. Since $h'(\lambda) = \frac{\exp(-\lambda)}{1 - \exp\left(-(t)^{1/\gamma}\right)} < 0, \forall \lambda \in [0, t]$, therefore, $h(\lambda)$ is increasing in $[0, t]$.□

Theorem 1. *The measure* $d_1(P, Q)$ *in Equation (4) is a valid IVIF-distance measure.*

Proof. In this regard, $d_1(P, Q)$ must fulfill the axioms (C_1)–(C_5) of Definition 6. (C_1). Let $P, Q \in IVIFSs(\Omega)$, and

$$\lambda = \frac{1}{2}\left(\sum_{i=1}^{t}\left(\begin{array}{c}\left|\mu_P^-(x_i) - \mu_Q^-(x_i)\right|^\gamma + \left|\mu_P^+(x_i) - \mu_Q^+(x_i)\right|^\gamma + \left|\nu_P^-(x_i) - \nu_Q^-(x_i)\right|^\gamma \\ +\left|\nu_P^+(x_i) - \nu_Q^+(x_i)\right|^\gamma + \left|\pi_P^-(x_i) - \pi_Q^-(x_i)\right|^\gamma + \left|\pi_P^+(x_i) - \pi_Q^+(x_i)\right|^\gamma\end{array}\right)\right)^{1/\gamma}.$$

Since $\lambda \in [0, t]$, therefore, $d_1(P, Q) = h(\lambda)$. Thus, utilizing Lemma 1, we have $0 \leq d_1(P, Q) \leq 1$.

(C$_2$). Let $P = Q$. Then $\mu_P^-(x_i) = \mu_Q^-(x_i)$, $\mu_P^+(x_i) = \mu_Q^+(x_i)$, $\nu_P^-(x_i) = \nu_Q^-(x_i)$ and $\nu_P^+(x_i) = \nu_Q^+(x_i), \forall_{x_i \in \Omega}$. Then, it is obvious from Equation (4) that $d_1(P, Q) = 0$.

Let $d_1(P, Q) = 0$. From Equation (4), we have

$$\frac{1-\exp\left[-\frac{1}{2}\left(\sum_{i=1}^{t}\left(\begin{array}{c}\left|\mu_P^-(x_i) - \mu_Q^-(x_i)\right|^\gamma + \left|\mu_P^+(x_i) - \mu_Q^+(x_i)\right|^\gamma + \left|\nu_P^-(x_i) - \nu_Q^-(x_i)\right|^\gamma \\ +\left|\nu_P^+(x_i) - \nu_Q^+(x_i)\right|^\gamma + \left|\pi_P^-(x_i) - \pi_Q^-(x_i)\right|^\gamma + \left|\pi_P^+(x_i) - \pi_Q^+(x_i)\right|^\gamma\end{array}\right)\right)^{1/\gamma}\right]}{1-\exp\left(-(t)^{1/\gamma}\right)} = 0.$$

It implies that

$$\sum_{i=1}^{t}\left(\begin{array}{c}\left|\mu_P^-(x_i) - \mu_Q^-(x_i)\right|^\gamma + \left|\mu_P^+(x_i) - \mu_Q^+(x_i)\right|^\gamma + \left|\nu_P^-(x_i) - \nu_Q^-(x_i)\right|^\gamma \\ +\left|\nu_P^+(x_i) - \nu_Q^+(x_i)\right|^\gamma + \left|\pi_P^-(x_i) - \pi_Q^-(x_i)\right|^\gamma + \left|\pi_P^+(x_i) - \pi_Q^+(x_i)\right|^\gamma\end{array}\right) = 0, \forall_{x_i \in \Omega}.$$

Hence $P = Q$.

(C$_3$). It is obvious from the definition that $d_1(P, Q) = 1 \Leftrightarrow Q = P^c$.

(C$_4$). Clearly, $d_1(P, Q) = d_1(Q, P)$.

(C$_5$). Let $P \subseteq Q \subseteq H$, then $\mu_P^-(x_i) \leq \mu_Q^-(x_i) \leq \mu_H^-(x_i)$, $\mu_P^+(x_i) \leq \mu_Q^+(x_i) \leq \mu_H^+(x_i)$, $\nu_P^-(x_i) \geq \nu_Q^-(x_i) \geq \nu_H^-(x_i)$ and $\nu_P^+(\alpha_i) \geq \nu_Q^+(\alpha_i) \geq \nu_H^+(\alpha_i)$, $\forall_{\alpha_i \in \alpha}$.

Now,

$$\lambda_1 = \frac{1}{2}\sum_{i=1}^{t}\left(\begin{array}{c}\left|\mu_P^-(x_i) - \mu_Q^-(x_i)\right|^\gamma + \left|\mu_P^+(x_i) - \mu_Q^+(x_i)\right|^\gamma + \left|\nu_P^-(x_i) - \nu_Q^-(x_i)\right|^\gamma \\ +\left|\nu_P^+(x_i) - \nu_Q^+(x_i)\right|^\gamma + \left|\pi_P^-(x_i) - \pi_Q^-(x_i)\right|^\gamma + \left|\pi_P^+(x_i) - \pi_Q^+(x_i)\right|^\gamma\end{array}\right)$$

$$\leq \lambda_2 = \frac{1}{2}\sum_{i=1}^{t}\left(\begin{array}{c}\left|\mu_P^-(x_i) - \mu_H^-(x_i)\right|^\gamma + \left|\mu_P^+(x_i) - \mu_H^+(x_i)\right|^\gamma + \left|\nu_P^-(x_i) - \nu_H^-(x_i)\right|^\gamma \\ +\left|\nu_P^+(x_i) - \nu_H^+(x_i)\right|^\gamma + \left|\pi_P^-(x_i) - \pi_H^-(x_i)\right|^\gamma + \left|\pi_P^+(x_i) - \pi_H^+(x_i)\right|^\gamma\end{array}\right), \forall_{x_i \in \Omega}.$$

From Lemma 1, we find $d_1(P, Q) = h(\lambda_1) \leq h(\lambda_2) = d_1(P, H)$. In the same way, we can prove that $d_1(Q, H) \leq d_1(P, H)$. Hence, $d_1(P, Q)$ is a suitable IVIF-distance measure. □

Next, an IVIF-distance measure between two matrices is discussed as follows:

Let $P = \left(p_{ij}\right)$ and $Q = \left(q_{ij}\right)$, $i = 1(1)s, j = 1(1)t$ be two IVIF matrices, where $p_{ij} = \left(\left[\mu_{ij}^{-p}, \mu_{ij}^{+p}\right], \left[\nu_{ij}^{-p}, \nu_{ij}^{+p}\right]\right)$ and $q_{ij} = \left(\left[\mu_{ij}^{-q}, \mu_{ij}^{+q}\right], \left[\nu_{ij}^{-q}, \nu_{ij}^{+q}\right]\right)$ are IVIFNs. Thus, the distance measure between P and Q is proposed as

$$d_2(P, Q) = \frac{1-\exp\left[-\frac{1}{2st}\left(\sum_{i=1}^{s}\sum_{j=1}^{t}\left(\begin{array}{c}\left|\mu_{ij}^{-p} - \mu_{ij}^{-q}\right|^\gamma + \left|\mu_{ij}^{+p} - \mu_{ij}^{+q}\right|^\gamma + \left|\nu_{ij}^{-p} - \nu_{ij}^{-q}\right|^\gamma \\ +\left|\nu_{ij}^{+p} - \nu_{ij}^{+q}\right|^\gamma + \left|\pi_{ij}^{-p} - \pi_{ij}^{-q}\right|^\gamma + \left|\pi_{ij}^{+p} - \pi_{ij}^{+q}\right|^\gamma\end{array}\right)\right)^{1/\gamma}\right]}{1-\exp(-1)}, \quad (5)$$

where $\gamma > 0$, $\gamma \neq 1$.

Theorem 2. *The measure $d_2(P, Q)$ in Equation (5) is a valid IVIF-distance measure.*

Proof. The proof is omitted. □

4. Proposed IVIF-DM-Relative Closeness Coefficient Model

This section suggests an integrated decision-analysis model known as the IVIF-DM-relative closeness coefficient model. The development of the IVIF-DM-relative closeness coefficient model is presented and depicted in Figure 1.

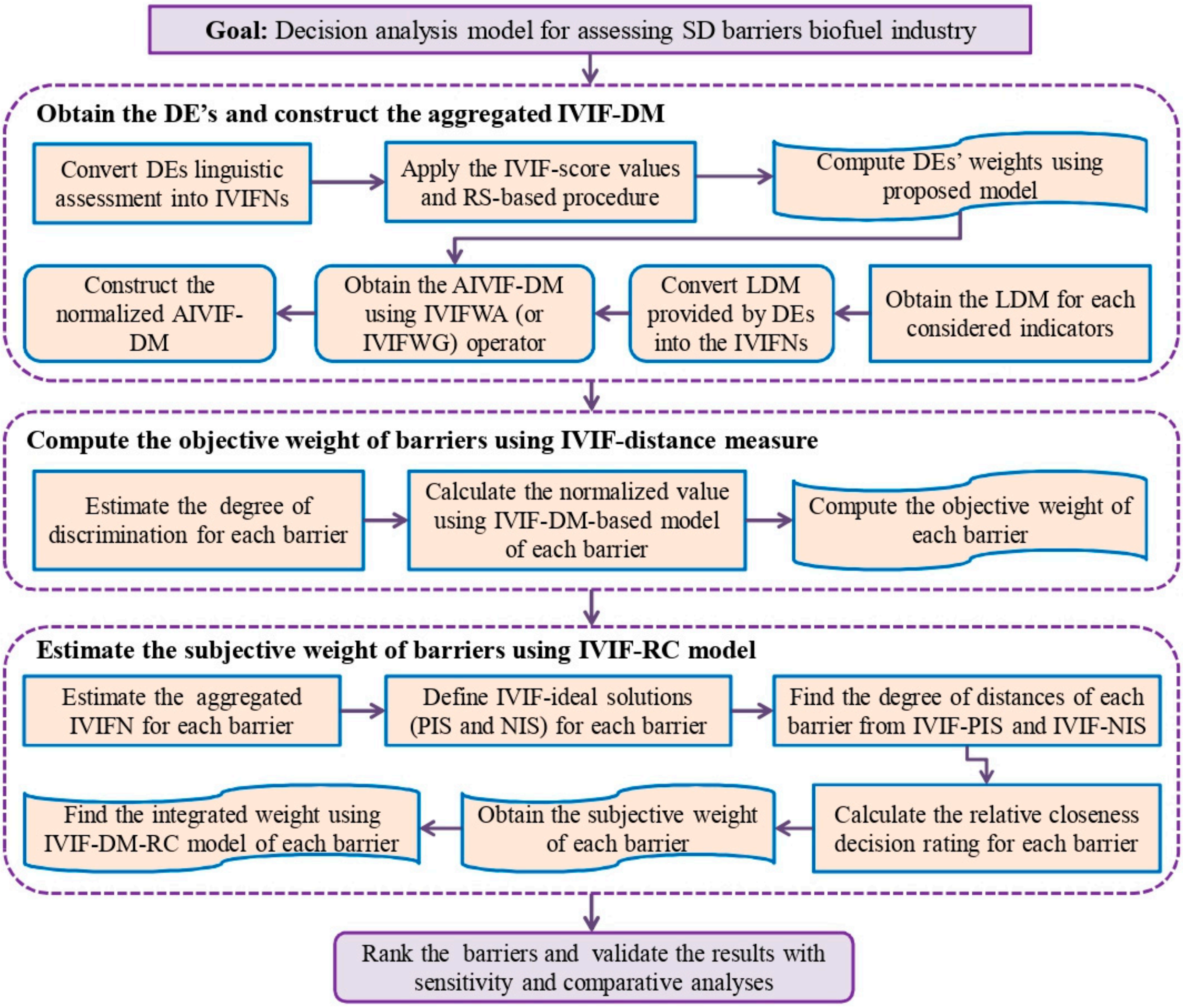

Figure 1. Flowchart of the developed IVIF-DM-relative closeness coefficient model.

Step 1: Create a "linguistic decision matrix (LDM)".

Consider a set of n criteria/SDB $Q = \{q_1, q_2, \ldots, q_n\}$. We create a set of DEs $E = \{e_1, e_2, \ldots, e_l\}$ to evaluate the SDBs to the biofuel industry in India. An LDM is created based on DEs' opinions in which each DE presents a "linguistic rating (LR)" for each criterion q_j with respect to different alternatives/firms of the biofuel industry.

Step 2: Obtain the DE's weight (λ_k).

Initially, the evaluation ratings of DEs are defined as the LRs and then changed into IVIFNs. Let $\alpha_k = \left([\mu_k^-, \mu_k^+], [\nu_k^-, \nu_k^+]\right), k = 1, 2, \ldots, l$ be the corresponding IVIFN and then the expression for finding DE's weight is given by

Step 2a: Find the IVIF-score matrix.

The normalized IVIF-score value $(\overline{\alpha}_k)$ of each IVIFN α_k is calculated as follows:

$$\overline{\alpha}_k = \frac{\mu_k^- + \mu_k^-(1 - \mu_k^- - \nu_k^-) + \mu_k^+ + \mu_k^+(1 - \mu_k^+ - \nu_k^+),}{\sum\limits_{k=1}^{l}\left(\mu_k^- + \mu_k^-(1 - \mu_k^- - \nu_k^-) + \mu_k^+ + \mu_k^+(1 - \mu_k^+ - \nu_k^+)\right)}, k = 1, 2, \ldots, l. \quad (6)$$

Step 2b: Estimate the ranking of relevant assessment DE and find the DE's weight $l - r_k + 1$, where r_k is the priority of *kth* criterion. Each weight is normalized as follows:

$$(\overline{\alpha}_k^r) = \frac{l - r_k + 1}{\sum\limits_{k=1}^{l}(l - r_k + 1)}, k = 1, 2, \ldots, l. \tag{7}$$

Step 2c: Calculation of the expert's weight.

To find the DE's weight, we combine Equations (6) and (7) as follows:

$$\lambda_k = \frac{1}{2}((\overline{\alpha}_k) + (\overline{\alpha}_k^r)),\ k = 1, 2, \ldots, l, \text{ where } \lambda_k \geq 0 \text{ and } \sum_{k=1}^{l}\lambda_k = 1. \tag{8}$$

Step 3: Create an "aggregated IVIF-DM (AIVIF-DM)".

All the IVIF-DMs are operated into AIVIF-DM. The IVIFWA (or IVIFWG) operator is utilized to generate the AIVIF-DM $Z = \left(\xi_{ij}\right)_{m\times n}$, where

$$\xi_{ij} = \left(\left[\mu_{ij}^-, \mu_{ij}^+\right], \left[\nu_{ij}^-, \nu_{ij}^+\right]\right) = IVIFWA_{\lambda_k}\left(\xi_{ij}^{(1)}, \xi_{ij}^{(2)}, \ldots, \xi_{ij}^{(l)}\right) \text{ or } IVIFWG_{\lambda_k}\left(\xi_{ij}^{(1)}, \xi_{ij}^{(2)}, \ldots, \xi_{ij}^{(l)}\right). \tag{9}$$

Step 4: Obtain the objective weight using the IVIF-distance measure weighting model.

The formula of the IVIF-distance-based weight-determining model for SDBs is presented as

$$w_j^o = \frac{\frac{1}{m-1}\sum\limits_{i=1}^{m}\sum\limits_{k=1}^{m} d_1\left(\xi_{ij}, \xi_{kj}\right)}{\sum\limits_{j=1}^{n}\left(\frac{1}{m-1}\sum\limits_{i=1}^{m}\sum\limits_{k=1}^{m} d_1\left(\xi_{ij}, \xi_{kj}\right)\right)},\ j = 1(1)n. \tag{10}$$

where $\sum\limits_{j=1}^{n} w_j^o = 1$ and $w_j^o \in [0, 1]$.

Step 5: Estimate the A-IVIFNs by combining the LDM assessment degrees provided by DEs using the IVIFWA operator and obtained $G = \left(z_j\right)_{1\times n}$.

Step 6: Describe the IVIF-ideal ratings.

An IVIFN has a positive ideal rating (IVIF-PIR) and a negative ideal rating (IVIF-NIR), which define grades $\phi^+ = (1, 0, 0)$ and $\phi^- = (0, 1, 0)$, respectively, while IVIF-PIR and IVIF-NIR are considered by maximum and minimum operators and it is found that there is no substantial gap in their results.

Step 7: Derive the degrees of discrimination of each SDB from IVIF-PIR and IVIF-NIR.

To compute the discrimination value, the proposed IVIF-distance measure is applied. Here, p_j^+ and p_j^- denote the positive and negative distance measures from $G = \left(\xi_j\right)_{1\times n}$, therefore, the IVIF-PIR and IVIF-NIR, respectively.

$$p_j^+ = \frac{1 - \exp\left[-\frac{1}{2}\left(\sum\limits_{j=1}^{n}\left(\left|\mu_{\xi_j}^- - \mu_{\phi^+}^-\right|^\gamma + \left|\mu_{\xi_j}^+ - \mu_{\phi^+}^+\right|^\gamma + \left|\nu_{\xi_j}^- - \nu_{\phi^+}^-\right|^\gamma + \left|\nu_{\xi_j}^+ - \nu_{\phi^+}^+\right|^\gamma + \left|\pi_{\xi_j}^- - \pi_{\phi^+}^-\right|^\gamma + \left|\pi_{\xi_j}^+ - \pi_{\phi^+}^+\right|^\gamma\right)\right)^{1/\gamma}\right]}{1 - \exp\left(-(n)^{1/\gamma}\right)}, \tag{11}$$

$$p_j^- = \frac{1 - \exp\left[-\frac{1}{2}\left(\sum\limits_{i=1}^{n}\left(\left|\mu_{\xi_j}^- - \mu_{\phi^-}^-\right|^\gamma + \left|\mu_{\xi_j}^+ - \mu_{\phi^-}^+\right|^\gamma + \left|\nu_{\xi_j}^- - \nu_{\phi^-}^-\right|^\gamma + \left|\nu_{\xi_j}^+ - \nu_{\phi^-}^+\right|^\gamma + \left|\pi_{\xi_j}^- - \pi_{\phi^-}^-\right|^\gamma + \left|\pi_{\xi_j}^+ - \pi_{\phi^-}^+\right|^\gamma\right)\right)^{1/\gamma}\right]}{1 - \exp\left(-(n)^{1/\gamma}\right)}. \tag{12}$$

Step 8: Compute the relative closeness-decision rating (RC-DR).

$$rc_j = \frac{p_j^-}{p_j^- + p_j^+},\ j = 1, 2, \ldots, n. \tag{13}$$

The RC-DR also states the optimization type (beneficial or non-beneficial) of each SDB to BEs.

Step 9: Obtain the subjective weight $\left(w_j^s\right)$ of each SDB as follows:

$$w_j^s = \frac{rc_j}{\sum_{j=1}^{n} rc_j}. \tag{14}$$

Step 10: Calculate the criteria weights by the IVIF-DM-relative closeness coefficient-based model.

To find the SDBs' weights, the IVIF-DM-relative closeness coefficient-based model is applied. Let $w = (w_1, w_2, \ldots, w_n)^T$ be the weight value of SDBs with $\sum_{j=1}^{n} w_j = 1$ and $w_j \in [0, 1]$. Then, the process for determining the attribute weight by the IVIF-DM-relative closeness coefficient-based model is discussed. With the use Equations (10)–(14), the integrated weight of SDB is defined as

$$w_j = \gamma w_j^s + (1-\gamma) w_j^o,\ j = 1, 2, \ldots, n, \tag{15}$$

where $\gamma \in [0,1]$ is the decision precision factor.

Step 11: Rank the SDBs.

Once all assessment degrees are calculated, finally, SDBs are ranked in descending order with their assessment scores. It should be stated that the SDBs with the largest degrees are the biggest obstacles among the other SDBs in the biofuel industry.

5. Case Study: Assessment of SDBs to BEs in India

In this article, twenty-five critical SDBs to BEs were recognized through the survey and DEs' opinions. Then, a questionnaire was created by inviting DEs from the enterprise and academia with at least fifteen years of experience. A DEs team (e_1, e_2, e_3, e_4, and e_5) is comprised of four sets: the first set contains two "supply chain (SC)" and logistics experts from case enterprise, the second set contains a professor from the agricultural science sector, the third set takes three farmers and environmental NGOs, and the fourth set contains a professor from the industrial engineering sector. The questionnaire then abridged the crucial SDBs to nineteen. The considered SDBs with five aspects, economic (*E*c), environmental (*E*n), social (*S*), technological (*T*), and regulatory (*R*), are revealed in Table 1. The respondent of each SDB is assessed using a 9-stage scale, where EL means extremely low and EH means extremely high, as presented in Tables 2 and 3.

Table 1. The assessment of SDBs to biofuel enterprises.

Dimensions	Barriers	Meaning	References
Economic (Ec)	Financial concerns during the whole lifespan of the plant (EC-1)	Financial problems that impact the SC performance and ambiguity related to return on investment are continuously an issue for stakeholders.	[9,36–38]
	Lack of effective storage services (EC-2)	Storage services need to be require enhanced, especially in the biomass zone.	[12]
	Lack of investors (EC-3)	The biofuel region has good prospects and investors must be fascinated to fund.	[12]
	High logistics costs (EC-4)	Logistic charge rises because of a lack of significantly sized resources, namely biomass.	[39,40]
Environmental (En)	By-products disposal with their chemical properties (EN-1)	Disposing of by-products is a key issue because of environmental pollution and chemical impacts.	[15,36,41]
	Emission of light at night (EN-2)	People continuously complain related to the emission of light at night from the biofuel plant.	[12,15]
	The minimum energy density of bioenergy (EN-3)	Fossil fuels ease effective transport; however, biomass has a minimum energy density problem.	[39–42]
	Emissions (water vapor and GHG) (EN-4)	Emission lessening must be taken into consideration for a "green image" of the enterprise.	[15,36–38,41]
Social (S)	Lack of entrepreneurship assistance (S-1)	Developing nations such as India can utilize social entrepreneurship.	[12,42]
	Unfriendly odor, noise, and vibration from the power plant (S-2)	Noise and vibration at power plants may cause accidents. The issue of odor must be addressed for a healthier working situation.	[15,34,41]
	Fear of public health and safety hazards (S-3)	Safety assessments must be conducted periodically to deal with the concern of public health and hazards.	[15,38,41]
	Lack of trust between local societies, enterprises, and inventors (S-4)	Owing to the lack of trust of diverse stakeholders, there is a suspension in plant expansion.	[38,41,43]
	Lack of public awareness of bioenergy technologies (S-5)	Government organizations and NGOs must be conducted awareness programs about bioenergy technologies.	[36,38]
Technological (T)	Seasonality of biomass (T-1)	Seasonality is an appropriate (weekly, monthly, or quarterly) occurrence of variation that ensued in a year. There are important technical and technological concerns.	[12,36,44]
	Technical issues about the conversion technologies (T-2)	Technical concerns in biofuel comprise fuel chain assessment, prolonged problems, and life cycle. Modern technological developments can be supportive.	[36,38,43]
	Lack of professional training institutions (T-3)	Training organizations must assist specialists, scholars, and DEs in training and education.	[12]
Regulatory (R)	Lack of administrative standards on SC coordination (R-1)	SC about the conversion, transport, records, and farming provide their own standards.	[36,38]
	Lack of biomass SC standards (R-2)	SC benchmarks must be defined predominantly for SC functioning in rural regions. SCM doctrines must be used by the inventors.	[36,38,41]
	Lack of governmental support for SSC solutions (R-3)	The Indian government must assist in solutions for SSC of effective employment in bioenergy.	[36,38,44]

Table 2. LRs for assessment of DEs.

LRs	IVIFNs
Extremely significant (ES)	([0.90, 0.95], [0.00, 0.05])
Very very significant (VVS)	([0.80, 0.85], [0.05, 0.10])
Very significant (VS)	([0.75, 0.85], [0.10, 0.15])
Significant (S)	([0.60, 0.70], [0.15, 0.30])
Moderate (M)	([0.50, 0.60], [0.30, 0.40])
Insignificant (I)	([0.30, 0.45], [0.45, 0.50])
Very insignificant (VI)	([0.20, 0.30], [0.50, 0.60])
Very very insignificant (VVI)	([0.10, 0.20], [0.60, 0.75])
Extremely insignificant (EI)	([0.00, 0.05], [0.80, 0.95])

Table 3. LRs for SDBs to the biofuel sector.

LRs	IVIFNs
Extremely good (EG)	([0.90, 0.95], [0.0, 0.05])
Very good (VG)	([0.80, 0.90], [0.05, 0.10])
Good (G)	([0.70, 0.80], [0.10, 0.15])
Slightly good (SG)	([0.65, 0.70], [0.15, 0.25])
Average (A)	([0.55, 0.65], [0.20, 0.35])
Slightly Low (SL)	([0.40, 0.50], [0.40, 0.45])
Low (L)	([0.25, 0.40], [0.45, 0.50])
Very Low (VL)	([0.15, 0.20], [0.60, 0.75])
Extremely Low (EL)	([0.05, 0.10], [0.80, 0.90])

Step 1: Each DE executes his/her views about the grading of SDBs to BEs. Here, Table 2 signifies the LRs in terms of IVIFNs to determine the weight value of DEs [30]. Table 3 articulates the LRs for evaluating the SDBs in the biofuel industry. Table 4 expresses the LDM of each DE's opinion for each SDB related to the different biofuel industries.

Table 4. The LDM for SDBs to the biofuel sector by DEs.

Barriers	T_1	T_2	T_3	T_4
q_1	(A,VG,SG,G,G)	(G,A,G,VG,SG)	(G, SG,A,G,A)	(SG,G,G,VG,SL)
q_2	(SL,G,A,VG,A)	(G,G,VL,SG,A)	(A,G,SG,SL,SL)	(SG,G,SG,VG,L)
q_3	(L,VG,SL,SG,G)	(SG,SL,G,VG,G)	(SL, G,VG,L,SG)	(VL,SL,VG,G,VG)
q_4	(VL,SL,A,G,VG)	(VL,G,VG,SL,G)	(VG,A,SL,SL,G)	(A,VG,SG,SL,SG)
q_5	(G,SG,A,SL,VG)	(VG,SG,A,A,G)	(A,SG,G,SG,SG)	(VG,G,G,SG,A)
q_6	(VG, G,VG,A,SG)	(SL,G,A,VG,SG)	(VG,SG,A,G,A)	(G,G,A,VG,SG)
q_7	(VG,SG,SL,L,VG)	(VG,SG,A,SL,SL)	(VG,VG,SG,SL,L)	(SL,G,VG,G,A)
q_8	(VL,SL,SG,VG,G)	(SL,L,SL,G,SG)	(L,SL,A,VG,VG)	(L,VG,A,SL,VG)
q_9	(L,SL,A,G,VG)	(A,SL,SL,VG,G)	(L,SG,G,SG,A)	(L,SL,SG,A,VG)
q_{10}	(A,SG,G,VG,L)	(VG,G,G,SL,VL)	(SG,SL,VG,G,A)	(SG,G,SL,G,A)
q_{11}	(VG,G,SG,G,A)	(SG,G,VG,SG,A)	(L,G,SG,G,SL)	(G,SG,G,VG,VL)
q_{12}	(L,SL,A,SG,VG)	(SL,SG,G,SL,G)	(G,A,SG,SL,G)	(A,SL,SG,A,VG)
q_{13}	(SG,G,A,L,VG)	(VG,G,A,A,SG)	(A,G,G,SL,SG)	(SG,G,SG,SG,A)
q_{14}	(G, SG,VG,A,SL)	(L,VG,A,G,SG)	(VG,SL,A,VG,A)	(SG,G,A,VG,G)
q_{15}	(SG,G,SL,VL,VG)	(G,SG,A,SG,SL)	(VG,G,SL,SL,L)	(SL,SG,VG,G,A)
q_{16}	(L,SL,G,VG,A)	(L,SL,SG,G,G)	(SL,SL,A,G,VG)	(SL,VG,A,SL,G)
q_{17}	(VL,SL,A,SG,VG)	(A,SG,SL,G,G)	(SL,SG,G,G,A)	(L,A,SG,A,VG)
q_{18}	(A,G,SG,VG,SL)	(SG,G,G,A,VL)	(G,SL,G,SG,A)	(SG,A,SG,G,A)
q_{19}	(G,G,VG,SG,A)	(G,SG,VG,G,A)	(SL,SG,VG,G,L)	(A,G,SG,VG,L)

Step 2: Based on the IVIFN scale given in Table 2 and Equations (6)–(8), the weights of DEs are computed and presented in Table 5 for the performance of SDBs selection of the biofuel industry.

Table 5. DEs' weights for SDBs to the biofuel sector.

	$\mathbf{e_1}$	$\mathbf{e_2}$	$\mathbf{e_3}$	$\mathbf{e_4}$	$\mathbf{e_5}$
LRs	Significant	Moderate	Very Significant	Extremely significant	Very very significant
IVIFNs	([0.60, 0.70], [0.15, 0.30])	([0.50, 0.60], [0.30, 0.40])	([0.75, 0.85], [0.10, 0.15])	([0.90,0.95], [0.0,0.05])	([0.80,0.85], [0.05, 0.10])
$\overline{\alpha}_k$	0.7250	0.6000	0.8562	0.9700	0.9063
r_k	4	5	3	1	2
Weights	0.1560	0.1073	0.2055	0.2862	0.2450

Step 3: Applying Equation (9) and Tables 3 and 4, the aggregated IVIF-DM is constructed and shown in Table 6.

Table 6. The AIVIF-DM for SDBs to the biofuel sector.

Barriers	$\mathbf{T_1}$	$\mathbf{T_2}$	$\mathbf{T_3}$	$\mathbf{T_4}$
q_1	([0.684, 0.780], [0.112, 0.174])	([0.710, 0.808], [0.098, 0.157])	([0.634, 0.731], [0.143, 0.227])	([0.676, 0.781], [0.123, 0.183])
q_2	([0.654, 0.757], [0.151, 0.232])	([0.571, 0.657], [0.192, 0.279])	([0.523, 0.614], [0.253, 0.326])	([0.646, 0.751], [0.137, 0.199])
q_3	([0.601, 0.701], [0.175, 0.236])	([0.705, 0.807], [0.101, 0.157])	([0.585, 0.697], [0.183, 0.248])	([0.683, 0.800], [0.112, 0.181])
q_4	([0.626, 0.741], [0.149, 0.234])	([0.604, 0.720], [0.171, 0.243])	([0.586, 0.701], [0.191, 0.265])	([0.600, 0.684], [0.185, 0.256])
q_5	([0.634, 0.743], [0.151, 0.228])	([0.651, 0.753], [0.132, 0.220])	([0.647, 0.717], [0.144, 0.235])	([0.675, 0.769], [0.119, 0.188])
q_6	([0.698, 0.798], [0.105, 0.177])	([0.664, 0.766], [0.130, 0.202])	([0.656, 0.759], [0.128, 0.213])	([0.698, 0.797], [0.104, 0.171])
q_7	([0.611, 0.738], [0.162, 0.233])	([0.550, 0.658], [0.226, 0.310])	([0.575, 0.692], [0.195, 0.263])	([0.660, 0.770], [0.132, 0.202])
q_8	([0.651, 0.756], [0.137, 0.205])	([0.564, 0.654], [0.214, 0.272])	([0.673, 0.797], [0.117, 0.195])	([0.602, 0.729], [0.170, 0.256])
q_9	([0.633, 0.752], [0.143, 0.219])	([0.647, 0.762], [0.141, 0.215])	([0.594, 0.681], [0.176, 0.249])	([0.609, 0.718], [0.164, 0.249])
q_{10}	([0.638, 0.755], [0.138, 0.211])	([0.557, 0.672], [0.207, 0.286])	([0.664, 0.766], [0.127, 0.200])	([0.609, 0.691], [0.168, 0.242])
q_{11}	([0.679, 0.776], [0.116, 0.184])	([0.674, 0.762], [0.123, 0.193])	([0.577, 0.677], [0.193, 0.251])	([0.649, 0.759], [0.133, 0.204])
q_{12}	([0.617, 0.722], [0.160, 0.238])	([0.586, 0.687], [0.263, 0.368])	([0.606, 0.700], [0.174, 0.239])	([0.639, 0.741], [0.145, 0.236])
q_{13}	([0.607, 0.724], [0.159, 0.239])	([0.643, 0.739], [0.139, 0.229])	([0.595, 0.687], [0.183, 0.252])	([0.634, 0.702], [0.154, 0.222])
q_{14}	([0.627, 0.734], [0.155, 0.237])	([0.626, 0.727], [0.149, 0.221])	([0.676, 0.791], [0.117, 0.207])	([0.703, 0.804], [0.105, 0.181])
q_{15}	([0.568, 0.677], [0.200, 0.282])	([0.589, 0.671], [0.190, 0.262])	([0.504, 0.631], [0.257, 0.325])	([0.655, 0.760], [0.137, 0.221])
q_{16}	([0.633, 0.754], [0.143, 0.223])	([0.615, 0.715], [0.159, 0.216])	([0.646, 0.759], [0.140, 0.216])	([0.576, 0.688], [0.198, 0.278])
q_{17}	([0.609, 0.709], [0.182, 0.298])	([0.625, 0.725], [0.192, 0.258])	([0.625, 0.724], [0.154, 0.226])	([0.621, 0.729], [0.152, 0.243])
q_{18}	([0.652, 0.757], [0.139, 0.212])	([0.555, 0.649], [0.201, 0.297])	([0.627, 0.716], [0.154, 0.226])	([0.634, 0.718], [0.148, 0.224])
q_{19}	([0.681, 0.777], [0.115, 0.184])	([0.690, 0.792], [0.107, 0.175])	([0.609, 0.726], [0.163, 0.227])	([0.632, 0.745], [0.144, 0.217])

Step 4: Applying Equation (10), we compute the objective weight of each SDB using the developed IVIF-distance measure (4) (or (5)) as follows (see Figure 2):

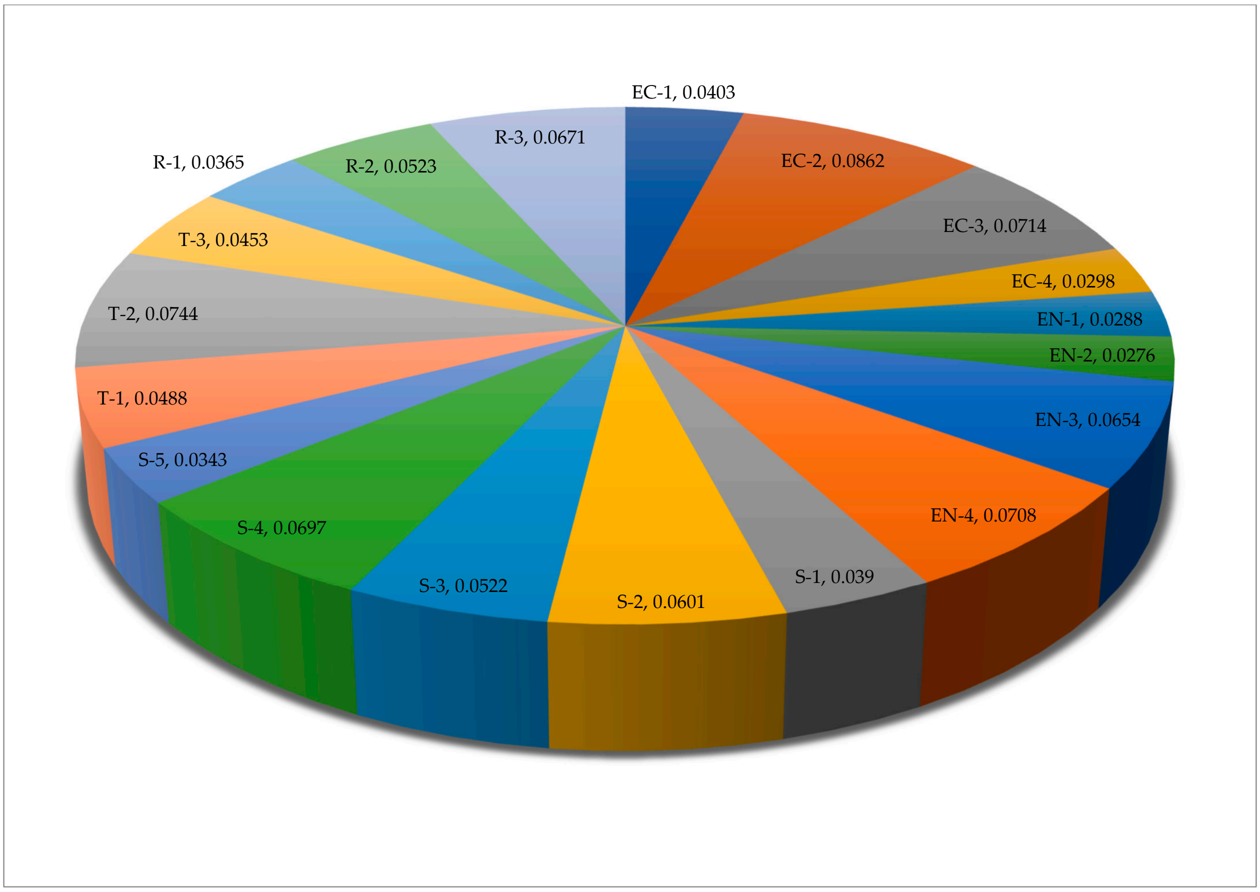

Figure 2. Objective weight of SDBs to the biofuel sector.

w_j^o =(0.0403, 0.0863, 0.0714, 0.0298, 0.0288, 0.0276, 0.0654, 0.0708, 0.0390, 0.0601, 0.0522, 0.0697, 0.0343, 0.0488, 0.0744, 0.0453, 0.0365, 0.0523, 0.0671).

Here, Figure 2 shows the SDBs' criteria weights with respect to the outcome. The lack of effective storage facilities (EC-2), with a weight of value 0.0863, has come out to be the most important SDB to the biofuel industry. Lack of investors (EC-3), with a weight of 0.0714, is the second most significant SDB in the biofuel industry. Technical problems related to conversion technologies (T-2) is third, with a weight value of 0.0744. Emissions (water vapor and greenhouse gases) (EN-4) is fourth, with a weight of 0.0708; lack of trust between local societies, enterprises, and inventors (S-4) with a weight of 0.0697 is the fifth most significant SDB to the biofuel industry and others are considered crucial SDBs to the biofuel industry.

Step 5: Estimate the AIVIF-DM $G = \left(z_j\right)_{1\times n}$ by combining the LDM assessment degrees for SDBs provided by DEs using the operator in Equation (9) and presented in Table 7.

Step 6: Define the IVIF-ideal ratings.

We define the IVIF-PIR ϕ^+ = (1, 0, 0) and IVIF-NIR ϕ^- = (0, 1, 0) for SDBs in the biofuel industry.

Step 7: Derive the degrees of discrimination of each SDB from IVIF-PIR and IVIF-NIR.

From Table 7 and Equations (11) and (12), the discrimination of AIVIF-DM from IVIF-PIR and IVIF-NIS is calculated.

Step 8: The IVIF-relative closeness coefficient rc_j is estimated using Equation (13) and mentioned in Table 7.

Step 9: The subjective weight of the criteria is computed using Equation (14) and is presented as follows:

w_j^s =(0.0534, 0.0530, 0.0560, 0.0559, 0.0509, 0.0523, 0.0532, 0.0518, 0.0520, 0.0537, 0.0545, 0.0478, 0.0544, 0.0507, 0.0550, 0.0511, 0.0477, 0.0540, 0.0525).

Table 7. Weight of SDBs in the form of LRs.

Barriers	d_1	d_2	d_3	d_4	d_5	AIVIF-DM	p_{ij}^{+}	p_{ij}^{-}	rc_j	w_j^s
q_1	G	VG	G	A	G	([0.677, 0.782], [0.113, 0.183])	0.346	0.872	0.716	0.0534
q_2	SG	A	VG	SG	SG	([0.679, 0.757], [0.123, 0.184])	0.352	0.866	0.711	0.0530
q_3	VG	SL	VG	G	G	([0.721, 0.828], [0.090, 0.146])	0.297	0.897	0.751	0.0560
q_4	A	A	VG	G	VG	([0.722, 0.830], [0.088, 0.156])	0.298	0.896	0.750	0.0559
q_5	SG	SL	SG	SG	G	([0.643, 0.713], [0.151, 0.203])	0.392	0.844	0.683	0.0509
q_6	G	SL	SG	A	VG	([0.661, 0.765], [0.130, 0.207])	0.365	0.859	0.702	0.0523
q_7	VG	SG	SL	VG	A	([0.675, 0.787], [0.121, 0.199])	0.348	0.868	0.714	0.0532
q_8	SL	VG	SG	VG	SL	([0.651, 0.761], [0.144, 0.221])	0.374	0.851	0.695	0.0518
q_9	VG	SG	G	SL	G	([0.651, 0.756], [0.139, 0.199])	0.371	0.856	0.697	0.0520
q_{10}	A	VG	VG	A	G	([0.684, 0.794], [0.109, 0.192])	0.340	0.874	0.720	0.0537
q_{11}	VG	SG	G	SG	G	([0.701, 0.789], [0.105, 0.158])	0.324	0.883	0.731	0.0545
q_{12}	A	G	SG	L	G	([0.571, 0.675], [0.186, 0.256])	0.452	0.810	0.642	0.0478
q_{13}	G	L	G	VG	SG	([0.694, 0.796], [0.106, 0.163])	0.327	0.882	0.729	0.0544
q_{14}	SG	SG	G	SG	A	([0.639, 0.713], [0.148, 0.216])	0.395	0.842	0.680	0.0507
q_{15}	G	A	SG	G	VG	([0.707, 0.805], [0.099, 0.158])	0.315	0.887	0.738	0.0550
q_{16}	L	VG	G	SG	SG	([0.640, 0.727], [0.146, 0.202])	0.388	0.848	0.686	0.0511
q_{17}	G	SG	SG	L	SG	([0.575, 0.657], [0.193, 0.249])	0.455	0.808	0.640	0.0477
q_{18}	A	VG	VG	G	A	([0.689, 0.798], [0.106, 0.186])	0.334	0.877	0.724	0.0540
q_{19}	SG	G	SG	G	SG	([0.671, 0.744], [0.128, 0.179])	0.361	0.863	0.705	0.0525

The value of the subjective weight of SDBs to the biofuel industry is depicted in Figure 3. Here, Figure 3 shows the criteria weights with respect to the outcome. Lack of investors (EC-3) with a weight of value 0.0560 has come out to be the most important SDB to the biofuel industry. High logistics costs (EC-4), with a weight of 0.0559, is the second most significant SDB. Technical problems related to conversion technologies (T-2) is third, with a weight value of 0.0550. Fear of public health and safety hazards (S-3) is fourth, with a weight of 0.0545; lack of public awareness of bioenergy technologies (S-5), with a weight of 0.0544, is the fifth most significant SDB to the biofuel industry and others are considered crucial SDBs to the biofuel industry.

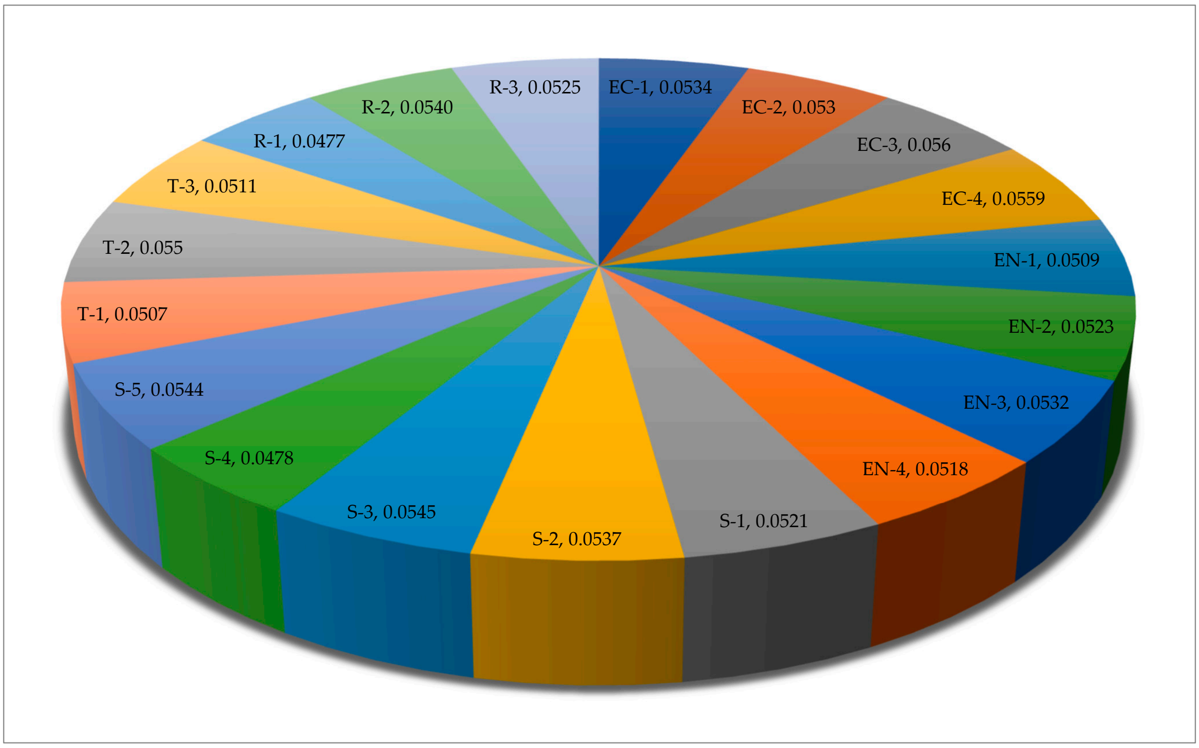

Figure 3. Subjective weight of SDBs in the biofuel sector.

Step 10: We combine the IVIF-DM-based weighting model and the IVIF-relative closeness coefficient-based model with the use of Equation (15). Hence, the combined weight of SDBs for $\tau = 0.5$ is depicted in Figure 4 and presented as:

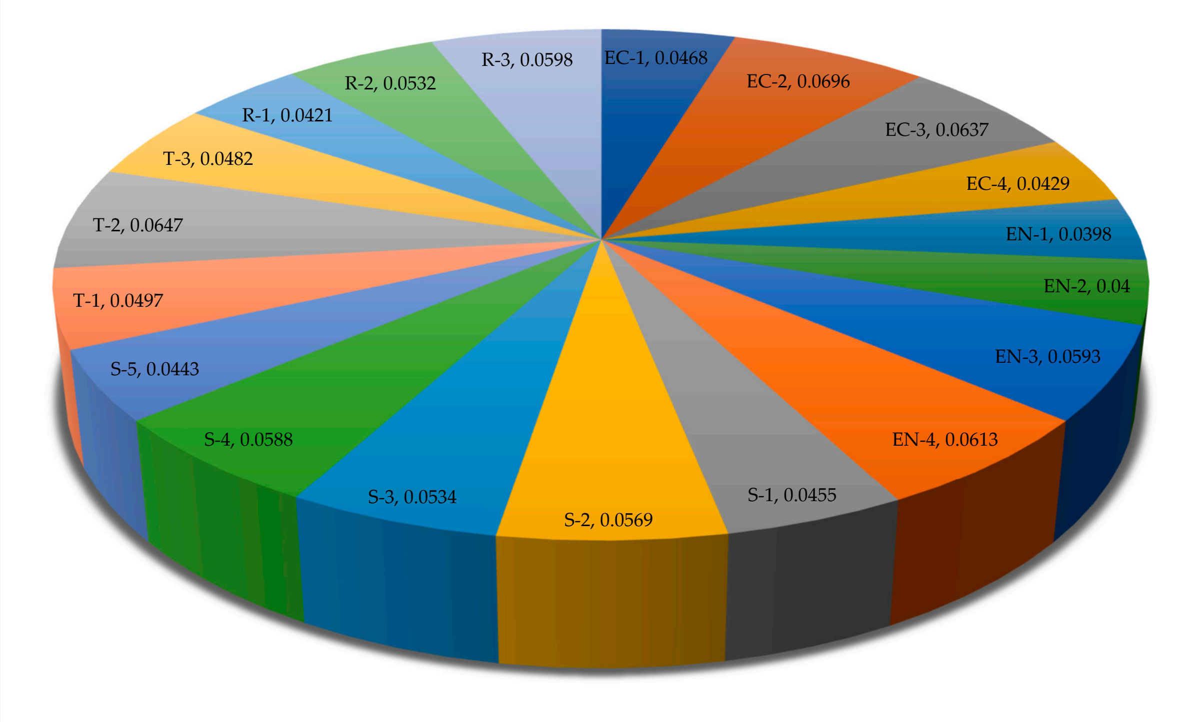

Figure 4. Combined weight of SDBs in the biofuel sector.

w_j = (0.0468, 0.0696, 0.0637, 0.0429, 0.0398, 0.0400, 0.0593, 0.0613, 0.0455, 0.0569, 0.0534, 0.0588, 0.0443, 0.0497, 0.0647, 0.0482, 0.0421, 0.0532, 0.0598).

Here, Figure 4 shows the SDBs' criteria weights with respect to the outcome. The lack of effective storage facilities (EC-2), with a weight of value 0.0696, has come out to be the most important SDB in the biofuel industry. Technical problems related to conversion technologies (T-2), with a weight of 0.0647, is the second most significant SDB in the biofuel industry. Lack of investors (EC-3) is third with a weight value of 0.0637. Emissions (water vapor and greenhouse gases) (EN-4) is fourth, with a weight of 0.0613; lack of governmental support for SSC solutions (R-3), with a weight of 0.0598, is the fifth most significant SDB in the biofuel industry and others are considered crucial SDBs in the biofuel industry.

Step 11: From Figure 5, we find that the lack of effective storage facilities (EC-2) is the most important SDB im the biofuel industry of the proposed model and IVIF-distance measure model, while the lack of investors (EC-3) has come out to be the most important SDB om biofuel industry based on the proposed IVIF-relative closeness coefficient model.

5.1. Sensitivity Analysis

In the current section, we discuss the variation of objective and subjective weighting models for considered SDBs in the developed weight-determining model. The analyses are performed by considering the following cases. In these two cases, we examine the usage of DEs' views in the subjective weighting tool while giving the assessment rating of each SDB and also modeling the data of the objective weighting tool of SDBs with changing $\gamma \in [0, 1]$ values.

Case-1. This case considers the SDBs' weight in the biofuel industry with the objective weighting model (when γ = 0.0) in place of an integrated weighting tool. Thus, the assessment ratings and priority of SDBs are estimated and given in Table 8. The lack of investors (EC-3), with a weight of value 0.0560, has come out to be the most important SDB in the biofuel industry.

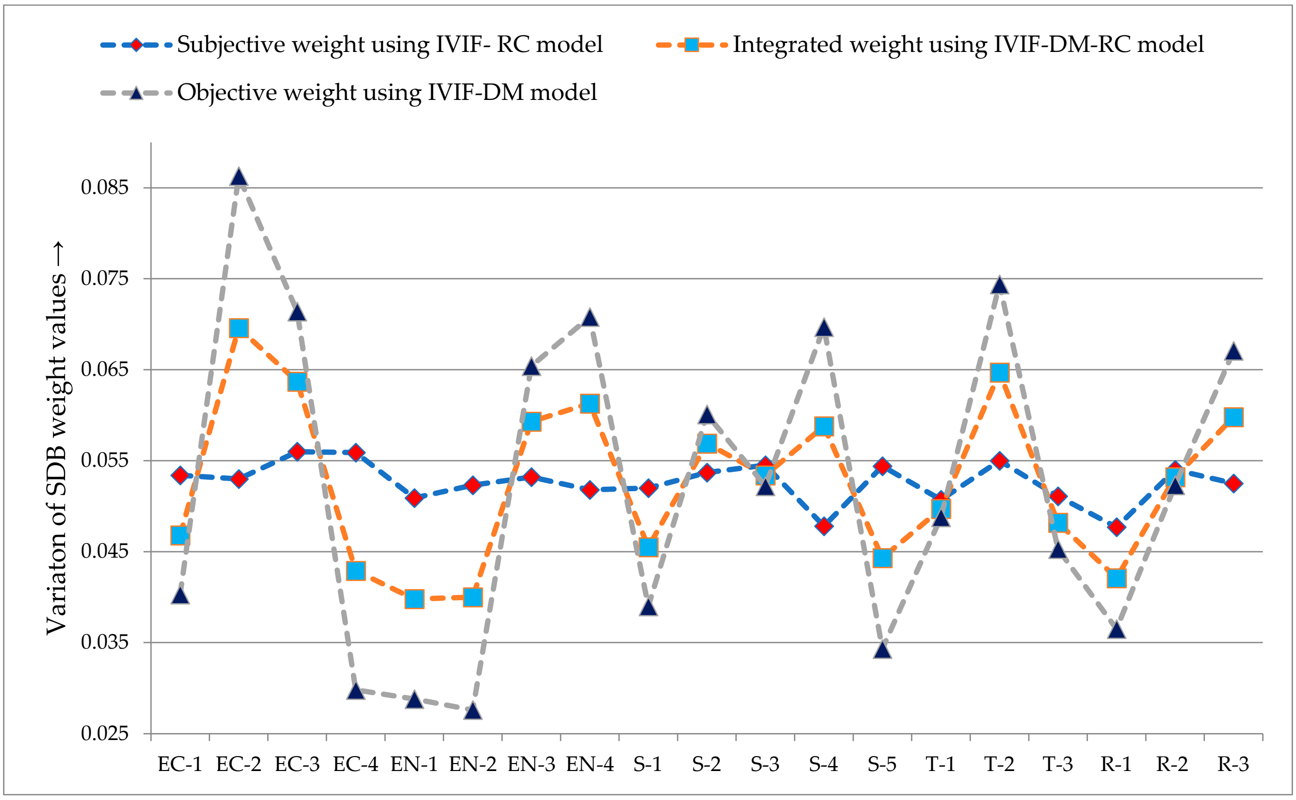

Figure 5. Variation of SDB values in the biofuel sector with the proposed model.

Table 8. Variation of SDB weights of the proposed IVIF-DM-RC method.

	$\gamma = 0.0$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
q_1	0.0534	0.0521	0.0508	0.0495	0.0482	0.0468	0.0455	0.0442	0.0429	0.0416	0.0403
q_2	0.0530	0.0563	0.0596	0.0630	0.0663	0.0696	0.0730	0.0763	0.0796	0.0829	0.0863
q_3	0.0560	0.0575	0.0591	0.0606	0.0621	0.0637	0.0652	0.0668	0.0683	0.0698	0.0714
q_4	0.0559	0.0533	0.0507	0.0481	0.0455	0.0429	0.0403	0.0376	0.0350	0.0324	0.0298
q_5	0.0509	0.0487	0.0465	0.0443	0.0421	0.0398	0.0376	0.0354	0.0332	0.0310	0.0288
q_6	0.0523	0.0499	0.0474	0.0449	0.0425	0.0400	0.0375	0.0350	0.0326	0.0301	0.0276
q_7	0.0532	0.0544	0.0556	0.0569	0.0581	0.0593	0.0605	0.0617	0.0629	0.0642	0.0654
q_8	0.0518	0.0537	0.0556	0.0575	0.0594	0.0613	0.0632	0.0651	0.0670	0.0689	0.0708
q_9	0.0520	0.0507	0.0494	0.0481	0.0468	0.0455	0.0442	0.0429	0.0416	0.0403	0.0390
q_{10}	0.0537	0.0543	0.0550	0.0556	0.0562	0.0569	0.0575	0.0582	0.0588	0.0595	0.0601
q_{11}	0.0545	0.0543	0.0541	0.0538	0.0536	0.0534	0.0531	0.0529	0.0527	0.0524	0.0522
q_{12}	0.0478	0.0500	0.0522	0.0544	0.0566	0.0588	0.0609	0.0631	0.0653	0.0675	0.0697
q_{13}	0.0544	0.0524	0.0504	0.0483	0.0463	0.0443	0.0423	0.0403	0.0383	0.0363	0.0343
q_{14}	0.0507	0.0505	0.0503	0.0501	0.0499	0.0497	0.0495	0.0494	0.0492	0.0490	0.0488
q_{15}	0.0550	0.0569	0.0589	0.0608	0.0627	0.0647	0.0666	0.0686	0.0705	0.0724	0.0744
q_{16}	0.0511	0.0505	0.0500	0.0494	0.0488	0.0482	0.0476	0.0471	0.0465	0.0459	0.0453
q_{17}	0.0477	0.0466	0.0454	0.0443	0.0432	0.0421	0.0410	0.0399	0.0387	0.0376	0.0365
q_{18}	0.0540	0.0538	0.0537	0.0535	0.0533	0.0532	0.0530	0.0528	0.0527	0.0525	0.0523
q_{19}	0.0525	0.0540	0.0555	0.0569	0.0584	0.0598	0.0613	0.0627	0.0642	0.0656	0.0671

Case-2. This case shows the SDB weight using the subjective weighting model (when $\gamma = 1.0$) rather than the integrated weighting tool. Hence, the assessment ratings and priority of SDBs are presented in Table 8. The lack of effective storage facilities (EC-2) with a weight of value 0.0696 has come out to be the most important SDB in the biofuel industry.

Based on the aforementioned discussion, we find the following outcomes: (i) prioritization of SDBs in case-1 demonstrates the performance of the considered SDBs from the objectivity perspective of DEs; (ii) prioritization of SDBs in case-2 illustrates the importance of DEs for SDBs from a subjectivity perspective. The following two cases elucidate that when changing the SDB weights, we obtain a diverse preference order of SDBs. Thus, due to this reason, we believe that we can select the most suitable SDBs in the biofuel industry by considering the combined IVIF-DM-relative closeness coefficient model. The outcomes of the analysis with anticipated weights are presented in Figure 6. According to the aforesaid discussion, it is concluded that considering the diverse ratings of parameters will enhance the strength of the proposed IVIF-DM-relative closeness coefficient model.

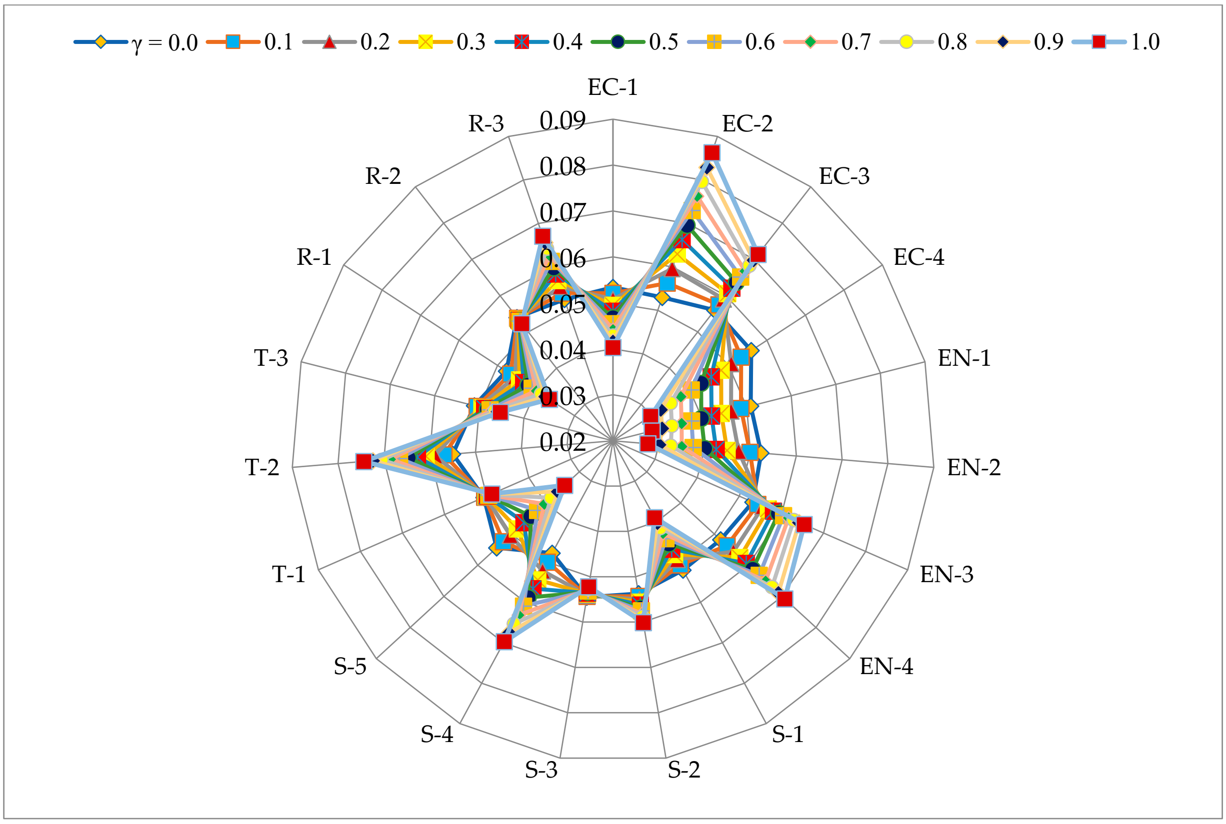

Figure 6. Sensitivity analysis of SDB degrees over various parameter (γ) values.

5.2. Discussion and Implications

The weighting outcomes revealed that the preservation of the social (S) factor had become the most significant pillar for the present SDB assessment (see Figure 7) in the biofuel industry. As a result, this aspect of SDB assessment should be taken sincerely, while economic (Ec), environmental (En), technological (T), and regulatory (R) should be also emphasized. Based on the aforesaid discussion, it can be concluded that the lack of effective storage facilities (EC-2), technical issues related to conversion technologies (T-2), lack of investors (EC-3), emissions (water vapor and greenhouse gases) (EN-4), and lack of governmental support for SSC solutions (R-3) are the most significant influencing SDBs in the biofuel industry for the given case study. From Figure 4, we can find the other important SDBs from a sustainability perspective. By means of the concept of IVIF-DM-relative closeness coefficient framework, we have combined the weight-determining models based on distance measure and the relative closeness coefficient model, which reduces information loss during the process of making a decision.

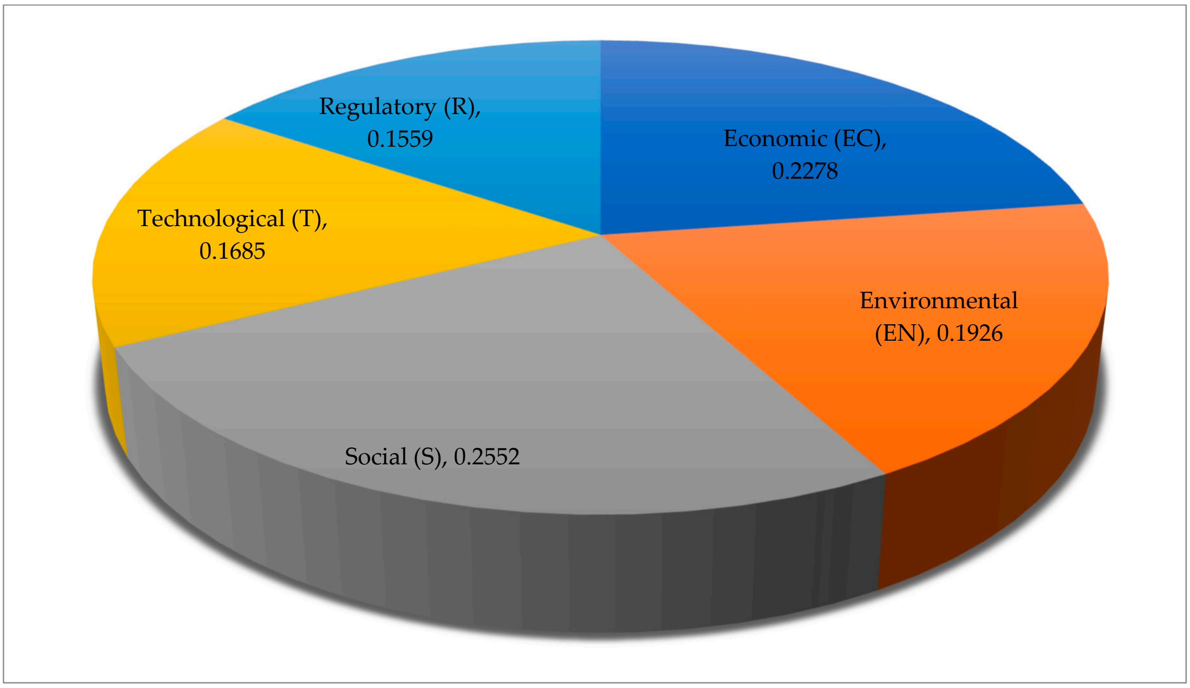

Figure 7. Depiction of the significance degrees of different sustainability aspects.

The development and implementation of the hybrid framework is the key contributions in this study, which can discuss the dual nature (qualitative and quantitative, precise and fuzzy) of semantic judgment in more practical situations. This procedure was documented based on the discussion with four DEs, in which they supposed the assessment of mixed information could better describe the decision. Here, we consider three kinds of criteria degrees, exact, interval, and fuzzy numbers. Quantitative assessments are described by precise and interval numbers, while qualitative assessments are discussed by IVIFNs. The utilization of IVIFNs makes it easier and faster for experts to make decisions and avoid errors caused by indeterminacy and non-intuition. In the integration of IVIF-DM and IVIF-relative closeness coefficient, qualitative and quantitative SDBs are categorized by different data types that can be estimated and compared in a similar dimension, which increases the efficiency and comprehensive assessment of SDB selection.

To show the effectiveness of the IVIF-DM-relative closeness coefficient framework, we relate the outcomes of the developed model with some of the extant models such as the "IVPF-SWARA [45]" and "IVIF-distance measure-entropy [21]" models. The comparative outcomes are presented in Figure 8 and Table 9. The purpose of choosing the IVPF-SWARA model is that the approach employs the subjective assessment of SDBs. In comparison with the IVPF-SWARA and IVIF-distance measure-entropy models, the proposed approach has the following advantages:

— In the present work, we determine a systematic assessment of the DEs' weights using the IVIF-score value and IVIF-rank sum model, which reduces the imprecision and biases in the MADA procedure, while existing studies do not provide this information.
— The developed method determines the integrated weights (combination of objective and subjective weighting) of SDBs using the IVIF-DM-relative closeness coefficient-based tool. In contrast, in IVPF-SWARA, the subjective weighting of SDB is estimated with the SWARA model, and in the IVIF-distance measure-entropy model, the objective weights of the SDBs are obtained using distance measure and entropy-based approach.
— Liang et al. [1] used the gray DEMATEL approach for assessing the success factors of the biofuel industry in China. In comparison with [1], the proposed approach has simpler computational steps and is easy to understand for decision experts during the assessment of SDBs.

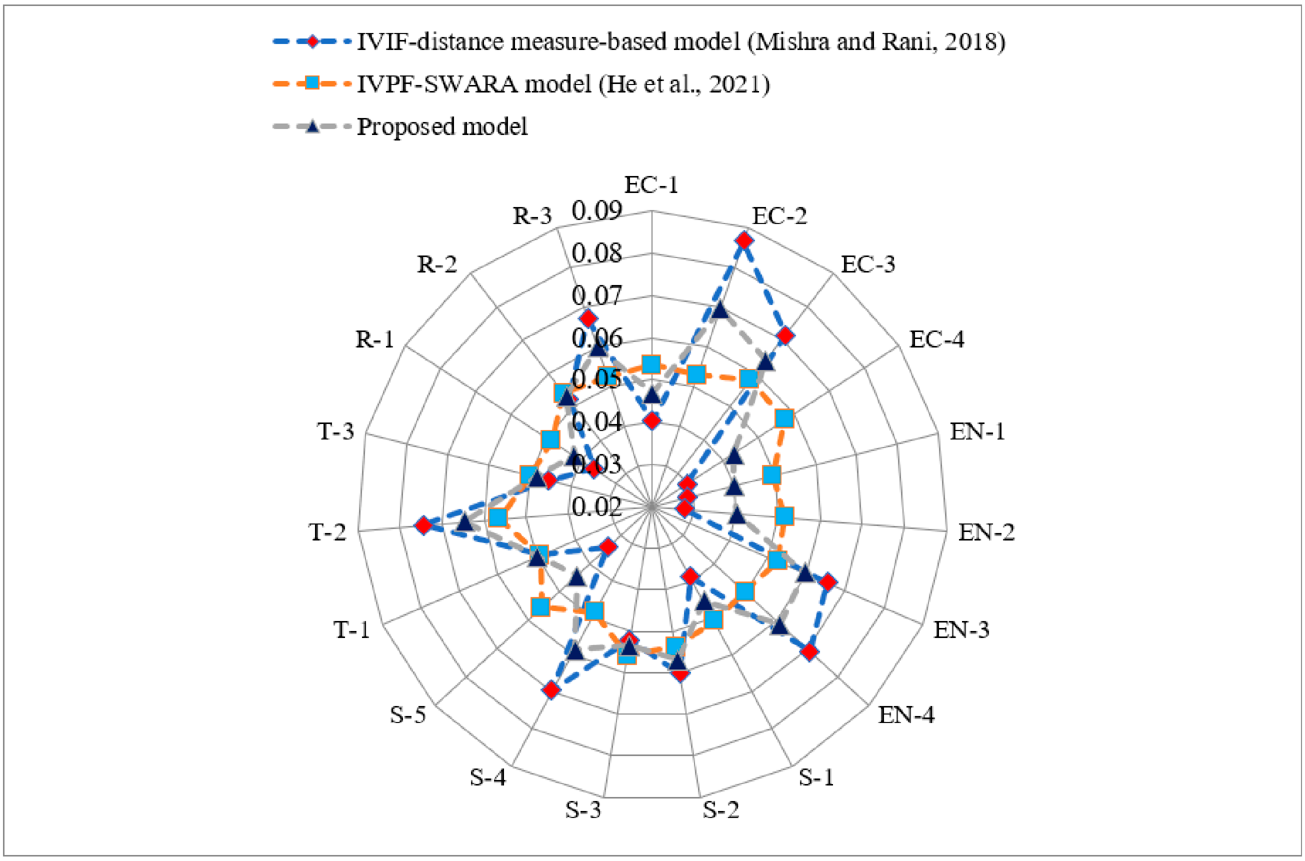

Figure 8. Comparison of SDB weights obtained by proposed and extant models [21,45].

Table 9. Comparison with existing methodologies.

Parameters	He et al. [45]	Mishra and Rani [21]	Proposed Model
Benchmark	IVPF-SWARA model	IVIF-distance measure-entropy model	IVIF-DM-relative closeness model
Alternatives/criteria assessments	IVPFSs	IVIFSs	IVIFSs
Criteria weight	Subjective weight	Objective weight	Integrated weight using objective and subjective weights
DMEs' weights	Assumed	Considered	IVIF-rank sum andScore degree-based model
Decision-making process	Group	Group	Group

As India is an energy-lacking nation, RESs are strategically important. It is noteworthy that the biofuel region can manufacture a sufficient amount of energy for considering numerous requirements of energy, namely industrial heat services, fuel for vehicles, electricity production, and others. The expansion of the biofuel zone will result in job creation, alleviation of climate change, enhanced industrial competitiveness, better exports, the establishment of infrastructure in the area, and better living standards. However, bio-waste assessment is a crucial issue that requires substantial attention from DEs.

Electricity alone will not be able to ensure the complete decarbonization process of energy systems, due to the presence of final energy uses such as maritime and air transport, which require synergy with other commodities. For a fully decarbonized transport sector, biofuels are expected to support the energy transition, particularly for some sectors. For a concrete and rational "green transition", a crucial role could be played by alternative biofuels which fit into a circular economy approach coherently with the European Green Deal and strategic plans of the European Commission. The large-scale production of biofuels must be designed in a sustainable way including the preservation of biodiversity, optimal water utilization, air quality, soil conservation, social issues, and fair labor practices [46]. Moreover, it is important to support sustainable agriculture and forestry to stimulate growth and employment, particularly in rural areas. Regardless, we must pay attention to the fact that since biodiesel production has risen globally, the prices for food and vegetable oils have also grown. So the principle that connects the ideas of circular economy, green economy, and bioeconomy is to find the right equilibrium between economic, environmental, and social objectives [46].

The current study has addressed three purposes, as mentioned in the introduction of this study. The first aim, i.e., recognizing the crucial SDBs to BEs, is solved in Section 5, where nineteen SDBs are recognized. Additionally, the second aim, i.e., assessing the significant degrees of identified SDBs using the proposed IVIF-DM-relative closeness coefficient tool, was carried out, and not only forms associations but also offers the integrated weights of the identified SDBs. Further, the sensitivity assessment and comparison of SDBs are also performed to show the utility of the developed model. Third, few policies are presented for disabling the substantial SDBs, which are given as the government can propose operative biomass SD benchmarks and execute stern procedures and guidelines to avoid and combat fraudulent actions. The constitutional authorities can articulate strategies/schemes/rules for the growth of the biofuel industry by harmonizing all the sustainability aspects.

6. Conclusions

The study presents the procedure for recognizing critical SDBs in the biofuel industry in India. Overall, nineteen SDBs are assessed using the proposed IVIF-DM-relative closeness coefficient approach. The top five significant SDBs are lack of effective storage facilities (EC-2), technical issues related to conversion technologies (T-2), lack of investors (EC-3), emissions (water vapor and greenhouse gases) (EN-4), and lack of governmental support for SSC solutions (R-3). Further, a new distance measure is developed with some elegant properties for evaluating the objective weighting of different SDBs in the biofuel sector. The present paper aims to assist the executives of the biofuel sector in understanding the impact of SDBs on the biofuel industry. The novel plans and schemes may be framed, or extant policies may be reformed to deal with concerns of the biofuel sector by reducing or dropping the impact of the considered SDBs. To lift or improve the biofuel industry in India, there is a requirement to promote biofuel practices by evolving compulsory strategies of integrating biofuels with traditional fuels. Furthermore, there is a requirement to promote the usage of biofuels amongst automobile operators with education and promotional activities. The management must sponsor the prospects of biomass energy, i.e., that bioenergy is environmentally beneficial, reasonable, entirely practical, and real. It may be distinguished that the sustainability of bioenergy is crucial and appropriate care should be considered to confirm the reduction GHGs in bioenergy tools. Additionally, comparisons with extant tools and sensitivity assessment have been studied to expose the rationality and solidity of the obtained outcomes. The findings of this study prove that the developed method has great significance and solidity, and is more dependable than extant tools.

This work has some limitations:

(i) The considered evaluation criteria are not inter-dependent;
(ii) Risk aspects of sustainability are missing during the assessment of SDBs;
(iii) The proposed work is not able to express uncertain, indeterminate, and inconsistent information simultaneously.

In the future, it would be exciting to use the introduced model for other decision-making scenarios. In addition, we extend the proposed model under different disciplines, namely, interval-valued Pythagorean fuzzy sets, q-ROFSs, FFSs, complex q-ROFSs, and others. Furthermore, we will try to use new technologies that encourage the energy conversion of different types of biomass such as woody energy crops, agricultural residues, and forestry residues.

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