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Article

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Operations Research Perspectives

Provided in Cooperation with:

Elsevier

Suggested Citation: Narayanamoorthy, Samayan; Pragathi, Subramaniam; Shutaywi, Meshal; Ahmadian, Ali; Kang, Daekook (2022) : Analysis of vaccine efficacy during the COVID-19 pandemic period using CSF-ELECTRE-I approach, Operations Research Perspectives, ISSN 2214-7160, Elsevier, Amsterdam, Vol. 9, pp. 1-13,
<https://doi.org/10.1016/j.orp.2022.100251>

This Version is available at:

<https://hdl.handle.net/10419/325739>

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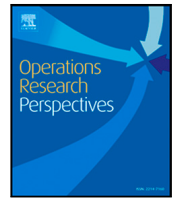
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Analysis of Vaccine efficacy during the COVID-19 pandemic period using CSF-ELECTRE-I approach

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ARTICLE INFO

Keywords:

Vaccine outbreak

MAGDM

CSF

ELECTRE-I

Score function

ABSTRACT

COVID-19 vaccinations have been shown to be safe, efficacious, and life-saving. They, like other vaccines, do not entirely protect everyone who receives them, and no one knows how effectively they can prevent people from spreading the virus to others or whether the booster dosage is dangerous to some vulnerable people. So, in addition to getting vaccinated, we must continue with additional efforts to combat the pandemic. Quantitatively, the pragmatic, appropriate, and phenomenal mechanism of the complex spherical fuzzy set enhances the decision-making efficacy and the ordering quality of the ELECTRE I method to include a profitable and optimal approach for MAGDM. In the CSF environment, critically ill patients are investigated systematically using a pairwise comparison based ELECTRE-I technique. In this paper, we improve the precision of the CSF-based ELECTRE-I approach to a unique score function. The suggested approach's comparability is examined with techniques that should provide equal importance to the alternatives, and the presented score function's reliability is validated using the existing score function with the two cases.

1. Introduction

COVID-19 disease is aggressively affecting the world and has a vast span of impacts, including chronic disease, comorbidities, and mortality. Vaccination is an effective way to avoid such serious outcomes. Further, the vaccine's efficacy need to reflect how well it protects us. Vaccination provides the innate reaction, which is frequently our first line of protection against anything unfamiliar [1]. The impacts of vaccination are extensively stated in the CDC, as : vaccines cannot provide complete (100%) protection against “breakthrough infections” because it is crucial to compare the individual from the vaccine in “real world” situations and to wait a few weeks after receiving each prescribed medication to develop immunity, but there is still a risk of infection. It has been demonstrated that individuals who are fully vaccinated can become infected with the virus. The dynamics of the well-known COVID-19 have been explored and evaluated using the non-local Atangana–Baleanu fractional-derivative technique, with the introduction of numerous infection stages and diverse routes of transmission [2]. According to the evaluation, candidate vaccinations should

be administered based on evidence of safety and efficacy in older people [3]. IoT-Health enables the more convenient ways to access remotely and efficiently the medical services for the patients, also provides health monitoring by the doctors, physicians, and nurses over the Internet. A secure and reliable RFID authentication protocol is defined using Digital Schnorr Cryptosystem for IoT-Health in COVID-19 patients care named SR2AP-DSC [4]. Physically, the dermatologic elements of the COVID-19 infection suggested that dermatologists are aware of the skin consequences and preventative actions may be implemented in the COVID-19 pandemic [5,6]. Like as a systematic analysis of the evolutionary development of healthcare, identifying the causes, means, and influence on subsequent processes is needed. Each stage of development is essential to analyze in terms of social significance, scientific and technological significance, communications, and application of information technologies [7]. According to the CDC, the coronavirus has a devastating impact on people over the age of 60 [8]. Older persons with co-morbidities and frailty are not eligible for vaccination, since there is no published evidence on safety and effectiveness in

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<https://doi.org/10.1016/j.orp.2022.100251>

Received 14 June 2022; Received in revised form 11 July 2022; Accepted 18 August 2022

Available online 25 August 2022

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Nomenclature

COVID-19	Corona Virus Disease 2019
IFS	Intuitionistic Fuzzy Set
CIFS	Complex Intuitionistic Fuzzy Set
PYFS	Pythagorean Fuzzy Set
CSF	Complex Spherical Fuzzy
CSFN	Complex Spherical Fuzzy Number
CSFWA	Complex Spherical Fuzzy Weighted Average
ACSF	Aggregated Complex Spherical Fuzzy
AWCSF	Aggregated Weighted Complex Spherical Fuzzy
MAGDM	Multi-Attribute Group Decision Making
ELECTRE-I	ELimination Et Choix Traduisant la Réalité-I
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
VIKOR	Vlekkriterijmsko KOmpromisno Rangiranje
EDAS	Evaluation based on Distance from Average Solution
WASPAS	Weighted Additive Sum Product Assessment

this population. On the other hand, obstetricians and gynaecologists (OB/GYNs) advised that women with asymptomatic infections and surgery are more sensitive to vaccination [9,10]. While the long-term impact of COVID-19 is unknown and the loss of physicians would increase existing impediments to women's health care [11]. People with comorbidities are well known as high-risk groups for COVID-19 [12]. The psychological and behavioral risk factors for poor vaccine responses, their relevance to the COVID-19 pandemic, as well as targeted psychological and behavioral interventions to boost vaccine efficacy and reduce side effects are investigated [13]. The physical activity in an individual also play a important role in determining the vaccine efficacy. Chronic aerobic exercise or physical activity high levels elevated influenza antibodies in humans more than vaccinated individuals who did not participate in exercise or physical activity [14]. As new understanding of the immunogenicity of several vaccine candidates is evaluated in the clinic, the variety of immune protective mechanisms that may be leveraged to develop unique vaccines that provide lasting protection against SARS-CoV-2 infection is explored [15]. According to, [16], autoimmune problems have occurred in response to some COVID-19 vaccines. Based on these limited evidences and suggestions from various supervisory health care professionals developing a strategy for selecting an appropriate group for vaccination is a need of the hour.

Multi-attribute group decision-making (MAGDM) is a complex cognitive approach that entails the analysis of quasi-ambiguous data as well as examining opinion expression. Outranking is a significant MCDM category that may be used to determine which alternative is preferred, incomparable, or indifferent by comparing one alternative to another under each criterion. The ELECTRE (ELimination Et Choix Traduisant la Réalité) approach is important in the outranking cluster. The innovative ELECTRE model using interval weights and fuzzy data are developed [17]. The ELECTRE's reliability metrics under sparse data correlate to the scenario when deciders are unsure that values each attribute should take, which may arise from insufficient, inaccurate, or conflicting information, as well as diverse inclinations among a group of deciders [18]. Later, the PYF-ELECTRE I approach is created and is used to pick a solid-waste management facility as well as a water desalination plant [19]. The hesitant fuzzy ELECTRE-I technique is described by the concepts of hesitant fuzzy concordance and hesitant

fuzzy discordance, which are based on the derived score function and deviation function, and applied to find the desirable alternative [20]. The ELECTRE I approach is expanded in fuzzy and bipolar neutrosophic environments [21,22]. An integrated Preference Ranking Organization METHod for Enrichment of Evaluation-II (PROMETHEE-II) approach is proposed for a priority ranking order for youngsters who have comorbidities before and after being impacted by COVID-19 [23]. Considering age, health status, a woman's status, and the kind of job as criteria for evaluating the COVID-19 vaccine using a neutrosophic AHP-TOPSIS method, the healthcare personnel, people with high health risk, elderly people, essential workers, pregnant and lactating mothers are suggested as the most prioritized people to take the vaccine dose first [24].

In modern analyses of the fuzzy set (FS) and its generalizations, the ambiguities in the data are treated with using membership degrees, which are a subset of real values that leave some meaningful data and hence impact the decision outcomes. The novel concept of intuitionistic fuzzy set (IFS) is usually advantageous to incorporate the excess characteristic of dissatisfaction degree γ , together with the fundamental constituent of satisfaction degree α in FSs. IFSs, as an extension of FSs, have been widely employed in MAGDM fields, but only with the requirement $\alpha + \beta \leq 1$ [25]. The ELECTRE method using deviation assessment in an intuitionistic fuzzy context to assess the ability of cellular telephone network operators [26]. The concept of Pythagorean fuzzy sets (PYFSs) are introduced to overcome the deficit of the IFSs by the condition $\alpha^2 + \beta^2 \leq 1$ [27]. Complex intuitionistic fuzzy sets (CIFSs) were proposed [28], while the theory for complex Pythagorean fuzzy sets are established [29,30]. The efficiency of Indian government lockdown relaxation protocols an Intuitionistic Fuzzy-Decision Making Trial and Evaluation Laboratory (IF-DEMATEL) method is constructed to scrutinize the relaxation protocols. The process of converting intuitionistic fuzzy into a crisp score (CIFCS) algorithm is proposed as a defuzzification approach for a Triangular Intuitionistic Fuzzy (TIF) set [31]. The transformation to such complex spherical fuzzy sets resolves the classes of complexities, whose limits diverge from the particular subset of the complex subset of the unit disc. Two MAGDM algorithms are established, CSF-VIKOR and CSF-TOPSIS to handle quantitative cases from the business area and to determine the optimal water supply plan for an Iranian hamlet, respectively [32,33].

The key objective of the suggested endeavor in this study is to adopt a unique form of complex fuzzy set known as complex spherical fuzzy sets, and the sophisticated score function which is proposed by Gulzar [34]. We attempted to demonstrate that development in ELECTRE techniques [35] is not a dead field. On the contrary, it is still growing and receiving greater response to new application areas and new methodological and theoretical advancements. We examined the weight attributes by utilizing pairwise comparisons and complex spherical fuzzy numbers to aggregation operations through operational rules. Gulzar's complex spherical fuzzy score function is explored for handling several unilateral comparison issues. In addition, a multi-attribute decision-making algorithm has been developed using these aggregation operators and score algorithms. Finally, we developed a numerical method for applying the suggested algorithm, and the robustness of the score function was tested using two aspects. The preceding reasons summarize the rationale and significance of the theoretical approach:

- Existing models from the CFS category, including CIFSs and CPYFSs, are inadequate to explain particular nature's neutral reaction. As a result, the CSFS is chosen as the best practical domain for the suggested technique.
- The ELECTRE I technique is often used on base of the group decision-making technique, which removes the less favorable alternative and designates the outranked outcomes by executing a pairwise comparison of possible options in regards of concordance and discordance sets.

- Emerging decision-making approaches, especially fuzzy-ELECTRE I, IF-ELECTRE I, PYF-ELECTRE I, CPYF-ELECTRE I, and perhaps the most recent augmentation of the ELECTRE I technique under CSF environment (CSF-ELECTRE I method), are capable of managing uncertain knowledge but are impotent to control multi-valuation and parameterizations. These limitation of standard methodologies convince us to apply the ELECTRE I methodology in the situation of well-versed CSFSs.
- Because of the increased complexities in real-world issues, MAGDM can provide the most reliable and accurate findings. Because it is suitable for get the information estimation from deciders with pertinent facts about the opposing aspects of the critical problem.
- The preceding argument directed our focus to the suggested adaptation, where the purpose is to use the innovative CSF set within the coherent approach of ELECTRE I in terms of conflict measures.

The contribution of the proposed study is detailed as follows:

- An investigational MAGDM method based on the CSF-ELECTRE I technique to handle CSF info that ensures four humanistic views (Yes, abstention, No, and rejection) in a two-dimensional context, together with multi-value parameterization.
- The feasibility and applicability of the offered technique are verified by a robust theoretical prediction of vaccine outbreak prevention during the pandemic period.
- We achieve our established MAGDM technology by comparison research with numerous existing methods. The final results of logic approaches indicate the credibility of the established procedure.
- Finally, the recommended MAGDM approach's primary insights demonstrate its adaptability, competency, and differentiation above high-tech group decision-making approaches.

The extremely applicable and effective model of CSF is combined with the multinary assessment skills of ELECTRE-I to create a model with more application and better management of multinary information. Section 2 describes a gradual way of resolving MAGDM problems with CSF-ELECTRE-I and the impacts of the vaccination and subsequent outbreaks on certain sensitive groups in the COVID-19 pandemic period. Section 3 covers the properties of the recommended set, as well as definitions that are explicitly stated. Section 4 provides analytical examples to construct and solve a real-world application in the MAGDM scenario. Section 5 proposes comparative research to illustrate the approach's benefits and shortcomings, as well as comparisons with existing methods and the sensitivity of the suggested method. Section 6 provides the detailed outline regarding the vaccination effectiveness and the approach's limitations are highlighted.

2. Preliminaries

Definition 1 ([36]). Consider an universe of discourse be Ψ . Let ρ on Ψ be CSFS in the form of

$$\rho = (\langle \zeta_\rho(\psi), \phi_\rho(\psi), \theta_\rho(\psi) \rangle | \psi \in \Psi) \\ = (\langle \Omega_\rho(\psi)e^{i2\pi\mu_\rho(\psi)}, \Phi_\rho(\psi)e^{i2\pi\nu_\rho(\psi)}, Y_\rho(\psi)e^{i2\pi\tau_\rho(\psi)} \rangle | \psi \in \Psi),$$

where, $i = \sqrt{-1}$, $\Omega_\rho(\psi)$, $\Phi_\rho(\psi)$, $Y_\rho(\psi)$ represents the amplitude terms and $\mu_\rho(\psi)$, $\nu_\rho(\psi)$, $\tau_\rho(\psi)$ describes the periodic terms. In the closed unit interval, periodic and amplitude terms have condition that for every $\psi \in \Psi$, $(\Omega_\rho(\psi))^2 + (\Phi_\rho(\psi))^2 + (Y_\rho(\psi))^2 \leq 1$ and $(\mu_\rho(\psi))^2 + (\nu_\rho(\psi))^2 + (\tau_\rho(\psi))^2 \leq 1$. The refusal grade of ψ in Ψ is determined as

$$\theta_\rho(\psi) = \sqrt{1 - (\Omega_\rho(\psi))^2 + (\Phi_\rho(\psi))^2 + (Y_\rho(\psi))^2} \\ \times e^{i2\pi\sqrt{1 - (\mu_\rho(\psi))^2 + (\nu_\rho(\psi))^2 + (\tau_\rho(\psi))^2}}.$$

Definition 2 ([36]). Consider a CSFN be $\rho = (\Omega_\rho(\psi)e^{i2\pi\mu_\rho(\psi)}, \Phi_\rho(\psi)e^{i2\pi\nu_\rho(\psi)}, Y_\rho(\psi)e^{i2\pi\tau_\rho(\psi)})$. The score function $\Sigma(\rho)$ is defined as where $\Sigma(\rho) \in [-2, 2]$

$$\Sigma(\rho) = \Omega_\rho(\psi)^2 - \Phi_\rho(\psi)^2 - Y_\rho(\psi)^2 + \mu_\rho(\psi)^2 - \nu_\rho(\psi)^2 - \tau_\rho(\psi)^2$$

where $\Sigma(\rho) \in [-2, 2]$. The accuracy function $\chi(\rho)$ is described as

$$\chi(\rho) = [\Omega_\rho(\psi)^2 + \Phi_\rho(\psi)^2 + Y_\rho(\psi)^2] + \mu_\rho(\psi)^2 + \nu_\rho(\psi)^2 + \tau_\rho(\psi)^2$$

where $\chi(\rho) \in [0, 2]$

Definition 3 ([34]). Let $\rho = (\Omega_\rho(\psi)e^{i2\pi\mu_\rho(\psi)}, \Phi_\rho(\psi)e^{i2\pi\nu_\rho(\psi)}, Y_\rho(\psi)e^{i2\pi\tau_\rho(\psi)})$ be a CSFN. The score function $\Sigma(\rho)$ is denoted as $\Sigma(\rho)$,

$$\Sigma(\rho) = (\Omega_\rho^2 + \Phi_\rho^2 - Y_\rho^2) + \frac{1}{2\pi} (\mu_\rho^2 + \nu_{rho}^2 - \tau_{rho}^2)$$

and accuracy function $\chi(\rho)$ is denoted as $\chi(\rho)$,

$$\chi(\rho) = (\Omega_\rho^2 + \Phi_\rho^2 + Y_\rho^2) + \frac{1}{2\pi} (\mu_\rho^2 + \nu_\rho^2 + \tau_\rho^2)$$

where $\Sigma(\rho) \in [-2, 2]$ and $\chi(\rho) \in [0, 2]$.

Definition 4 ([36]). For any two CSFNs be $\rho_1 = (\Omega_1(\psi)e^{i2\pi\mu_1(\psi)}, \Phi_1(\psi)e^{i2\pi\nu_1(\psi)}, Y_1(\psi)e^{i2\pi\tau_1(\psi)})$ and $\rho_2 = (\Omega_2(\psi)e^{i2\pi\mu_2(\psi)}, \Phi_2(\psi)e^{i2\pi\nu_2(\psi)}, Y_2(\psi)e^{i2\pi\tau_2(\psi)})$

1. If $\Sigma(\rho_1) < \Sigma(\rho_2)$, then $\rho_1 < \rho_2$ (ρ_1 is inferior to ρ_2).
2. If $\Sigma(\rho_1) > \Sigma(\rho_2)$, then $\rho_1 > \rho_2$ (ρ_1 is superior to ρ_2).
3. If $\Sigma(\rho_1) = \Sigma(\rho_2)$, then
 - (i) $\chi(\rho_1) < \chi(\rho_2)$, then $\rho_1 < \rho_2$ (ρ_1 is inferior to ρ_2);
 - (ii) $\chi(\rho_1) > \chi(\rho_2)$, then $\rho_1 > \rho_2$ (ρ_1 is superior to ρ_2);
 - (iii) $\chi(\rho_1) = \chi(\rho_2)$, then $\rho_1 \sim \rho_2$ (ρ_1 is equivalent to ρ_2).

Definition 5 ([36]). Let $\rho_1 = (\Omega_1(\psi)e^{i2\pi\mu_1(\psi)}, \Phi_1(\psi)e^{i2\pi\nu_1(\psi)}, Y_1(\psi)e^{i2\pi\tau_1(\psi)})$ and $\rho_2 = (\Omega_2(\psi)e^{i2\pi\mu_2(\psi)}, \Phi_2(\psi)e^{i2\pi\nu_2(\psi)}, Y_2(\psi)e^{i2\pi\tau_2(\psi)})$ be CSFNs and $h > 0$. The operations related with CSFNs are

$$\rho_1 \oplus \rho_2 = \left(\sqrt{\Omega_1^2 + \Omega_2^2 - \Omega_1^2 \Omega_2^2} e^{i2\pi\sqrt{\mu_1^2 + \mu_2^2 - \mu_1^2 \mu_2^2}}, \right. \\ \left. \Phi_1 \Phi_2 e^{i2\pi\nu_1 \nu_2}, Y_1 Y_2 e^{i2\pi\tau_1 \tau_2} \right), \\ \rho_1 \otimes \rho_2 = \left(\Omega_1 \Omega_2 e^{i2\pi\mu_1 \mu_2}, \sqrt{\Phi_1^2 + \Phi_2^2 - \Phi_1^2 \Phi_2^2} e^{i2\pi\sqrt{\nu_1^2 + \nu_2^2 - \nu_1^2 \nu_2^2}}, \right. \\ \left. \sqrt{Y_1^2 + Y_2^2 - Y_1^2 Y_2^2} e^{i2\pi\sqrt{\tau_1^2 + \tau_2^2 - \tau_1^2 \tau_2^2}} \right) \\ h\rho_1 = \left(\sqrt{1 - (1 - \Omega_1^2)^h} e^{i2\pi\sqrt{1 - (1 - \mu_1^2)^h}}, \Phi_1^h e^{i2\pi\nu_1^h}, Y_1^h e^{i2\pi\tau_1^h} \right), \\ \rho_1^h = \left(\Omega_1^h e^{i2\pi\mu_1^h}, \sqrt{1 - (1 - \Phi_1^2)^h} \right. \\ \left. \times e^{i2\pi\sqrt{1 - (1 - \nu_1^2)^h}}, \sqrt{1 - (1 - Y_1^2)^h} e^{i2\pi\sqrt{1 - (1 - \tau_1^2)^h}} \right).$$

Definition 6 ([36]). Let $\rho_1 = (\Omega_1(\psi)e^{i2\pi\mu_1(\psi)}, \Phi_1(\psi)e^{i2\pi\nu_1(\psi)}, Y_1(\psi)e^{i2\pi\tau_1(\psi)})$ and $\rho_2 = (\Omega_2(\psi)e^{i2\pi\mu_2(\psi)}, \Phi_2(\psi)e^{i2\pi\nu_2(\psi)}, Y_2(\psi)e^{i2\pi\tau_2(\psi)})$ be two CSFNs. The normalized Euclidean distance between ρ_1 and ρ_2 are evaluated as follows :

$$d(\rho_1, \rho_2) \\ = \sqrt{\frac{(\Omega_1^2 - \Omega_2^2)^2 + (\Phi_1^2 - \Phi_2^2)^2 + (Y_1^2 - Y_2^2)^2 + (\mu_1^2 - \mu_2^2)^2 + (\nu_1^2 - \nu_2^2)^2 + (\tau_1^2 - \tau_2^2)^2}{3}}. \quad (1)$$

Definition 7 ([36]). Assume a collection of CSFNs be $\rho_i = (\Omega_i(\psi)e^{i2\pi\mu_i(\psi)}, \Phi_i(\psi)e^{i2\pi\nu_i(\psi)}, Y_i(\psi)e^{i2\pi\tau_i(\psi)})$, ($i = 1, 2, \dots, m$) and $\varphi =$

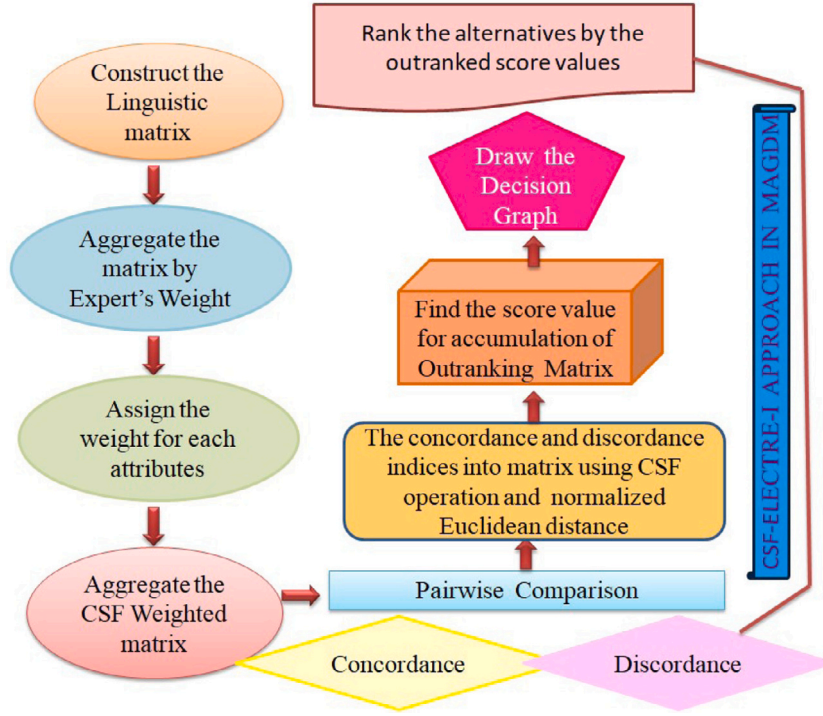


Fig. 1. Overview of CSF-ELECTRE-I method.

$(\varphi_1, \varphi_2, \dots, \varphi_m)^T$ be the weight vector of ρ_i with $\varphi > 0$ and $\sum_{i=1}^m = 1$. The complex spherical fuzzy weighted average (CSFWA) operator is described as

$$\text{CSFWA}(\rho_1, \rho_2, \dots, \rho_m) = \varphi_1 \rho_1 \oplus \varphi_2 \rho_2 \oplus \dots \oplus \varphi_m \rho_m$$

$$= \left(\frac{\sqrt{[1 - \prod_{i=1}^m (1 - \Omega_i^2)^{\varphi_i}] e^{i2\pi \sqrt{[1 - \prod_{i=1}^m (1 - \mu_i^2)^{\varphi_i}]}}}{[\prod_{i=1}^m (\Phi_i)^{\varphi_i}] e^{i2\pi [\prod_{i=1}^m (\nu_i)^{\varphi_i}]}}, [\prod_{i=1}^m (\Upsilon_i)^{\varphi_i}] e^{i2\pi [\prod_{i=1}^m (\tau_i)^{\varphi_i}]} \right)$$

3. CSF in ELECTRE-I approach

This part covers the description of ELECTRE-I approach to achieve a plausible solution to the MAGDM problems over complex spherical fuzzy environment. The mechanism of the CSF-ELECTRE-I approach is detailed in Fig. 1.

Assume S_1, S_2, \dots, S_p be the alternatives and P_1, P_2, \dots, P_a be the attributes in the decision making process. Let D_1, D_2, \dots, D_e be the decision makers who are set up the matrix as per realistic opinions. In the MAGDM scenario, explication of the CSF-ELECTRE I approach proceeds as follows:

Step 1:

Determine the linguistic scale required to follow the CSF operations and properties, then assign linguistic terms to each alternative with parameters that dynamically incorporate the CSFNs into the decision-making process. According to the linguistic scale, the decision matrix with regard to alternatives and attributes, taking into account the perspective of experts (D_e) in the CSF context, is as follows:

$$V_{xy}^{(z)} = (\varsigma_{xy}^{(z)}, \varphi_{xy}^{(z)}, \vartheta_{xy}^{(z)}) = (\Omega_{xy}^{(z)} e^{i2\pi \mu_{xy}^{(z)}}, \Phi_{xy}^{(z)} e^{i2\pi \nu_{xy}^{(z)}}, \Upsilon_{xy}^{(z)} e^{i2\pi \tau_{xy}^{(z)}})$$

$$V^{(z)} = \begin{pmatrix} (\varsigma_{11}^{(z)}, \varphi_{11}^{(z)}, \vartheta_{11}^{(z)}) & (\varsigma_{12}^{(z)}, \varphi_{12}^{(z)}, \vartheta_{12}^{(z)}) & \dots & (\varsigma_{1a}^{(z)}, \varphi_{1a}^{(z)}, \vartheta_{1a}^{(z)}) \\ (\varsigma_{21}^{(z)}, \varphi_{21}^{(z)}, \vartheta_{21}^{(z)}) & (\varsigma_{22}^{(z)}, \varphi_{22}^{(z)}, \vartheta_{22}^{(z)}) & \dots & (\varsigma_{2a}^{(z)}, \varphi_{2a}^{(z)}, \vartheta_{2a}^{(z)}) \\ \vdots & \vdots & \ddots & \vdots \\ (\varsigma_{p1}^{(z)}, \varphi_{p1}^{(z)}, \vartheta_{p1}^{(z)}) & (\varsigma_{p2}^{(z)}, \varphi_{p2}^{(z)}, \vartheta_{p2}^{(z)}) & \dots & (\varsigma_{pa}^{(z)}, \varphi_{pa}^{(z)}, \vartheta_{pa}^{(z)}) \end{pmatrix}, \quad (2)$$

where, $x \in \{1, 2, \dots, p\}$, $y \in \{1, 2, \dots, a\}$ and $z \in \{1, 2, \dots, e\}$.

Step 2:

In the MAGDM framework, each expert D_e has a subjective standpoint; hence, the MAGDM assigns the linear and normalized weight vector $d = (d_1, d_2, \dots, d_e)^T$ for the panel of experts, such that the analysts' opinions are formed using the CSFWA operator as

$$\begin{aligned} V_{xy} &= \text{CSFWA}_d(V_{xy}^{(1)}, V_{xy}^{(2)}, \dots, V_{xy}^{(e)}) \\ &= d_1 V_{xy}^{(1)} \oplus d_2 V_{xy}^{(2)} \oplus \dots \oplus d_e V_{xy}^{(e)} \\ &= \left(\sqrt{1 - \prod_{z=1}^e (1 - (\Omega_{xy}^{(z)})^2)^{d_z}} e^{i2\pi \sqrt{1 - \prod_{z=1}^e (1 - (\mu_{xy}^{(z)})^2)^{d_z}}} \right. \\ &\quad \cdot \prod_{z=1}^e [\Phi_{xy}^{(z)}]^{d_z} e^{i2\pi \prod_{z=1}^e [\nu_{xy}^{(z)}]^{d_z}} \prod_{z=1}^e [\Upsilon_{xy}^{(z)}]^{d_z} e^{i2\pi \prod_{z=1}^e [\tau_{xy}^{(z)}]^{d_z}} \Big) \\ &= (\Omega_{xy} e^{i2\pi \mu_{xy}}, \Phi_{xy} e^{i2\pi \nu_{xy}}, \Upsilon_{xy} e^{i2\pi \tau_{xy}}). \end{aligned} \quad (3)$$

The CSF matrix is aggregated in the following way,

$$V = \begin{pmatrix} (\varsigma_{11}, \varphi_{11}, \vartheta_{11}) & (\varsigma_{12}, \varphi_{12}, \vartheta_{12}) & \dots & (\varsigma_{1d}, \varphi_{1d}, \vartheta_{1d}) \\ (\varsigma_{21}, \varphi_{21}, \vartheta_{21}) & (\varsigma_{22}, \varphi_{22}, \vartheta_{22}) & \dots & (\varsigma_{2d}, \varphi_{2d}, \vartheta_{2d}) \\ \vdots & \vdots & \ddots & \vdots \\ (\varsigma_{b1}, \varphi_{b1}, \vartheta_{b1}) & (\varsigma_{b2}, \varphi_{b2}, \vartheta_{b2}) & \dots & (\varsigma_{bd}, \varphi_{bd}, \vartheta_{bd}) \end{pmatrix} \quad (4)$$

Step 3:

The prominence of the criteria is characterized based on their linguistic weights, which are then assessed by the analysts and allocated CSFNs. The CSFWA operator aggregates the experts' choices to

determine the CSF-weights of the attributes p_v^w as follows:

$$\begin{aligned} \rho_y^{(z)} &= \left(\Omega_y^{(z)} e^{i2\pi\mu_y^{(z)}}, \Phi_y^{(z)} e^{i2\pi\nu_y^{(z)}}, \Upsilon_y^{(z)} e^{i2\pi\tau_y^{(z)}} \right) \\ \rho_y &= CSFWA_d \left(\rho_y^{(1)}, \rho_y^{(2)}, \dots, \rho_y^{(e)} \right) \\ &= d_1 \rho_y^{(1)} \oplus d_2 \rho_y^{(2)} \oplus \dots \oplus d_e \rho_y^{(e)} \\ &= \left(\sqrt{1 - \prod_{z=1}^e \left(1 - \left(\Omega_y^{(z)} \right)^2 \right)^{d_z}} e^{i2\pi \sqrt{1 - \prod_{z=1}^e \left(1 - \left(\mu_y^{(z)} \right)^2 \right)^{d_z}}}, \right. \\ &\quad \left. \prod_{z=1}^e \left[\Sigma_y^{(z)} \right]^{d_z} e^{i2\pi \prod_{z=1}^e \left[\nu_y^{(z)} \right]^{d_z}}, \prod_{z=1}^e \left[\Upsilon_y^{(z)} \right]^{d_z} e^{i2\pi \prod_{z=1}^e \left[h_v^{(w)} \right]^{k_w}} \right) \\ &= \left(\Omega_y e^{i2\pi\mu_y}, \Phi_y e^{i2\pi\nu_y}, \Upsilon_y e^{i2\pi\tau_y} \right). \end{aligned} \quad (5)$$

Step 4:

The elements of the aggregated weighted complex spherical fuzzy (AWCSF) matrix $\bar{V} = (\bar{V}_{xy})_{\rho \times a} = \left(\bar{s}_{xy}^i, \bar{\Omega}_{xy} e^{i2\pi\mu_{xy}}, \bar{\Phi}_{xy} e^{i2\pi\nu_{xy}}, \bar{\Upsilon}_{xy} e^{i2\pi\tau_{xy}} \right)$ are examined using the ACSF matrix and criteria weightage ρ_y .

$$\begin{aligned} \bar{V} &= (\bar{V}_{xy})_{\rho \times a} = \left(\bar{s}_{xy}^i, \bar{\Omega}_{xy} e^{i2\pi\mu_{xy}}, \bar{\Phi}_{xy} e^{i2\pi\nu_{xy}}, \bar{\Upsilon}_{xy} e^{i2\pi\tau_{xy}} \right) \bar{v}_{xy} = v_{xy} \otimes \rho_y \\ &= \left(\Omega_{xy} \Omega_y e^{i2\pi\mu_{xy}\mu_y}, \sqrt{\Phi_{xy}^2 + \Phi_y^2 - \Phi_{xy}^2 \Phi_y^2} e^{i2\pi \sqrt{v_{xy}^2 + v_y^2 - v_{xy}^2 v_y^2}}, \right. \\ &\quad \left. \times \sqrt{\Upsilon_{xy}^2 + \Upsilon_y^2 - \Upsilon_{xy}^2 \Upsilon_y^2} e^{i2\pi \sqrt{\tau_{xy}^2 + \tau_y^2 - \tau_{xy}^2 \tau_y^2}} \right) \\ &= \left(\bar{\Omega}_{xy} e^{i2\pi\mu_{xy}}, \bar{\Phi}_{xy} e^{i2\pi\nu_{xy}}, \bar{\Upsilon}_{xy} e^{i2\pi\tau_{xy}} \right) = (\bar{\zeta}_{xy}, \bar{\varphi}_{xy}, \bar{\delta}_{xy}). \end{aligned} \quad (6)$$

The AWCSF matrix is constructed in the following manner.

$$\bar{V} = \begin{pmatrix} (\bar{\zeta}_{11}, \bar{\varphi}_{11}, \bar{\delta}_{11}) & (\bar{\zeta}_{12}, \bar{\varphi}_{12}, \bar{\delta}_{12}) & \dots & (\bar{\zeta}_{1a}, \bar{\varphi}_{1a}, \bar{\delta}_{1a}) \\ (\bar{\zeta}_{21}, \bar{\varphi}_{21}, \bar{\delta}_{21}) & (\bar{\zeta}_{22}, \bar{\varphi}_{22}, \bar{\delta}_{22}) & \dots & (\bar{\zeta}_{2a}, \bar{\varphi}_{2a}, \bar{\delta}_{2a}) \\ \vdots & \vdots & \ddots & \vdots \\ (\bar{\zeta}_{p1}, \bar{\varphi}_{p1}, \bar{\delta}_{p1}) & (\bar{\zeta}_{p2}, \bar{\varphi}_{p2}, \bar{\delta}_{p2}) & \dots & (\bar{\zeta}_{pa}, \bar{\varphi}_{pa}, \bar{\delta}_{pa}) \end{pmatrix}$$

Step 5:

The CSF-ELECTRE I approach acts on the premise of a pairwise evaluation of alternatives based on some appropriate criteria. In that, the score, accuracy, and the refusal grade of CSFNs are utilized to compare two CSFNs. When referred to other viable options, an alternative with a superior score, better accuracy, and a lower refusal degree is preferable. The CSF concordance and discordance sets are classified as strong, mid-range, and weak, based on the score, accuracy, and refusal grade of CSFN, respectively. For each attribute, the CSF concordance set indices reveals that the alternative Ψ_η is superior to Ψ_i .

(i) The complex spherical fuzzy strong concordance set $C_{\eta i}$ can be constructed as

$$\begin{aligned} C_{\eta i} &= \left\{ y : \Sigma \left(\bar{v}_{dy} \right) \geq \Sigma \left(\bar{v}_{iy} \right), \chi \left(\bar{v}_{dy} \right) \right. \\ &\quad \left. \geq \chi \left(\bar{v}_{iy} \right); \theta \left(\bar{v}_{dy} \right) < \theta \left(\bar{v}_{iy} \right) \right\} \end{aligned} \quad (7)$$

(ii) The complex spherical fuzzy mid-range concordance set $C'_{\eta i}$ can be determined in the following manner:

$$\begin{aligned} C'_{\eta i} &= \left\{ y : \Sigma \left(\bar{v}_{ny} \right) \geq \Sigma \left(\bar{v}_{iy} \right), \chi \left(\bar{v}_{dy} \right) \right. \\ &\quad \left. \geq \chi \left(\bar{v}_{iy} \right); \theta \left(\bar{v}_{ny} \right) \geq \theta \left(\bar{v}_{iy} \right) \right\} \end{aligned} \quad (8)$$

(iii) The complex spherical fuzzy weak concordance set $C''_{\eta i}$ can be constructed in the following manner:

$$\begin{aligned} C''_{\eta i} &= \left\{ y : \Sigma \left(\bar{v}_{ny} \right) \geq \Sigma \left(\bar{v}_{iy} \right), \chi \left(\bar{v}_{ny} \right) \right. \\ &\quad \left. < \chi \left(\bar{v}_{iy} \right); \theta \left(\bar{v}_{ny} \right) \geq \theta \left(\bar{v}_{iy} \right) \right\}. \end{aligned} \quad (9)$$

$C_{\eta i}$ has the higher concordant than $C'_{\eta i}$ and $C''_{\eta i}$, where, $(\eta, i = 1, 2, 3, \dots, p, \eta \neq i)$ and $y = 1, 2, 3, \dots, a$.

The CSF concordance set have complementary subsets that is named as discordance sets which has the indices for each criteria whereby Ψ_i is superior than Ψ_η .

(i) The complex spherical fuzzy strong discordance set $D_{\eta i}$ can be formalized in the following way,

$$\begin{aligned} D_{\eta i} &= \left\{ y : \Sigma \left(\bar{v}_{ny} \right) < \Sigma \left(\bar{v}_{iy} \right), \chi \left(\bar{v}_{ny} \right) \right. \\ &\quad \left. < \chi \left(\bar{v}_{iy} \right); \theta \left(\bar{v}_{ny} \right) \geq \theta \left(\bar{v}_{iy} \right) \right\} \end{aligned} \quad (10)$$

(ii) The complex spherical fuzzy mid-range discordance set $D'_{\eta i}$ can be detailed in the prescribed manner:

$$\begin{aligned} D'_{\eta i} &= \left\{ y : \Sigma \left(\bar{v}_{ny} \right) < \Sigma \left(\bar{v}_{iy} \right), \chi \left(\bar{v}_{ny} \right) \right. \\ &\quad \left. < \chi \left(\bar{v}_{iy} \right); \theta \left(\bar{v}_{ny} \right) < \theta \left(\bar{v}_{iy} \right) \right\} \end{aligned} \quad (11)$$

(iii) The complex spherical fuzzy weak discordance set $D''_{\eta i}$ can be formalized as follows:

$$\begin{aligned} D''_{\eta i} &= \left\{ y : \Sigma \left(\bar{v}_{ny} \right) < \Sigma \left(\bar{v}_{iy} \right), \chi \left(\bar{v}_{ny} \right) \right. \\ &\quad \left. \geq \chi \left(\bar{v}_{iy} \right); \theta \left(\bar{v}_{ny} \right) < \theta \left(\bar{v}_{iy} \right) \right\} \end{aligned} \quad (12)$$

$D_{\eta i}$ is the higher discordant than $D'_{\eta i}$ and $D''_{\eta i}$, where, $(\eta, i = 1, 2, 3, \dots, p, \eta \neq i)$ and $y = 1, 2, 3, \dots, a$.

Step 6:

The optimal CSF concordance indices $J_{\eta i}$ ($\eta, i = 1, 2, 3, \dots, p, \eta \neq i$) are calculated by pursuing the weights $w_{D_{\eta i}}$, $w'_{D_{\eta i}}$, and $w''_{D_{\eta i}}$ to the CSF strong, mid-range, and weak concordance sets, respectively. In CSF-ELECTRE I approach, the concordance index $J_{\eta i} = (m_{J_{\eta i}}^y, \zeta_{J_{\eta i}}^y, \varphi_{J_{\eta i}}^y, \theta_{J_{\eta i}}^y) = (m_{J_{\eta i}}^y, \Omega_{J_{\eta i}}^y e^{i2\pi\mu_{J_{\eta i}}^y}, \Phi_{J_{\eta i}}^y e^{i2\pi\nu_{J_{\eta i}}^y}, \Upsilon_{J_{\eta i}}^y e^{i2\pi\tau_{J_{\eta i}}^y})$, indicating the supremacy of the alternative Ψ_η from alternative Ψ_i , is determined as.

$$J_{\eta i} = \left(w_{C_{\eta i}} \otimes \sum_{y \in C_{\eta i}} \rho_y \right) \oplus \left(w'_{C'_{\eta i}} \otimes \sum_{y \in C'_{\eta i}} \rho_y \right) \oplus \left(w''_{C''_{\eta i}} \otimes \sum_{y \in C''_{\eta i}} \rho_y \right)$$

where, $\rho_y = (\Omega_y e^{i2\pi\mu_y}, \Phi_y e^{i2\pi\nu_y}, \Upsilon_y e^{i2\pi\tau_y})$ represents the CSF weightage of the y th criteria. The CSF concordance matrix is formalized in the following way, Eq. (13) is given in Box I.

Step 7:

The probable CSF discordance indices $\mathfrak{J}_{\eta i}$ ($\eta, i = 1, 2, 3, \dots, p, \eta \neq i$) are evaluated by obtaining the weights $w_{D_{\eta i}}$, $w'_{D_{\eta i}}$, and $w''_{D_{\eta i}}$ to the CSF strong, mid-range, and weak discordance sets, respectively. In CSF-ELECTRE I approach, the discordance index $\mathfrak{J}_{\eta i} = (m_{\mathfrak{J}_{\eta i}}^y, \zeta_{\mathfrak{J}_{\eta i}}^y, \varphi_{\mathfrak{J}_{\eta i}}^y, \theta_{\mathfrak{J}_{\eta i}}^y) = (m_{\mathfrak{J}_{\eta i}}^y, \Omega_{\mathfrak{J}_{\eta i}}^y e^{i2\pi\mu_{\mathfrak{J}_{\eta i}}^y}, \Phi_{\mathfrak{J}_{\eta i}}^y e^{i2\pi\nu_{\mathfrak{J}_{\eta i}}^y}, \Upsilon_{\mathfrak{J}_{\eta i}}^y e^{i2\pi\tau_{\mathfrak{J}_{\eta i}}^y})$, indicating the supremacy of the alternative Ψ_η from alternative Ψ_i , is defined as Eq. (14) is given in Box II.

$$\mathfrak{J}_{\eta i} = \frac{\max_{y \in (D_{\eta i} \cup D'_{\eta i} \cup D''_{\eta i})} \left\{ w_{D_{\eta i}} \otimes d \left(\bar{v}_{ny}, \bar{v}_{iy} \right), w'_{D'_{\eta i}} \otimes d \left(\bar{v}_{ny}, \bar{v}_{iy} \right), w''_{D''_{\eta i}} \otimes d \left(\bar{v}_{ny}, \bar{v}_{iy} \right) \right\}}{\max_y d \left(\bar{v}_{ny}, \bar{v}_{iy} \right)}$$

The CSF discordance matrix is defined in the following manner,

$$M_{D_{\eta i}} = \begin{pmatrix} - & \mathfrak{J}_{12} & \dots & \mathfrak{J}_{1(a-1)} & \mathfrak{J}_{1a} \\ \mathfrak{J}_{21} & - & \dots & \mathfrak{J}_{2(a-1)} & \mathfrak{J}_{2a} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \mathfrak{J}_{p1} & \mathfrak{J}_{p2} & \dots & \mathfrak{J}_{p(a-1)} & - \end{pmatrix} \quad (15)$$

Step 8:

A threshold value, referred to as the concordance grade X , is specified to attain the dominant one in the feasible set of alternatives as follows:

$$X = \frac{1}{p(p-1)} \max_{\eta} \left[\Sigma \left(J_{\eta i} \right) \right] \quad (16)$$

The score function is designed to look at CSF concordant indices organized in the CSF concordant matrix $m_{J_{\eta i}}$. Furthermore, two possibilities

$$M_{J_{\eta}}^{(y)} = \begin{pmatrix} - & (\zeta_{J_{12}}^{(y)}, \varphi_{J_{12}}^{(y)}, \vartheta_{J_{12}}^{(y)}) & \cdots & (\zeta_{J_{1(a-1)}}^{(y)}, \varphi_{J_{1(a-1)}}^{(y)}, \vartheta_{J_{1(a-1)}}^{(y)}) & (\zeta_{J_{1a}}^{(y)}, \varphi_{J_{1a}}^{(y)}, \vartheta_{J_{1a}}^{(y)}) \\ (\zeta_{J_{21}}^{(y)}, \varphi_{J_{21}}^{(y)}, \vartheta_{J_{21}}^{(y)}) & - & \cdots & (\zeta_{J_{2(a-1)}}^{(y)}, \varphi_{J_{2(a-1)}}^{(y)}, \vartheta_{J_{2(a-1)}}^{(y)}) & (\zeta_{J_{2a}}^{(y)}, \varphi_{J_{2a}}^{(y)}, \vartheta_{J_{2a}}^{(y)}) \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ (\zeta_{J_{p1}}^{(y)}, \varphi_{J_{p1}}^{(y)}, \vartheta_{J_{p1}}^{(y)}) & (\zeta_{J_{p2}}^{(y)}, \varphi_{J_{p2}}^{(y)}, \vartheta_{J_{p2}}^{(y)}) & \cdots & (\zeta_{J_{p(a-1)}}^{(y)}, \varphi_{J_{p(a-1)}}^{(y)}, \vartheta_{J_{p(a-1)}}^{(y)}) & - \end{pmatrix} \quad (13)$$

Box I.

$$d(\bar{v}_{\eta y}, \bar{v}_{iy}) = \sqrt{\frac{(\bar{\Omega}_{\eta y}^2 - \bar{\Omega}_{iy}^2)^2 + (\bar{\Phi}_{\eta y}^2 - \bar{\Phi}_{iy}^2)^2 + (\bar{Y}_{\eta y}^2 - \bar{Y}_{i\text{otay}}^2)^2 + (\bar{\mu}_{\eta y}^2 - \bar{\mu}_{iy}^2)^2 + (\bar{v}_{\eta y}^2 - \bar{v}_{iy}^2)^2 + (\bar{\tau}_{\eta y}^2 - \bar{\tau}_{iy}^2)^2}{3}} \quad (14)$$

Box II.

are derived which is either the score value of the concordant index exceeds or falls short of the threshold value of X . Thus, the greater the value of the CSF concordant index J_{η} over X , the higher chance of preferring alternative Ψ_{η} over Ψ_i . If the CSF concordant index J_{η} is less than X , the likelihood of preferring alternative Ψ_{η} over Ψ_i decreases. The concordance Boolean matrix $X = (X_{\eta i})_{p \times p}$ can be compiled as follows:

$$X = \begin{pmatrix} - & x_{12} & \cdots & x_{1(a-1)} & x_{1a} \\ x_{21} & - & \cdots & x_{2(a-1)} & x_{2a} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ x_{p1} & x_{p2} & \cdots & x_{p(a-1)} & - \end{pmatrix} \quad (17)$$

where,

$$x_{\eta i} = \begin{cases} 1, & \text{if } \Sigma(J_{\eta i}) \geq X \\ 0 & \text{if } \Sigma(J_{\eta i}) < X \end{cases} \quad (18)$$

Step 9:

The discordant value is assisted and compared with the entries of the CSF concordant matrix comprising the concordant indices \mathfrak{J} that reflect the level of inadequacy of the alternative Ψ_{η} over the Ψ_i in order to evaluate the dominant alternative among all feasible possibilities. The discordant degree F is formalized as follows:

$$F = \frac{1}{a(a-1)} \sum_{\eta, \eta \neq i} \sum_{i, i \neq \eta} \mathfrak{J}_{\eta i}, \quad (19)$$

when the value of \mathfrak{J} exceeds the value of the discordant scale F , it enhances the premises that Ψ_{η} is less important than Ψ_i . The effective discordance matrix $\mathcal{D} = (\mathcal{D}_{\eta i})_{p \times p}$ is just as shown in: (see Fig. 2).

$$\mathcal{D} = \begin{pmatrix} - & \mathcal{D}_{12} & \cdots & \mathcal{D}_{1(a-1)} & \mathcal{D}_{1a} \\ \mathcal{D}_{21} & - & \cdots & \mathcal{D}_{2(a-1)} & \mathcal{D}_{2a} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \mathcal{D}_{p1} & \mathcal{D}_{p2} & \cdots & \mathcal{D}_{p(a-1)} & - \end{pmatrix} \quad (20)$$

where,

$$\mathcal{D}_{\eta i} = \begin{cases} 1, & \text{if } \mathfrak{J}_{\eta i} \leq F \\ 0, & \text{if } \mathfrak{J}_{\eta i} > F \end{cases} \quad (21)$$

Step 10:

The aggregated outranking Boolean matrix contributes to the information about the symmetrical correlations of the suitable alternatives according to the debatable criteria that validate the dominant alternative. The CSF effective concordance and discordance matrices are

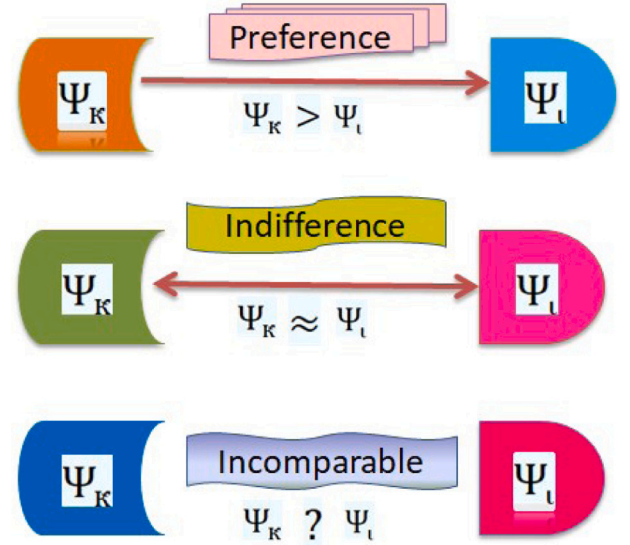


Fig. 2. Visualization of outranking decision graph.

integrated to produce the aggregated outranking Boolean matrix as,

$$R = \begin{pmatrix} - & k_{12} & \cdots & k_{1(d-1)} & k_{1d} \\ k_{21} & - & \cdots & k_{2(d-1)} & k_{2d} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ k_{p1} & k_{p2} & \cdots & k_{p(d-1)} & - \end{pmatrix}$$

where, $k_{\eta i} = x_{\eta i} \times \mathcal{D}_{\eta i}$.

Step 11:

A directed graph is drawn in the final round of the CSF-ELECTRE I technique to ensure the best option among the possible options. Fig. 1 depicts precise features for constructing directed graphs, which are further developed by the following scenarios:

- If $R_{\eta i} = 1$, then Ψ_{η} is either strictly superior to Ψ_i or Ψ_{η} strictly inferior to Ψ_i , i.e., $(\Psi_{\eta} > \Psi_i)$.
- If $R_{\eta i} = 1$ and $R_{i\eta} = 1$, Ψ_{η} and Ψ_i represent indifferent associations, i.e., $(\Psi_{\eta} \approx \Psi_i)$.
- If $R_{\eta i} = 0$, Ψ_{η} and Ψ_i are not comparable.

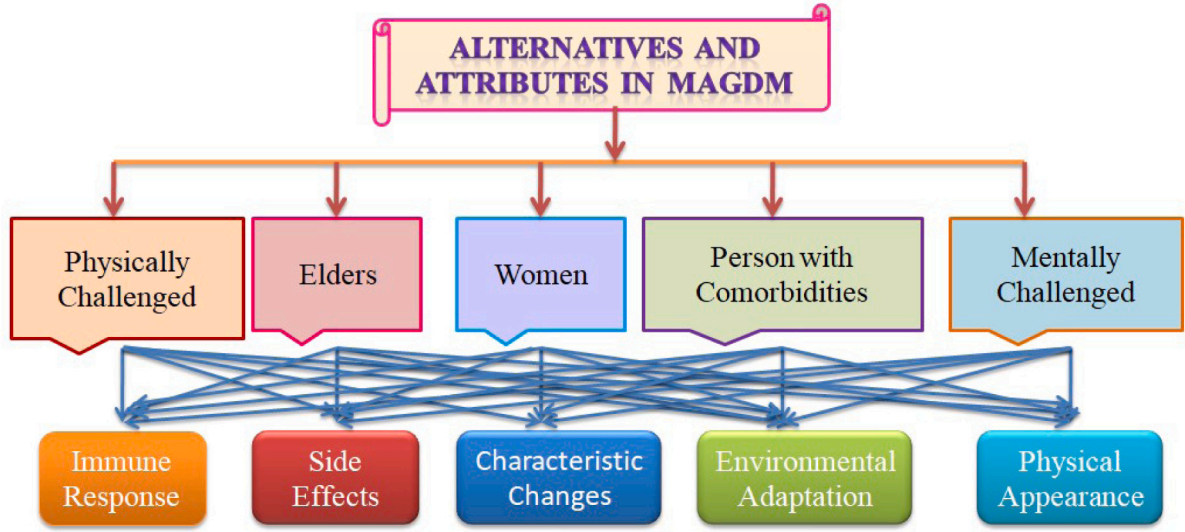


Fig. 3. Deciders choices among criteria in MAGDM.

Step 12:

The suggested ELECTRE I approach can be strengthened by evaluating the linear ranking order of the alternatives using the net outranking index. The net outranking index is derived:

$$\mathfrak{F}_x = \sum_{\eta=1, \eta \neq x}^p \Sigma(M_{J_{x\eta}}) - \sum_{i=1, i \neq x}^p \Sigma(M_{J_{xi}}) \quad (22)$$

where, $(M_{J_{x\eta}})$ stands for concordant outranking index and $(M_{J_{xi}})$ stands for discordant outranking index. Eqs. (12) and (13) may be used to get the concordant outranking index $(M_{J_{x\eta}})$ and the discordant outranking index $(M_{J_{xi}})$, respectively. The values of are sorted in decreasing order, with the option with the greatest net outranking index being declared the better option among the possible options.

$$\mathfrak{F}_x = \sum_{\eta=1, \eta \neq x}^p (M_{J_{x\eta}}) - \sum_{i=1, i \neq x}^p (M_{J_{xi}}) \quad (23)$$

The net outranking index of \mathfrak{J}_x is evaluated in the following manner:

$$\mathfrak{J}_x = \mathfrak{F}_x - \mathfrak{F}_x \quad (24)$$

4. Numerical exemplification

An account of the vaccine effectiveness during the pandemic period, the preliminary measures regard outbreak is discussed for vulnerable groups. The people who are easily diseased such as physically challenged [14], elder [8], women [9–11], person with comorbidities [12], mentally challenged [13]. Those informations are studied through the literary survey and we set up them as alternatives physically challenged (S_1), elder (S_2), women (S_3), person with comorbidities (S_4), mentally challenged (S_5). The common problem regard vaccine response among them is featured as criteria that are immune response (P_1), side effects (P_2), characteristic changes (P_3), environmental adaptation (P_4), physical appearance (P_5). Because which is more complex to conclude with the consensus and also we may not stop them as they are.

Particularly, one cannot determine the safety measure of vulnerable people while vaccine outbreak. So, there is a need to formalize a team of health professionals to safeguard them. Neurologist (D_1), psychologist (D_2), immunologist (D_3), family physician (D_4), dermatologist (D_5) and gynecologist (D_6) are grouped to suggest who are all in the complex situation. The aforementioned persons are all at the critical stage during

Table 1

Linguistic scale for CSFNs.

Linguistic terms	CSFNs
Very Anomalous Effectiveness (VAE)	$(0.98 \ e^{i2\pi(0.93)}, 0.26 \ e^{i2\pi(0.24)}, 0.19 \ e^{i2\pi(0.12)})$
Anomalous Effectiveness (AE)	$(0.81 \ e^{i2\pi(0.78)}, 0.36 \ e^{i2\pi(0.23)}, 0.25 \ e^{i2\pi(0.21)})$
Normal Effectiveness (NE)	$(0.58 \ e^{i2\pi(0.61)}, 0.44 \ e^{i2\pi(0.39)}, 0.48 \ e^{i2\pi(0.37)})$
Moderate Effectiveness (ME)	$(0.45 \ e^{i2\pi(0.41)}, 0.48 \ e^{i2\pi(0.43)}, 0.67 \ e^{i2\pi(0.61)})$
Poor Effectiveness (PE)	$(0.36 \ e^{i2\pi(0.35)}, 0.46 \ e^{i2\pi(0.39)}, 0.66 \ e^{i2\pi(0.62)})$
Very Poor Effectiveness (VPE)	$(0.24 \ e^{i2\pi(0.18)}, 0.34 \ e^{i2\pi(0.31)}, 0.79 \ e^{i2\pi(0.89)})$

Table 2

Expert's opinion on alternatives an account of criteria in Linguistic terms.

Criteria	Alternatives	D_1	D_2	D_3	D_4	D_5	D_6
P_1	S_1	NE	ME	NE	NE	ME	NE
	S_2	VAE	AE	VAE	AE	VAE	PE
	S_3	ME	NE	NE	ME	NE	AE
	S_4	PE	VAE	ME	AE	VPE	ME
	S_5	PE	AE	ME	VAE	ME	ME
P_2	S_1	ME	NE	NE	AE	PE	NE
	S_2	AE	VAE	VAE	AE	AE	VAE
	S_3	NE	ME	PE	VPE	AE	VAE
	S_4	AE	AE	ME	VPE	ME	NE
	S_5	VAE	VAE	AE	ME	AE	NE
P_3	S_1	NE	AE	ME	NE	PE	ME
	S_2	AE	VAE	ME	AE	ME	ME
	S_3	PE	AE	VPE	ME	ME	ME
	S_4	ME	VAE	AE	AE	ME	NE
	S_5	AE	VAE	VAE	ME	AE	ME
P_4	S_1	VAE	ME	AE	PE	VPE	NE
	S_2	AE	VAE	ME	ME	AE	AE
	S_3	ME	ME	NE	VPE	AE	PE
	S_4	AE	VAE	AE	ME	AE	ME
	S_5	ME	AE	PE	NE	ME	ME
P_5	S_1	AE	AE	ME	NE	NE	ME
	S_2	VAE	AE	AE	ME	ME	AE
	S_3	NE	VAE	PE	NE	AE	VAE
	S_4	ME	VPE	VPE	AE	NE	ME
	S_5	AE	VAE	ME	AE	ME	NE

the pandemic period. So, we need to order them based on their health-care perspectives. Complex spherical fuzzy sets are adaptive to these periodic conditions, and the ELECTRE-I technique is appropriate for issue pre-determination. As a result, CSF-ELECTRE-I is recommended to order the alternatives based on expert recommendations, such as

Table 3
Aggregated CSF decision matrix.

	P_1	P_2	P_3	P_4	P_5
S_1	(0.5242 $e^{i2\pi(0.532)}$, 0.4855 $e^{i2\pi(0.4743)}$, 0.5664 $e^{i2\pi(0.4959)}$)	(0.5777 $e^{i2\pi(0.5598)}$, 0.4691 $e^{i2\pi(0.4337)}$, 0.5117 $e^{i2\pi(0.4583)}$)	(0.5646 $e^{i2\pi(0.5330)}$, 0.4746 $e^{i2\pi(0.4373)}$, 0.5357 $e^{i2\pi(0.4930)}$)	(0.7514 $e^{i2\pi(0.6011)}$, 0.4151 $e^{i2\pi(0.4064)}$, 0.4630 $e^{i2\pi(0.4235)}$)	(0.6387 $e^{i2\pi(0.5957)}$, 0.4569 $e^{i2\pi(0.4015)}$, 0.4632 $e^{i2\pi(0.4216)}$)
S_2	(0.9166 $e^{i2\pi(0.7843)}$, 0.3520 $e^{i2\pi(0.3120)}$, 0.2873 $e^{i2\pi(0.2325)}$)	(0.9299 $e^{i2\pi(0.8271)}$, 0.3380 $e^{i2\pi(0.6443)}$, 0.2485 $e^{i2\pi(0.1971)}$)	(0.7799 $e^{i2\pi(0.6407)}$, 0.4261 $e^{i2\pi(0.3786)}$, 0.4202 $e^{i2\pi(0.3782)}$)	(0.8042 $e^{i2\pi(0.6812)}$, 0.4113 $e^{i2\pi(0.3505)}$, 0.3723 $e^{i2\pi(0.3318)}$)	(0.8356 $e^{i2\pi(0.7346)}$, 0.3906 $e^{i2\pi(0.335)}$, 0.3132 $e^{i2\pi(0.2748)}$)
S_3	(0.5809 $e^{i2\pi(0.5602)}$, 0.4727 $e^{i2\pi(0.4405)}$, 0.5171 $e^{i2\pi(0.4630)}$)	(0.7219 $e^{i2\pi(0.5713)}$, 0.4211 $e^{i2\pi(0.3983)}$, 0.4952 $e^{i2\pi(0.4588)}$)	(0.5053 $e^{i2\pi(0.4428)}$, 0.4584 $e^{i2\pi(0.4229)}$, 0.6108 $e^{i2\pi(0.6148)}$)	(0.5133 $e^{i2\pi(0.4708)}$, 0.4603 $e^{i2\pi(0.4308)}$, 0.5924 $e^{i2\pi(0.5771)}$)	(0.8934 $e^{i2\pi(0.7149)}$, 0.3761 $e^{i2\pi(0.3712)}$, 0.3669 $e^{i2\pi(0.2980)}$)
S_2	(0.9166 $e^{i2\pi(0.7843)}$, 0.3520 $e^{i2\pi(0.3120)}$, 0.2873 $e^{i2\pi(0.2325)}$)	(0.9299 $e^{i2\pi(0.8271)}$, 0.3380 $e^{i2\pi(0.6443)}$, 0.2485 $e^{i2\pi(0.1971)}$)	(0.7799 $e^{i2\pi(0.6407)}$, 0.4261 $e^{i2\pi(0.3786)}$, 0.4202 $e^{i2\pi(0.3782)}$)	(0.8042 $e^{i2\pi(0.6812)}$, 0.4113 $e^{i2\pi(0.3505)}$, 0.3723 $e^{i2\pi(0.3318)}$)	(0.8356 $e^{i2\pi(0.7346)}$, 0.3906 $e^{i2\pi(0.335)}$, 0.3132 $e^{i2\pi(0.2748)}$)
S_3	(0.5809 $e^{i2\pi(0.5602)}$, 0.4727 $e^{i2\pi(0.4405)}$, 0.5171 $e^{i2\pi(0.4630)}$)	(0.7219 $e^{i2\pi(0.5713)}$, 0.4211 $e^{i2\pi(0.3983)}$, 0.4952 $e^{i2\pi(0.4588)}$)	(0.5053 $e^{i2\pi(0.4428)}$, 0.4584 $e^{i2\pi(0.4229)}$, 0.6108 $e^{i2\pi(0.6148)}$)	(0.5133 $e^{i2\pi(0.4708)}$, 0.4603 $e^{i2\pi(0.4308)}$, 0.5924 $e^{i2\pi(0.5771)}$)	(0.8934 $e^{i2\pi(0.7149)}$, 0.3761 $e^{i2\pi(0.3712)}$, 0.3669 $e^{i2\pi(0.2980)}$)
S_4	(0.7315 $e^{i2\pi(0.5620)}$, 0.4247 $e^{i2\pi(0.3958)}$, 0.5021 $e^{i2\pi(0.4726)}$)	(0.6156 $e^{i2\pi(0.5573)}$, 0.4391 $e^{i2\pi(0.3874)}$, 0.4951 $e^{i2\pi(0.4749)}$)	(0.7889 $e^{i2\pi(0.6664)}$, 0.4193 $e^{i2\pi(0.3929)}$, 0.3957 $e^{i2\pi(0.3473)}$)	(0.8095 $e^{i2\pi(0.6903)}$, 0.4079 $e^{i2\pi(0.3651)}$, 0.3618 $e^{i2\pi(0.3217)}$)	(0.4680 $e^{i2\pi(0.3953)}$, 0.4147 $e^{i2\pi(0.3895)}$, 0.6517 $e^{i2\pi(0.6991)}$)
S_5	(0.7313 $e^{i2\pi(0.5735)}$, 0.4448 $e^{i2\pi(0.4122)}$, 0.4932 $e^{i2\pi(0.4533)}$)	(0.8738 $e^{i2\pi(0.7407)}$, 0.3821 $e^{i2\pi(0.3624)}$, 0.3297 $e^{i2\pi(0.2732)}$)	(0.8737 $e^{i2\pi(0.7242)}$, 0.3854 $e^{i2\pi(0.3450)}$, 0.3449 $e^{i2\pi(0.2918)}$)	(0.5433 $e^{i2\pi(0.4674)}$, 0.4803 $e^{i2\pi(0.4464)}$, 0.5650 $e^{i2\pi(0.5350)}$)	(0.8551 $e^{i2\pi(0.6957)}$, 0.3992 $e^{i2\pi(0.3758)}$, 0.3830 $e^{i2\pi(0.3213)}$)

who is more susceptible during vaccination outbreaks. The graphical representation of alternatives and criteria are shown in Fig. 3.

Step 1:

Each expert considers the vaccine's normal and abnormal effectiveness for physically challenged (S_1), elder (S_2), women (S_3), people with chronic disease (S_4), and mentally affected (S_5) individuals who fought with unimaginable impact. Linguistic concepts are classified in Table 1 according to a fuzzy scale, as determined by experts. Deciders use CSF sets to standardize the given problem with their opinions, which are quantitatively scaled as decision matrices in Table 2.

Step 2:

Each expert must assess their recommendation in the context of the CSF. The weight of the specialists $D = (0.162, 0.157, 0.174, 0.147, 0.125, 0.145)^T$ is assigned based on their demands in the particular problem and CSFWA operator are applied and aggregated CSF decision matrix is evaluated by Eq. (3) as $R = (R_{xy})_{p \times a}$ in Table 3.

Step 3:

The deciders' opinions on attributes are linguistically scaled an account of alternatives which is in Table 4, and the attribute weights ρ are consolidated using Eq. (5).

$$\rho = \begin{pmatrix} 0.8747e^{i2\pi(0.7271)}, 0.3810e^{i2\pi(0.3315)}, 0.3369e^{i2\pi(0.2856)} \\ 0.9091e^{i2\pi(0.7552)}, 0.3665e^{i2\pi(0.3375)}, 0.3252e^{i2\pi(0.2643)} \\ 0.7888e^{i2\pi(0.6753)}, 0.4154e^{i2\pi(0.3430)}, 0.3748e^{i2\pi(0.3370)} \\ 0.5301e^{i2\pi(0.4817)}, 0.4579e^{i2\pi(0.4157)}, 0.5791e^{i2\pi(0.5647)} \\ 0.5559e^{i2\pi(0.5264)}, 0.4811e^{i2\pi(0.4426)}, 0.5521e^{i2\pi(0.5065)} \end{pmatrix}, \quad (25)$$

Step 4:

The AWCSF matrix \bar{V}_{xy} is evaluated with respect to aggregated decision matrix V_{xy} and weight value ρ_y using Eq. (6) and is displayed in Table 5.

Step 5:

The CSF concordance sets Σ_{η_i} , Σ'_{η_i} and Σ''_{η_i} are calculated using the Eqs. (6)–(8), where the score, accuracy, and refusal scale of the elements R of AWCSFM are evaluated by Table 5 and outcomes are in Table 6. The CSF-strong concordance set Σ_{η_i} , CSF-mid-range concordance set Σ'_{η_i} , and CSF-weak concordance set Σ''_{η_i} are demonstrated as

Table 4
Linguistic terms for weights of the attributes.

Criteria	D_1	D_2	D_3	D_4	D_5	D_6
P_1	AE	VAE	VAE	AE	PE	ME
P_2	VAE	VAE	AE	VAE	ME	ME
P_3	AE	AE	ME	AE	VAE	ME
P_4	ME	AE	ME	NE	PE	VPE
P_5	ME	ME	NE	ME	AE	NE

follows:

$$\Sigma_{\eta_i} = \begin{pmatrix} - & \{\} & \{\} & \{\} & \{\} \\ \{1, 2, 3\} & - & \{1, 2, 3\} & \{1, 2\} & \{1, 2\} \\ \{2, 5\} & \{5\} & - & \{2\} & \{\} \\ \{1, 3\} & \{\} & \{1\} & - & \{\} \\ \{1, 2, 3, 5\} & \{3\} & \{1, 2, 3, 4\} & \{1, 2, 3\} & - \end{pmatrix}$$

$$\Sigma'_{\eta_i} = \begin{pmatrix} - & \{\} & \{\} & \{\} & \{\} \\ \{\} & - & \{\} & \{\} & \{\} \\ \{\} & \{\} & - & \{\} & \{\} \\ \{\} & \{\} & \{\} & - & \{\} \\ \{\} & \{\} & \{\} & \{\} & - \end{pmatrix}$$

$$\Sigma''_{\eta_i} = \begin{pmatrix} - & \{\} & \{\} & \{\} & \{\} \\ \{\} & - & \{\} & \{\} & \{\} \\ \{\} & \{\} & - & \{\} & \{\} \\ \{\} & \{\} & \{\} & - & \{\} \\ \{\} & \{\} & \{\} & \{\} & - \end{pmatrix}$$

The CSF discordance sets χ_{η_i} , χ'_{η_i} and χ''_{η_i} are calculated by Eqs. (9)–(11). The score, accuracy, and refusal value of the entities R of AWCSFM are found by Table 5. The CSF-strong discordance set Σ_{η_i} , CSF-mid-range discordance set Σ'_{η_i} , and CSF-weak discordance set Σ''_{η_i} are demonstrated as follows:

$$\chi_{\eta_i} = \begin{pmatrix} - & \{1, 2, 3\} & \{2, 5\} & \{1, 3\} & \{1, 2, 3, 5\} \\ \{\} & - & \{5\} & \{\} & \{3\} \\ \{\} & \{1, 2, 3\} & - & \{1\} & \{1, 2, 3\} \\ \{\} & \{1, 2\} & \{2\} & - & \{1, 2, 3\} \\ \{\} & \{1, 2\} & \{\} & \{\} & - \end{pmatrix}$$

$$\chi'_{\eta_i} = \begin{pmatrix} - & \{\} & \{\} & \{\} & \{\} \\ \{\} & - & \{\} & \{\} & \{\} \\ \{\} & \{\} & - & \{\} & \{\} \\ \{\} & \{\} & \{\} & - & \{\} \\ \{\} & \{\} & \{\} & \{\} & - \end{pmatrix}$$

Table 5
AWCSF decision matrix \bar{V}_{xy} .

	P_1	P_2	P_3	P_4	P_5
S_1	(0.4585 $e^{i2\pi(0.3869)}$, 0.5888 $e^{i2\pi(0.5569)}$, 0.6308 $e^{i2\pi(0.5545)}$)	(0.5252 $e^{i2\pi(0.4228)}$, 0.5699 $e^{i2\pi(0.5297)}$, 0.5830 $e^{i2\pi(0.5150)}$)	(0.4454 $e^{i2\pi(0.3599)}$, 0.5991 $e^{i2\pi(0.5351)}$, 0.6222 $e^{i2\pi(0.5736)}$)	(0.3983 $e^{i2\pi(0.2895)}$, 0.5881 $e^{i2\pi(0.5563)}$, 0.6913 $e^{i2\pi(0.6641)}$)	(0.3551 $e^{i2\pi(0.3136)}$, 0.6260 $e^{i2\pi(0.5705)}$, 0.6738 $e^{i2\pi(0.6234)}$)
S_2	(0.8018 $e^{i2\pi(0.5703)}$, 0.5011 $e^{i2\pi(0.4433)}$, 0.4321 $e^{i2\pi(0.3622)}$)	(0.8454 $e^{i2\pi(0.6246)}$, 0.4829 $e^{i2\pi(0.6941)}$, 0.4012 $e^{i2\pi(0.3256)}$)	(0.6152 $e^{i2\pi(0.4327)}$, 0.5681 $e^{i2\pi(0.4941)}$, 0.5406 $e^{i2\pi(0.4903)}$)	(0.4263 $e^{i2\pi(0.3281)}$, 0.5860 $e^{i2\pi(0.5239)}$, 0.6538 $e^{i2\pi(0.6276)}$)	(0.4645 $e^{i2\pi(0.3867)}$, 0.5905 $e^{i2\pi(0.5349)}$, 0.6107 $e^{i2\pi(0.5592)}$)
S_3	(0.5081 $e^{i2\pi(0.4073)}$, 0.5798 $e^{i2\pi(0.5316)}$, 0.5921 $e^{i2\pi(0.5277)}$)	(0.6563 $e^{i2\pi(0.4314)}$, 0.5365 $e^{i2\pi(0.5045)}$, 0.5701 $e^{i2\pi(0.5154)}$)	(0.3986 $e^{i2\pi(0.2990)}$, 0.5886 $e^{i2\pi(0.5248)}$, 0.6791 $e^{i2\pi(0.6698)}$)	(0.2721 $e^{i2\pi(0.2268)}$, 0.6141 $e^{i2\pi(0.5712)}$, 0.7541 $e^{i2\pi(0.7387)}$)	(0.4966 $e^{i2\pi(0.3763)}$, 0.5832 $e^{i2\pi(0.5538)}$, 0.6312 $e^{i2\pi(0.5679)}$)
S_2	(0.6398 $e^{i2\pi(0.4086)}$, 0.5471 $e^{i2\pi(0.4993)}$, 0.5805 $e^{i2\pi(0.5354)}$)	(0.5596 $e^{i2\pi(0.4209)}$, 0.5488 $e^{i2\pi(0.4969)}$, 0.5700 $e^{i2\pi(0.5288)}$)	(0.6223 $e^{i2\pi(0.4500)}$, 0.5639 $e^{i2\pi(0.5038)}$, 0.5245 $e^{i2\pi(0.4696)}$)	(0.4291 $e^{i2\pi(0.3325)}$, 0.5841 $e^{i2\pi(0.5320)}$, 0.6499 $e^{i2\pi(0.6240)}$)	(0.2602 $e^{i2\pi(0.2081)}$, 0.6030 $e^{i2\pi(0.5638)}$, 0.7746 $e^{i2\pi(0.7873)}$)
S_3	(0.6397 $e^{i2\pi(0.4170)}$, 0.5606 $e^{i2\pi(0.5110)}$, 0.5737 $e^{i2\pi(0.5199)}$)	(0.7944 $e^{i2\pi(0.5594)}$, 0.5106 $e^{i2\pi(0.4799)}$, 0.4505 $e^{i2\pi(0.3732)}$)	(0.6892 $e^{i2\pi(0.4891)}$, 0.5436 $e^{i2\pi(0.4719)}$, 0.4927 $e^{i2\pi(0.4348)}$)	(0.2880 $e^{i2\pi(0.2251)}$, 0.6261 $e^{i2\pi(0.5811)}$, 0.7400 $e^{i2\pi(0.7168)}$)	(0.4754 $e^{i2\pi(0.3662)}$, 0.5949 $e^{i2\pi(0.5563)}$, 0.6378 $e^{i2\pi(0.5773)}$)

Table 6
Score, accuracy and refusal grades of AWCSF matrix.

	P_1	P_2	P_3	P_4	P_5
S_1	(0.2811, 1.0769, 0.8479)	(0.3761, 1.0558, 0.7899)	(0.2887, 1.0630, 0.8434)	(0.1594, 1.1152, 0.9168)	(0.1933, 1.1013, 0.8982)
S_2	(0.8112, 1.1846, 0.4345)	(0.9426, 1.2645, 0.2396)	(0.5159, 1.1004, 0.6958)	(0.2212, 1.0761, 0.8825)	(0.3106, 1.0565, 0.8303)
S_3	(0.3595, 1.0606, 0.8003)	(0.5060, 1.1560, 0.7029)	(0.1736, 1.0960, 0.9091)	(0.0295, 1.1668, 0.9852)	(0.3110, 1.1078, 0.8301)
S_4	(0.4836, 1.1575, 0.7186)	(0.4014, 1.0512, 0.7737)	(0.5379, 1.0881, 0.6798)	(0.2275, 1.0723, 0.8789)	(-0.0126, 1.1875, 1.0063)
S_5	(0.5066, 1.1649, 0.7024)	(0.7975, 1.2034, 0.4500)	(0.6313, 1.1169, 0.6072)	(0.0709, 1.1661, 0.9639)	(0.2968, 1.1103, 0.8386)

$$\chi''_{\eta} = \begin{pmatrix} - & \{\} & \{\} & \{\} & \{\} \\ \{\} & - & \{\} & \{\} & \{\} \\ \{\} & \{\} & - & \{\} & \{\} \\ \{\} & \{\} & \{\} & - & \{\} \\ \{\} & \{\} & \{\} & \{\} & - \end{pmatrix}$$

Step 6:

The decision maker's weights with respect to their importance in the MAGDM problem is in Eq. (26) and the CSF strong, mid-range, and weak concordance sets are utilized to determine the concordance matrix.

$$(w_{\Sigma_{\eta}}, w'_{\Sigma_{\eta}}, w''_{\Sigma_{\eta}}) = (1, \frac{2}{6}, \frac{1}{6}) \quad (26)$$

The CSF concordance indices are examined, further which are constructed as concordance matrix in Eq. (13) and its score value κ is found as like,

$$\kappa = \begin{pmatrix} - & 0.3183 & 0.3183 & 0.3183 & 0.3183 \\ 1.4775 & - & 1.4775 & 1.4045 & 1.4045 \\ 1.3081 & 0.6714 & - & 1.2355 & 0.3183 \\ 1.3479 & 0.3183 & 1.1676 & - & 0.3183 \\ 1.4775 & 1.0131 & 1.4775 & 1.4775 & - \end{pmatrix} \quad (27)$$

$$(w_{\chi_{\eta}}, w'_{\chi_{\eta}}, w''_{\chi_{\eta}}) = (1, \frac{2}{6}, \frac{1}{6}) \quad (28)$$

Step 7:

The weight values of CSF discordance set is shown in Eq. (26) and the CSF discordance matrices are formulated using the normalized Euclidean distance $d(\bar{V}_{\eta y}, \bar{V}_{iy})$. Then, the CSF discordance matrix \ominus is formalized as follows.

$$\ominus = \begin{pmatrix} - & 1 & 0.9693 & 0.9105 & 1 \\ 0 & - & 0.0976 & 0 & 0.3821 \\ 0 & 1 & - & 0.3862 & 1 \\ 0 & 1 & 0.2891 & - & 1 \\ 0 & 1 & 0 & 0 & - \end{pmatrix}$$

Step 8:

Table 7
Outranking decision of the alternatives.

Alternatives	Preference alternatives	Indifference alternatives	Incomparable alternatives
S_1	-	-	-
S_2	S_1, S_3, S_4, S_5	-	-
S_3	S_1, S_4	S_3	-
S_4	S_1, S_3	S_4	-
S_5	S_1, S_3, S_4	-	-

With the help of Eq. (15), the threshold value X is calculated and the CSF concordance matrix κ is formulated by Eq. (17).

Step 9:

From Eq. (18), the threshold value F is find out then, the CSF discordance matrix κ is formalized by Eq. (20).

Step 10:

The CSF concordance and discordance matrices are formalized using the Boolean matrix which gives the outranking matrix R as follows.

$$R = \begin{pmatrix} - & 0 & 0 & 0 & 0 \\ 1 & - & 1 & 1 & 1 \\ 1 & 0 & - & 1 & 0 \\ 1 & 0 & 1 & - & 0 \\ 1 & 0 & 1 & 1 & - \end{pmatrix}$$

Step 11:

From Table 7, the preference, indifference, and incomparable demonstration of S_1, S_2, S_3, S_4 , and S_5 are quantitatively described and the pictorial representation of the outranking decision graph is in Fig. 4 explores that when compared to others S_1 has lesser impact and S_2 needs more precaution in the pandemic and outbreak periods.

Step 12:

The score value of CSF concordance outranking matrix ($M_{\Sigma_{xy}}$) and CSF discordance outranking index ($M_{\chi_{xy}}$) by \ominus is used, further the concordance and discordance elements of the matrices are unified by the Boolean aggregated outranking matrix R. With that, the net outranking index is evaluated to rank the alternatives and as per the ranking result of the alternatives in Table 8, the graphical illustration

Table 8
Alternatives outranking using the score value.

Alternatives	Outranking of concordance	Outranking of discordance	Overall outranking	Ranking
S_1	-4.3378	3.8798	-8.2176	5
S_2	3.4429	-3.5203	6.9632	1
S_3	-0.9076	1.0302	-1.9378	4
S_4	1.2837	0.9924	0.2913	3
S_5	3.0862	-2.3821	5.4683	2

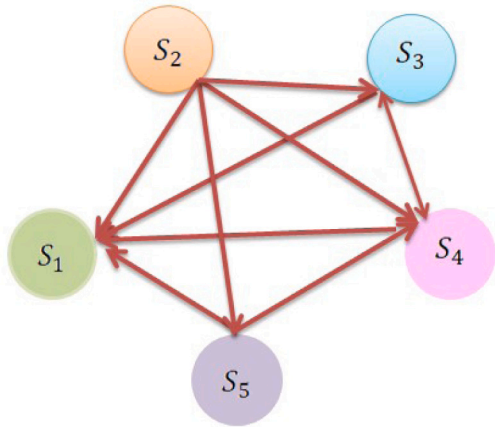


Fig. 4. Outranking decision graph of the alternatives.

of result is represented in Fig. 5. The net outranking index is then used to rank the alternatives, and the graphical representation of the results is provided in Fig. 5 which follows the quantitative ranking result of the alternatives in Table 8.

5. Validation of the result

5.1. Comparison analysis

Decision makers are unsure about the value to use in each parameter, which may be due to insufficient, erroneous, or contradictory information, as well as different preferences within a group of decision makers. Under biased information, ELECTRE's credibility indices correlate these scenarios and provide a realistic solution. ELECTRE-I employs a pairwise comparison technique based on every attribute

Table 9
Ranking outcomes of MAGDM methods for comparison analysis.

Methods/Alternatives	S_1	S_2	S_3	S_4	S_5
EDAS	0.0171	1	0.0435	0.2696	0.6747
TOPSIS	0.3132	0.7205	0.3704	0.4378	0.6070
WASPAS	0.4853	1.2464	0.5423	0.6543	0.9709
VIKOR	1	0	0.8649	0.8441	0.4192
Proposed method	-8.2176	6.9632	-1.9378	0.2913	5.4683

weight. Here, the most often used methods [37] are revised and we particularly choose few methods which provides equal importance to the responses. The distance based methods, TOPSIS [38], VIKOR [39] and EDAS [40], were compared with the ELECTRE-I approach in a CSF environment, and we also investigated the CSF-ELECTRE-I with the utility based WASPAS technique [41]. A numerical evaluation of EDAS, TOPSIS, WASPAS, VIKOR and Proposed Method is shown in Table 9 and the graphical representation of comparative ranking result is in Fig. 6 which shows that compared to proposed method VIKOR method is not acceptable as per experts choice and EDAS, TOPSIS, WASPAS method is does not have the anonymous ranking result.

5.2. Sensitivity analysis

Predominantly, the sensibleness of the proposed result is examined using Akram's Score function [36]. Normally, the sensitivity of the problem is evaluated as per weight value. Here, the pathway of ELECTRE-I approach is based on weights and mathematically shows if we change the weight value an account of criteria in step 3, it definitely gives changes in the result. So, we stepforward to analyze the Akram's score function with proposed score function. The outranking result of experts score value (\mathfrak{R}) is compared with the various score values which follows Definitions 2 and 3. Here, Akram's and the proposed score function has two cases which are denoted as \mathfrak{R}_a , \mathfrak{R}_b , \mathfrak{R}_c and \mathfrak{R}_d respectively in Table 10. The sensibility of proposed score function when compared to Akram's score function is demonstrated in Fig. 7 which shows that the requested score function \mathfrak{R}_d provides greater accuracy than the other three \mathfrak{R}_a , \mathfrak{R}_b and \mathfrak{R}_c .

6. Conclusion and future work

The CSF set theory is evolving as a beneficial expansion of sets that assist in authentic decision-making issues. Based on the MAGDM problem, the suggested technique correctly determines the number of viable options and then suitably fuses them with a two-dimensional paradigm

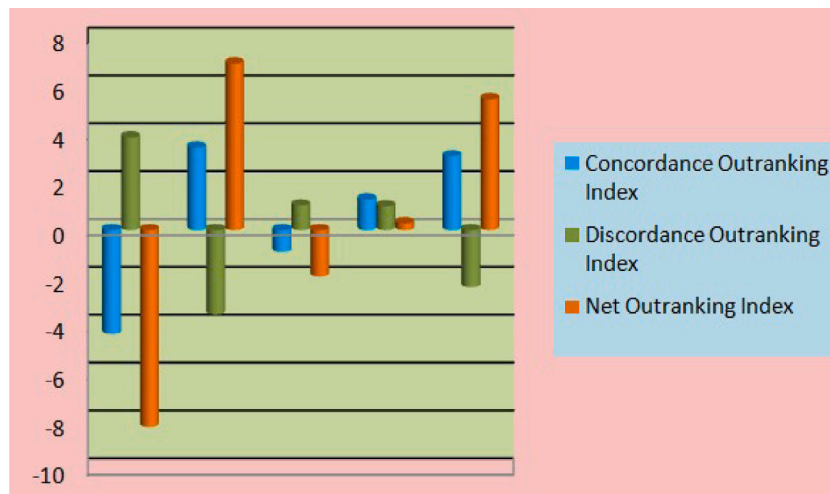


Fig. 5. Alternatives outranking indices.

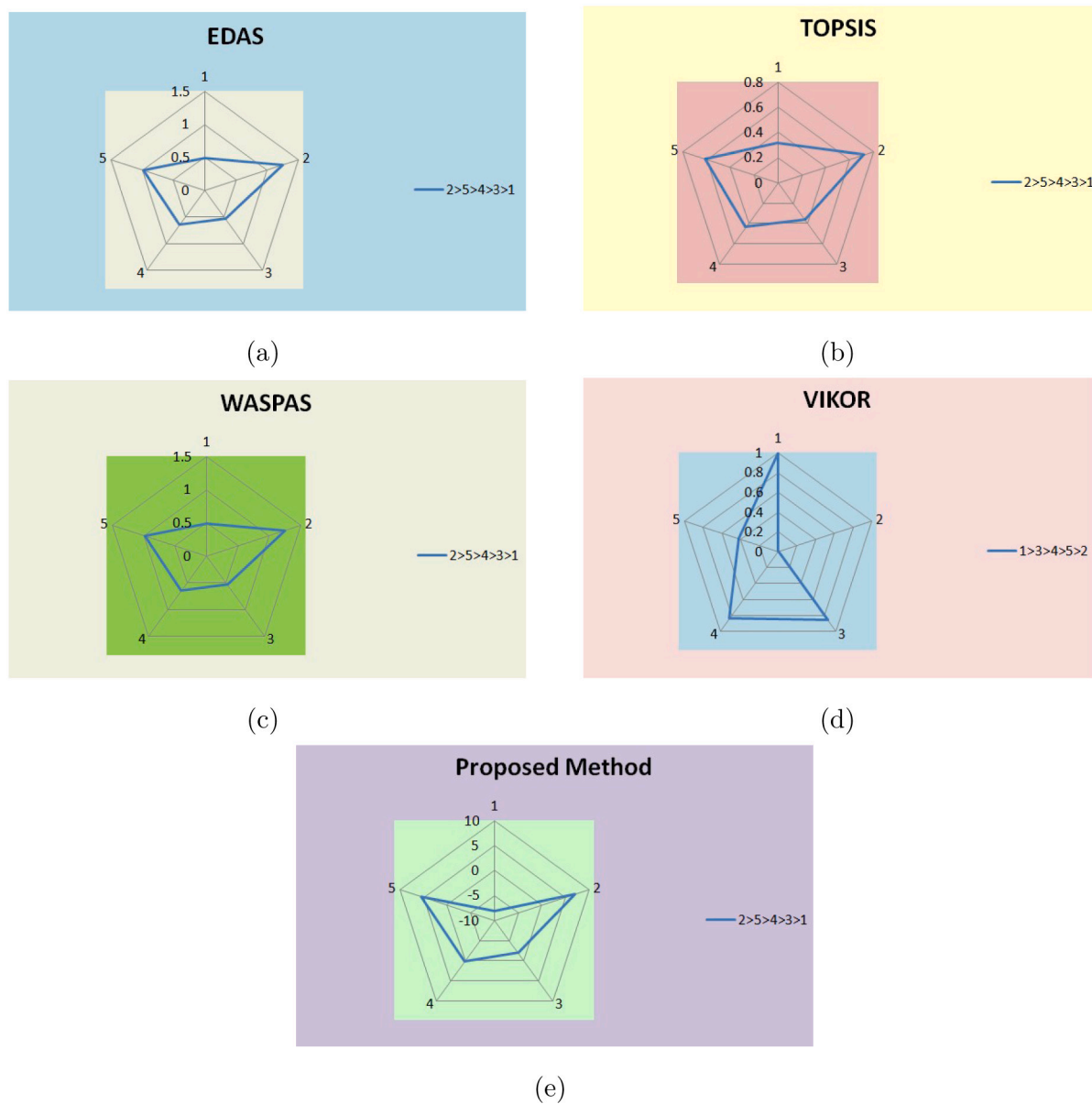


Fig. 6. Comparison of CSF-ELECTRE-I with EDAS, TOPSIS, WASPAS and VIKOR methods.

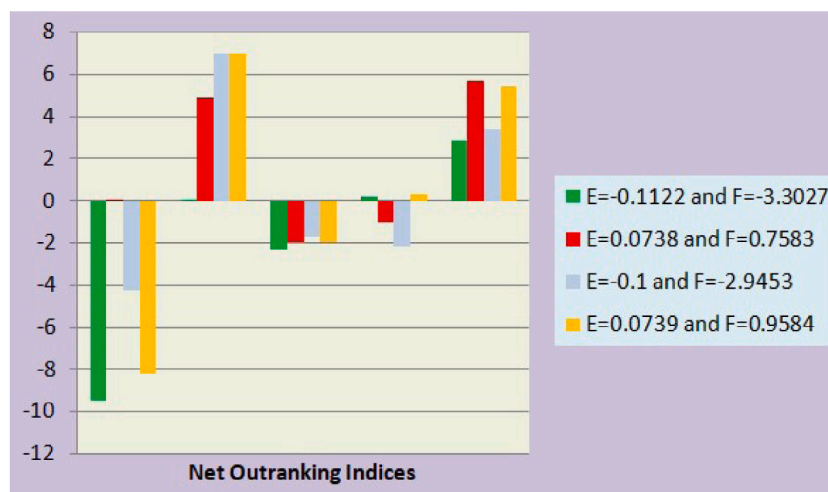


Fig. 7. Visualization of sensibleness in the ranking results.

Table 10

Outranking result for score functions.

Alternatives/Score functions	\mathfrak{R}_a	\mathfrak{R}_b	\mathfrak{R}_c	\mathfrak{R}_d
S_1	-9.4806	0.0334	-4.2604	-8.2176
S_2	0.0736	4.9	7	6.9632
S_3	-2.2751	-1.9806	-1.7244	-1.9378
S_4	0.1557	-1.0513	-2.1395	0.2913
S_5	2.9099	5.71377	3.3965	5.4683

of CSF information. A thorough exploration of the MAGDM approach has been provided and implemented in ELECTRE I, which is a creative assorted technique. In this work, we expanded the theoretical foundation of CSF in directions supported by their implications in certain contexts and their capability in a number of opinions. The ELECTRE-based outranking algorithms are utilized for pursuing synchronized CSF information. The CSF-ELECTRE I methodology correctly combines sophisticated non-binary assessment methods with many factors and is therefore capable of decision-making. Based on this, we assessed the CSF-ELECTRE I approach for identifying the most vulnerable group during the vaccine outbreak period. We performed numerical computations for the proposed problem and obtained the result through outranking graphs and net outranking indices, which suggests that the elderly need more precaution in the pandemic and vaccine outbreak period. The proposed result is compared with the earlier methodologies, proving that the CSF-ELECTRE I method can not only predict compatible results but also significantly alleviate efforts for non-binary assessment. Certain important insights and boundaries of the suggested CSF-ELECTRE I approach, as well as some future goals, are accounted for.

As for future research objectives, we may apply the proposed approach to key MAGDM issues in real-life situations such as medical research, pharmaceuticals, neuroscience, and so on. Furthermore, the proposed approach will be extended to the most generalized complex spherical fuzzy rough set and introduce the CSF-ELECTRE Tri because of the adaptability of the CSF model.

CRedit authorship contribution statement

Samayan Narayanamoorthy: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Subramaniam Pragathi:** Writing – original draft, Data curation, Writing – review & editing. **Meshal Shutaywi:** Resources, Visualization, Writing – review & editing. **Ali Ahmadian:** Resources, Validation, Visualization, Writing – review & editing. **Daekook Kang:** Funding acquisition, Investigation, Resources, Supervision, Validation, Visualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This work was supported by Department of Mathematics, Bharathiar University Coimbatore, India and National Research Foundation (NRF) of Korea grant funded by the Korean Government (MSIT) Grant NRF-2020S1A5A8044635.

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