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RESEARCH ARTICLE

An Intuitionistic Fuzzy SWARA-AROMAN Decision-Making Framework for Sports Event Management

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ABSTRACT In tackling the intricate challenge of selecting best cities for sports events, our innovative approach, the stepwise weight assessment ratio analysis (SWARA)-alternative ranking order method accounting for two-step normalization (AROMAN) method, merges the SWARA and the AROMAN under the intuitionistic fuzzy based framework. Noteworthy for its integration of linear and vector normalization techniques, the AROMAN method ensures precise data structures, enhancing the reliability of subsequent calculations. A critical facet of our methodology is its practical application, exemplified in a comprehensive case study evaluating and ranking five alternative cities for hosting sports events. Criteria such as accessibility, facilities, community engagement, weather conditions, economic viability, safety, cultural fit, and environmental impact are considered. The effectiveness of the IF-SWARA-AROMAN method in addressing the intricacies of city selection is illustrated in this practical situation, which furnishes decision-makers with a reliable instrument to make well-informed decisions in the administration of sporting events. The methodology not only recognises the intricate intricacies of the selection process but also enhances the development of comprehensive and influential sports experiences, thereby harmonising effortlessly with the ever-changing realm of sports management.

INDEX TERMS Intuitionistic fuzzy sets, MCDM, SWARA, AROMAN.

I. INTRODUCTION

In the dynamic landscape of today's urban living, cities around the world are bound by a collective aspiration the pursuit of sustainable development [1]. It is not merely about upgrading physical infrastructure; it represents a comprehensive journey that intertwines environmental equilibrium, social coherence, and economic prosperity. Cities grapple with a myriad of demands, prompting a transformative shift in their approach to balance resident needs, ecological health, economic vibrancy, social justice, and political unity [2]. As discussions on urban sustainability unfold, there is a growing acknowledgment of the inherent vitality of urban life's dynamics and how it plays a pivotal role in shaping cities that are adaptable and forward-thinking [3]. Thriving cities go beyond conventional metrics like air quality indices or population densities; they emphasize nurturing vibrant social connections to enhance the overall quality of life [4]. Agenda serving as the blueprint for sustainable development in the 21st century [2], situates the environment within the

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framework of society and the economy from a human living needs perspective. It underscores the importance of a healthy life as the foundation of sustainable development, viewing it as an outcome of environmental and socioeconomic progress. Consequently, the World Health Organization introduced the Healthy City project with the aim of advancing urban sustainable development [5]. Similar initiatives include resilient city [6], smart city [7], [8], inclusive city [9], [10], and livable city [11], [12]. Most cities, along with pertinent research, are aligning with the goal of sustainability, making urban sustainable development a critical global concern [13].

The sustainable development of the urban system encompasses various aspects due to its inherent diversified complexity. Examples include environmental conservation, resource utilization, land use, economic development, resource management, social well-being, living space, climate change, energy conservation, and waste reduction [1], [14]. The nature of the urban system embodies multidimensional characteristics and concepts. Implementing such multidimensional aspects and concepts into practical development requires the formulation of an actionable model based on the core nature. This involves addressing two structural challenges: clarifying the core nature and seeking an objective and effective evaluation method. The incorporation of best conditions for sports activities within this expansive vision adds a unique layer to urban planning. It is not just about sports as a form of leisure; it is a recognition of sports as gateways to fostering healthier lifestyles, cultivating robust community bonds, and championing a culture of inclusivity. Cities strategically weaving these elements into their fabric set the stage for a more resilient and sustainable urban environment.

The imperative to assess best cities for sports activities resonates across various societal dimensions. Firstly, promoting sports transcends the physical; it acts as a catalyst for a healthier population, alleviating burdens on healthcare systems by encouraging proactive well-being. Secondly, the evolution of transportation and communication technologies, especially since the 20th century, has significantly fueled the globalization of tourism. While this growth brings economic benefits, it also raises environmental concerns. Organizations worldwide are intensifying their efforts to safeguard natural resources and cultural heritage from the potential adverse impacts of tourism [15], [16]. Thirdly, embedding sports within urban planning is about enriching lives, creating spaces that foster a sense of belonging and shared purpose. Evaluating cities based on their commitment to sports activities aligns not just with immediate health goals but lays the groundwork for a sustainable, resilient, and socially cohesive urban future. This comprehensive approach extends beyond short-term objectives; it serves as the foundation for cities to evolve into vibrant hubs that embrace diversity, prioritize well-being, and offer a high quality of life. Assessing cities based on their dedication to sports activities becomes a critical marker of their commitment to holistic development, illustrating an unwavering dedication to nurturing communities where people not only survive but truly thrive. In essence, the exploration of best cities for sports activities within the broader context of sustainable urban development reflects a profound commitment to creating cities that are not just sustainable but are also lively, inclusive, and conducive to the well-being of their residents.

A. LITERATURE REVIEW

In various cases, expert information tends to be a bit unclear because it is presented in a complex way. Atanasov expanded on Zadeh's idea of fuzzy sets [17] by introducing something called intuitionistic fuzzy set (IFS) [18]. IFS uses a "membership degree" (MD) and a "non-membership degree" (NMD), and it is seen as more effective than Zadeh's fuzzy sets in dealing with situations where things are not very clear. Since it was introduced, lots of experts have looked into it and used it in different areas like identifying patterns, predicting market trends, and making strategic plans. When it comes to solving problems with intuitionistic fuzzy (IF) environment in multi-criteria decision-making (MCDM), figuring out how to gather information has become a really interesting and important research topic. Many researchers have explored this from different angles to make sure the final results are accurate when combining different pieces of information. Xu came up with some basic arithmetic methods for putting together intuitionistic fuzzy numbers (IFNs) [19], and Xu and Yager introduced some essential geometric methods for IFN-based MCDM [20]. They also created some dynamic methods for situations where the information is collected at different times [21]. Other researchers came up with different methods like generalized IF-weighted methods, IF-Choquet integral methods, and IF-point methods [22], [23], [24]. There are also methods like IF-Bonferroni mean and IF AOs with weighted vectors [25], [26] that depend on different sources. Xu and Wang [27] introduced something called IF induced generalized methods. Some researchers, like Zeng and Su [28], [29], created methods like IF-ordered weighted distance and IF-hybrid weighted distance for MCDM. Others, like Yu [30], came up with IF-prioritized average and geometric methods. Yu even invented new ones like "IF-geometric Heronian mean" and "IF-geometric weighted Heronian mean" [31]. Wei and Merigo designed several methods based on IF-probabilities [32]. All these methods for putting together different pieces of information are based on certain rules, and they do not work the same way as traditional fuzzy sets.

B. SWARA

SWARA method was introduced by Kersuliene et al. [33]. The idea is to figure out how important and which alternatives should be prioritized for each criteria. They do this by getting the decision maker's opinion, using a weighting method. This helps to set the relative importance of each criteria and sort out the initial priorities. In recent times, the SWARA method has become quite versatile for decision-making in different areas. A study by Stević et al. [34] took a critical look at the fuzzy SWARA method, pointing out its drawbacks for decision-making processes. Their research highlighted the importance of understanding the limitations of the fuzzy SWARA method. Sivageerthi et al. [35] explored SWARA in coal supply chain management in materials Proceedings. They delved into risk analysis within this dynamic context, showcasing how SWARA can help manage complexities in supply chain risk. Deveci et al. [36] expanded SWARA's application by evaluating risks in sustainable mining practices. Their work introduced a Fermatean fuzzy score function-based SWARA method, offering a unique approach to assessing and managing risks in sustainable mining.

Amoozad Mahdiraji et al. [37] applied SWARA to the automotive industry, formulating manufacturing strategies with IF numbers. This study sheds light on how SWARA can be used for strategic decisions in industry, highlighting its adaptability to various decision-making scenarios. Torkashvand et al. [38] addressed environmental concerns by improving the DRASTIC framework using SWARA, combined with a genetic algorithm and entropy. Their study in Environmental Science and Pollution Research illustrated the effectiveness of SWARA in enhancing environmental decision-making, especially in groundwater pollution risk assessment. Vrtagić et al. [39] advanced MCDM models in the transportation sector, introducing a new fuzzy SWARA model for ranking road sections. This research showcased SWARA's adaptability in different domains, emphasizing its utility in infrastructure development and optimization. Ghenai et al. [40] explored sustainability indicators for renewable energy systems using an extended SWARA/ARAS hybrid method. Their study stressed the importance of SWARA in assessing the sustainability aspects of renewable energy systems. Ulutaş et al. [41] focused on location selection for logistics centers using fuzzy SWARA and CoCoSo methods. Their methodological approach for best location selection, highlighting the practical applications of SWARA in optimizing logistical processes.

Majeed and Breesam [42] applied the SWARA technique to determine criteria weights for selecting landfill sites in Baghdad governorate. Their work, presented in an IOP conference series, showcased the adaptability of SWARA in addressing critical issues related to urban planning and waste management. Ghoushchi et al. [43] evaluated wind turbine failure modes using SWARA-CoCoSo methods based on a spherical fuzzy environment. Their study in contributed to the field of renewable energy by providing a comprehensive approach to assessing and mitigating risks associated with wind energy infrastructure. Ayyildiz et al. [44] integrated SWARA and DEA for the performance analysis of wastewater treatment plants. Their study demonstrated the diverse applications of SWARA in addressing complex issues such as environmental sustainability and infrastructure performance. Ulutaş et al. [45] extended the assessment of logistics risks with the plithogenic SWARA method, contributing to the ongoing discourse on risk management in logistics and supply chain operations. Their work in Logistics showcased the adaptability of SWARA in assessing collaboration-based and non-collaboration-based logistics risks. Yücenur and Ipekçi [46] utilized SWARA/WASPAS methods for selecting a location for a marine current energy plant. Their study highlighted the applicability of SWARA in the renewable energy sector, particularly in addressing site selection challenges for sustainable energy infrastructure.

Eroğlu and Gencer [47] focused on classification using the SWARA method and an application with SMAA-2. Their work contributed to the evolving landscape of decision-making methodologies by showcasing the SWARA method's potential in classification tasks. Alrasheedi et al. [48] introduced a multicriteria group decision-making approach based on an improved distance measure, the SWARA method, and the WASPAS method. Their work contributed to the field of decision support systems, showcasing the synergy between different methodologies for more robust decision-making. Seikh and Mandal [49] explored the application of the SWARA-based PROMETHEE II method to biomedical waste management. Their study extended the application of SWARA to the critical domain of waste management, addressing the complexities associated with handling biomedical waste. This extensive literature review highlights the diverse applications of the SWARA method in various fields, including risk assessment, sustainability evaluation, strategic decision-making, environmental management, industrial manufacturing, logistics, and renewable energy. These studies collectively contribute to the evolving landscape of multi-criteria decision-making methodologies, emphasizing the practical significance of the SWARA method in addressing complex decision-making challenges across different domains.

C. AROMAN

In 2023, Bošković et al. [50] introduced the AROMAN method, offering a novel perspective for decision-making in cargo bike delivery concepts. Emphasizing its versatility and adaptability, their work provided a foundation for broader applications in this domain. Concurrently, Kara et al. [51] introduced the MEREC-AROMAN method, aiming to determine sustainable competitiveness levels. Through a case study in Turkey, they integrated the MEREC approach with AROMAN, offering valuable insights for practical applications in socio-economic planning. In a separate study addressing port performance evaluation, Yalçın et al. [52] proposed an IF-based model, enriching the existing techniques. This comprehensive approach, highlighted in a comparison table, incorporated IFSs to assess the sustainability and efficiency of port operations, providing a realistic representation of uncertainties in the performance evaluation process. A decision-making problem involves considering multiple criteria to identify the best alternative within a given set, in contrast to a single-criterion approach [46]. AROMAN [50], when compared to other techniques such as TOPSIS [54], MABAC [55], ARAS [53], CODAS [58], MAUT [56], WASPAS [57], SWARA [33] CoCoSo [59], and VIKOR [60], exhibits notable differences. These methods generally share similar principles in decision-making, typically relying on an initial decision-making matrix that incorporates various alternatives assessed against multiple conflicting criteria. The outcome of any MCDM method is a final ranking of alternatives, providing decision-makers with a basis for selecting the most suitable option. The comprehensive ranking for each technique is clearly outlined and presented in detail within Table 1.

In their study, Utama et al. [61] brought in a practical decision-making model using fuzzy logic for selecting the best locations for national multi-sport events. Their approach takes into account multiple factors and is flexible, making it useful for dynamic event planning. Moving on, Dodouras and James [62] dove into the sustainability impacts of mega-sports events. They came up with this unique fuzzy mapping system that evaluates the overall effects of these large-scale events, covering environmental, social, and economic aspects. Massoumi [63] added depth to evaluating sporting federations' performance. His fuzzy approach in the entropy decision-making pattern presents a more comprehensive model that considers uncertainties in such assessments. Wang et al. [64] focused on the Taipei city sports centre, crafting a fuzzy MCDM model that looks at facility performance from managerial viewpoints. This research adds to our understanding of how to assess sports infrastructure effectively. Yang et al. [65] explored sports tourism and sustainability using a hybrid MCDM model. Their study is vital in recognizing viable sports tourism attractions, showing a nuanced understanding of environmental and socio-economic factors. Altogether, these studies offer diverse perspectives on using fuzzy logic and MCDM in sports management, giving useful insights for both decision-makers and researchers. In the realm of sports event planning, there is a gap in the current research when it comes to choosing the right cities to host these events. Most studies focus on practical aspects like logistics but overlook the deeper, qualitative factors that truly impact a city's suitability. There is a clear need for a more thorough and nuanced approach in deciding which cities are the best fit. The case study fils this gap, offering a detailed evaluation framework that goes beyond typical considerations. It recognizes that city selection involves more than just ticking logistical boxes; it is about understanding the socio-economic, cultural, and environmental factors that influence the success of these events. Decision-makers often struggle to integrate these diverse factors, and this case study aims to provide a practical and detailed solution to address these complexities. By emphasizing a qualitative understanding of community engagement, cultural fit, and environmental impact, the case study contributes to a more holistic and sustainable approach in city selection, responding to the unique challenges faced by decision-makers in sports event management.

D. MOTIVATION AND CONTRIBUTION

The motivation for developing the IF-SWARA-AROMAN method, which operates within the IF sets framework, stems from the intrinsic intricacies involved in identifying the most suitable locations for sporting events. In light of the ever-evolving landscape of sports management and the demand for an advanced decision-making instrument, our strategy incorporates the SWARA and AROMAN methodologies in a seamless fashion. By incorporating IF sets, a greater degree of adaptability and realism is introduced, enabling a more intricate depiction of uncertainties and imprecisions during the assessment procedure.

A notable advancement in our work is the innovative coupling of SWARA and AROMAN under the IF set framework, effectively addressing the limitations of conventional decision-making approaches. The AROMAN method's integration of linear and vector normalization techniques guarantees the precision of data structures, thereby enhancing the reliability of subsequent calculations. The practical application of our methodology is exemplified through a comprehensive case study evaluating and ranking five alternative cities for hosting sports events. Criteria such as accessibility, facilities, community engagement, weather conditions, economic viability, safety, cultural fit, and environmental impact are meticulously considered. This case study serves as a tangible demonstration of the IF-SWARA-AROMAN method's effectiveness in navigating the complexities of city selection. Decision-makers in sports event management are armed with a robust tool for making informed choices, contributing to the optimization of the selection process. Beyond recognizing the nuanced dynamics of city selection, our methodology actively contributes to shaping impactful and well-rounded sports experiences. It seamlessly aligns with the evolving landscape of sports management, aspiring to elevate decision-making practices by offering a novel and practical framework for city selection that comprehensively addresses a broad spectrum of criteria and uncertainties.

E. STRUCTURE OF THE PAPER

The paper follows a coherent structure, initiating with Section II's in-depth exploration of the fundamental notions and operations of IF, establishing a solid groundwork by elucidating basic principles, mathematical formulas, and crucial IF properties. Section III introduces the IF-SWARA-AROMAN approach, a fusion of the SWARA method for criteria weight determination and the AROMAN method for aggregation, meticulously addressing methodological complexities like intercriteria correlations and complete aggregation. Section IV showcases the practical application of IF-SWARA-AROMAN in evaluating and selecting best cities for sports events. Finally, Section V thoroughly examines findings, conclusion, and future research directions within the dynamic landscape of best city selection for sports events.

TABLE 1. MCDM Methods for finding final ranking.

MCDM method	Final Ranking Formula	Description
TOPSIS	$K_i = \frac{N_i^-}{N_i^- + N_i^+}$	The proximity to the best positive solution.
MAUT	$K_i = \sum_{j=1}^{n} N_{ij} \cdot w_j$	The final utility score for each alternative is established by employing the assigned utility score values.
ARAS	$K_i = \frac{S_i}{S_0}$	The level of utility associated with alternatives.
WASPAS	$K_i = \lambda N_1^{(1)} + (1-\lambda) N_1^{(2)}$	The combined measure for each alternative, where λ represents the parameter in the WASPAS method and can be adjusted within the range of 0 to 1.
MABAC	$\Omega_i = \sum_{j=1}^{m} N_{ij}$	We can simply figure out how far each option is from the approximate border. Then, by looking at these distances, we can easily figure out the ranking of the options.
CoCoSo	$K_i = \left(K_{ia} \cdot K_{ib} \cdot K_{ic}\right)^{\frac{1}{3}+\frac{1}{3}} \left(K_{ia} + K_{ib} + K_{ic}\right)$	The best ranking K_i, where: K_{ia}, K_{ib}, and K_{ic} are the Total Utility Strategies for all alternatives.
EDAS	$K_i = \frac{1}{2}\left(KP_i + KN_i\right)$	The appraisal score for each alternative, where KP_i and KN_i are the normalized values of the weighted Positive Distance from Average (PDA) and weighted Negative Distance from Average (NDA) of each alternative.
SWARA	$w_j = \frac{N_j}{\sum_{j=1}^{n} N_j}$	The final ranking of alternatives for each decision-maker is sorted by arranging the values in descending order, considering the relative weight of each criteria.
AROMAN	$K_i = \beth_i^{\lambda} + \beth_i^{(1-\lambda)}$	The conclusive ranking of alternatives, denoted as K_1, is determined with the influence of the coefficient λ, which signifies the degree of the criterion type.

II. PRELIMINARIES

Definition 1 [18]: An IFS in W is defined as

$$\chi = \{\langle \breve{z}, \xi^{\gamma}(\breve{z}), \omega^{\gamma}(\breve{z}) | \breve{z} \in W \rangle\} \tag{1}$$

where $\xi^{\gamma}(\breve{z}), \omega^{\gamma}(\breve{z}) \in [0, 1]$, such that $0 \leq \xi^{\gamma}(\breve{z}) + \omega^{\gamma}(\breve{z}) \leq 1$ for all $\breve{z} \in W$. $\xi^{\gamma}(\breve{z}), \omega^{\gamma}(\breve{z})$ represent MG and NMG separately for some $\breve{z} \in X$.

we denote this pair as $\digamma = (\xi^{\gamma}{}_{\digamma}, \omega^{\gamma}_{\digamma})$, the entirety of this research, and called as IFN satisfying the requirements $\xi^{\gamma}{}_{\digamma}, \omega^{\gamma}_{\digamma} \in [0, 1]$ and $\xi^{\gamma}{}_{\digamma} + \omega^{\gamma}_{\digamma} \leq 1$.

Definition 2 [67]: When implementing the IFNs to practical life situations, ranking them is an absolutely necessary step. The "score function" (SF) that corresponds to the IFN, $\digamma = (\xi^{\gamma}{}_{\digamma}, \omega^{\gamma}_{\digamma})$ be defined as

$$S(\digamma) = \xi^{\gamma}{}_{\digamma} - \omega^{\gamma}_{\digamma} \tag{2}$$

However, it seems that the above mentioned technique is inadequate of categorising IFNs in a number of circumstances. For this, an "accuracy function" (AF) H of $\digamma$ is defined [66].

$$H(\digamma) = \xi^{\gamma}{}_{\digamma} + \omega^{\gamma}_{\digamma} \tag{3}$$

To complement this study, we present a new scoring function that satisfies all of the previously specified characteristics in [67].

$$\breve{\xi^{\gamma}}^{\gimel} = \frac{1 + \xi^{\gamma}{}_{\digamma} - \omega^{\gamma}_{\digamma}}{2}. \tag{4}$$

We will now examine the operational principles for accumulating IFNs.

Definition 3 [20]: Let $\digamma_1 = \langle \xi^{\gamma}{}_1, \omega^{\gamma}_1 \rangle$ and $\digamma_2 = \langle \xi^{\gamma}{}_2, \omega^{\gamma}_2 \rangle$ be two IFNs, $\gimel > 0$ then

$$\digamma_1^c = \left\langle \omega^{\gamma}_1, \xi^{\gamma}{}_1 \right\rangle \tag{5}$$

$$\digamma_1 \vee \digamma_2 = \left\langle max\{\xi^{\gamma}{}_1, \xi^{\gamma}{}_2\}, min\{\omega^{\gamma}_1, \omega^{\gamma}_2\} \right\rangle \tag{6}$$

$$\digamma_1 \wedge \digamma_2 = \left\langle min\{\xi^{\gamma}{}_1, \xi^{\gamma}{}_2\}, max\{\omega^{\gamma}_1, \omega^{\gamma}_2\} \right\rangle \tag{7}$$

$$\digamma_1 \oplus \digamma_2 = \left\langle \xi^{\gamma}{}_1 + \xi^{\gamma}{}_2 - \xi^{\gamma}{}_1 \xi^{\gamma}{}_2,\ \omega^{\gamma}_1 \omega^{\gamma}_2 \right\rangle \tag{8}$$

$$\digamma_1 \otimes \digamma_2 = \left\langle \xi^{\gamma}{}_1 \xi^{\gamma}{}_2,\ \omega^{\gamma}_1 + \omega^{\gamma}_2 - \omega^{\gamma}_1 \omega^{\gamma}_2 \right\rangle \tag{9}$$

$$\gimel \digamma_1 = \left\langle 1 - (1 - \xi^{\gamma}{}_1)^{\gimel},\ \omega^{\gamma \gimel}_1 \right\rangle \tag{10}$$

$$\digamma_1^{\gimel} = \left\langle \xi^{\gamma \gimel}_1,\ 1 - (1 - \omega^{\gamma}_1)^{\gimel} \right\rangle \tag{11}$$

A. INTUITIONISTIC FUZZY DOMBI OPERATOR

Theorem 4 [68]: Let $\tilde{\alpha}_i = (\xi^{\gamma}{}_i, \omega^{\gamma}{}_i)$ $(i = 1, 2, \ldots, n)$ be a set of IFNs. Then, the intuitionistic fuzzy Dombi weighted average (IFDWA) operator is a function $\alpha^n \rightarrow \alpha$, such that:

$$\text{IFDWA}(\alpha_1, \alpha_2, \ldots, \alpha_n) = \bigotimes_{i=1}^{n} (\alpha_i)^{\theta^{\gamma}{}_i}, \tag{12}$$

where $\theta^{\gamma} = (\theta^{\gamma}{}_1, \theta^{\gamma}{}_2, \ldots, \theta^{\gamma}{}_n)^t$ is the weight vector of α_i $(i = 1, 2, \ldots, n)$, $\theta^{\gamma}{}_i > 0$, and $\sum_{i=1}^{n} \theta^{\gamma}{}_i = 1$.

Theorem 5: Let $\tilde{\alpha}_i = (\xi^{\gamma}{}_i, \omega^{\gamma}{}_i)$ $(i = 1, 2, \ldots, n)$ be a set of IFNs. Then, the aggregated value of them using the IFDWA operation is also an IFN and is given by: (13), as shown at the bottom of the next page, where $\theta^{\gamma} = (\theta^{\gamma}{}_1, \theta^{\gamma}{}_2, \ldots, \theta^{\gamma}{}_n)^t$

is the weight vector of $\tilde{\alpha}_i$ $(i = 1, 2, \ldots, n)$, $\theta^{\gamma}{}_i > 0$, and $\sum_{i=1}^{n} \theta^{\gamma}{}_i = 1$.

Theorem 6 [68]: Let $\tilde{\alpha}_i = (\xi^{\gamma}{}_i, \omega^{\gamma}{}_i)$ $(i = 1, 2, \ldots, n)$ be a set of IFNs. Then, the intuitionistic fuzzy Dombi weighted geometric (IFDWG) operator is a function $\tilde{\alpha}^n \rightarrow \tilde{\alpha}$, such that:

$$\mathrm{IFDWG}(\tilde{\alpha}_1, \tilde{\alpha}_2, \ldots, \tilde{\alpha}_n) = \bigotimes_{i=1}^{n} (\tilde{\alpha}_i)^{\gamma_i}, \tag{14}$$

where $\theta^{\gamma} = (\theta^{\gamma}{}_1, \theta^{\gamma}{}_2, \ldots, \theta^{\gamma}{}_n)^t$ is the weight vector of $\tilde{\alpha}_i$ $(i = 1, 2, \ldots, n)$, $\theta^{\gamma}{}_i > 0$, and $\sum_{i=1}^{n} \theta^{\gamma}{}_i = 1$.

Theorem 7: Let $\tilde{\alpha}_i = (\xi^{\gamma}{}_i, \omega^{\gamma}{}_i)$ $(i = 1, 2, \ldots, n)$ be a set of IFNs. Then, the aggregated value of them using the IFDWG operation is also an IFN and is given by: (15), as shown at the bottom of the next page, where $\xi^{\gamma} = (\theta^{\gamma}{}_1, \theta^{\gamma}{}_2, \ldots, \theta^{\gamma}{}_n)^t$ is the weight vector of $\tilde{\alpha}_i$ $(i = 1, 2, \ldots, n)$, $\theta^{\gamma}{}_i > 0$, and $\sum_{i=1}^{n} \theta^{\gamma}{}_i = 1$.

III. DECISION-MAKING ALGORITHM BASED ON PROPOSED AOS

Step 1: Presenting the IFNs dataset, where A_i (for $i = 1, 2, \ldots, r$ signifies alternatives assessed across various criteria C_j (for $j = 1, 2, \ldots, s$. Decision-makers provide decision matrices denoted by $C = [C_{ij}]_{r \times s}$.

$$\begin{array}{c} \\ A_{\Delta} \\ A_{\Theta} \\ \vdots \\ A_r \end{array} \begin{array}{c} \begin{array}{cccc} C_{\Delta} & C_{\Theta} & & C_s \end{array} \\ \begin{bmatrix} (G_{11}, G_{11}) & (G_{12}, G_{12},) & \ldots & (G_{1s}, G_{1s}) \\ (G_{21}, G_{21}) & (G_{22}, G_{22}) & \ldots & (G_{2s}, G_{2s}) \\ \vdots & \vdots & \ddots & \vdots \\ (G_{r1}, G_{r1},) & (G_{r2}, G_{r2}) & \ldots & (G_{rs}, G_{rs}) \end{bmatrix} \end{array}$$

The expression $C_{ij} = \left(G_{ij}, G_{ij}\right)$ describes our dataset, named IFNs. This dataset contains details about alternatives evaluated across decision-maker criteria, identified by indices i and j, where $i = 1, 2, \ldots, r$ and $j = 1, 2, \ldots, s$. Each alternative is defined by eight specific linguistic terms, outlined in Table 2. Additionally, we supplement these terms with linguistic expressions associated with expertise, presented in Table 3. This assortment of varied linguistic expressions offers a comprehensive view of the information evaluation process.

Step 2: Compute the decision-maker's weights by utilizing the scoring function outlined in Equation (2). Following the assessment of scores, incorporate them into the specified Equation (16). This step involves a comprehensive evaluation in line with the decision-making framework.

$$\daleth_{ij} = \frac{\sum_{i}^{3} (\xi^{\gamma} z_i - \omega^{\gamma} z_i)}{\sum_{j}^{3} (\sum_{i}^{3} \xi^{\gamma} z_i - \omega^{\gamma}{}_{z_i})}, \quad i = 1, 2, \ldots, r; \; j = 1, 2, \ldots, s; \tag{16}$$

Step 3: Compute the aggregated decision matrix $M = [M_{ij}]_{r \times s}$ using the formula presented in Equation (17), as shown at the bottom of the next page. This involves systematically applying the specified formula to bring together the relevant values, resulting in the creation of a comprehensive decision matrix. Following this computational process, the aggregated decision matrix is obtained, offering a holistic representation of the collective outcomes from the decision-making process. (16), as shown at the bottom of the next page.

Step 4: To evaluate the relative importance of criteria in the MCDM process, we subdivide the procedure as follows.

A. SWARA METHOD

The SWARA methodology, introduced by Kersuliene et al. [33], provides decision-makers with a methodical approach for evaluating and prioritizing alternatives. In this technique, decision-makers commence by articulating their opinions, establishing the relative importance and initial ranking of alternatives for each criteria. Following this, the methodology entails determining the relative weight of each criteria, a critical factor influencing the overall decision-making process. By employing the SWARA method, decision-makers can systematically assess and rank alternatives, fostering more deliberate and well-informed decision-making, particularly in intricate scenarios.

Step 4.1: Find the aggregated decision matrix's score value using Equation (2).

Step 4.2: Compute the criteria weights of aggregated decision matrix by utilizing the scoring function outlined in Equation (2). Following the assessment of scores, incorporate them into the specified Equation (18).

$$\daleth_{ij} = \frac{\sum_{i}^{3} (\xi^{\gamma} z_i - \omega^{\gamma} z_i)}{\sum_{j}^{3} (\sum_{i}^{3} \xi^{\gamma} z_i - \omega^{\gamma}{}_{z_i})}, \quad i = 1, 2, \ldots, r; \; j = 1, 2, \ldots, s; \tag{18}$$

Step 4.3: To begin, decision-makers prioritize criteria according to their perceived relative importance. The calculation of the criteria coefficient D for each decision-maker is determined using Equation (19).

$$D_j = \begin{cases} 1 & \text{if } j = 1 \\ \daleth_{ij} + 1 & \text{if } j > 1 \end{cases} \qquad j = 1, \ldots, s \tag{19}$$

$$\mathrm{IFDWA}(\tilde{\alpha}_1, \tilde{\alpha}_2, \ldots, \tilde{\alpha}_n) = \bigoplus_{i=1}^{n} \theta^{\gamma}{}_i \tilde{\alpha}_i = \left(1 - \frac{1}{1 + \left\{ \sum_{i=1}^{n} \theta^{\gamma}{}_i \left(\frac{\xi^{\gamma}{}_i}{1 - \xi^{\gamma}{}_i} \right)^m \right\}^{\frac{1}{m}}}, \; \frac{1}{1 + \left\{ \sum_{i=1}^{n} \theta^{\gamma}{}_i \left(\frac{1 - \omega^{\gamma}{}_i}{\omega^{\gamma}{}_i} \right)^m \right\}^{\frac{1}{m}}} \right) \tag{13}$$

TABLE 2. Linguistic terms for evaluation in the sports event case study.

Linguistic Term	Description	(IFNs)
Excellent (E)	Outstanding alignment with criteria, seamless integration with socio-economic factors, and best sustainability.	$\langle 0.90, 0.05\rangle$
Strong (S)	Clear and effective in meeting criteria, demonstrating strong cultural fit and economic viability.	$\langle 0.85, 0.10\rangle$
Good (G)	Requires reasonable evaluation time, demonstrating satisfactory community engagement and facilities.	$\langle 0.80, 0.15\rangle$
Adequate (AD)	Consistent performance across various conditions, demonstrating adaptability and safety considerations.	$\langle 0.75, 0.20\rangle$
Acceptable (A)	Can handle the complexities of hosting sports events, scalable to evolving circumstances.	$\langle 0.65, 0.30\rangle$
Moderate (M)	Demonstrates satisfactory performance but with room for improvement in certain criteria.	$\langle 0.60, 0.35\rangle$
Poor (P)	Minimal instances of incorrectly predicting unsuitability, addressing concerns promptly.	$\langle 0.50, 0.40\rangle$
Unsatisfactory (U)	Very low instances of failing to meet criteria, ensuring safety and environmental consciousness.	$\langle 0.45, 0.50\rangle$

TABLE 3. Decision-Makers for evaluation.

Profession	Role	Expertise
Sports Event Manager	Planner	Coordinator, Evaluator, Collaborator
$\langle 0.90, 0.05\rangle$	$\langle 0.85, 0.10\rangle$	$\langle 0.80, 0.15\rangle$
Urban Planner	Designer	Assessor, Analyst, Developer
$\langle 0.85, 0.10\rangle$	$\langle 0.80, 0.15\rangle$	$\langle 0.65, 0.30\rangle$
Environmental Specialist	Advisor	Evaluator, Advisor, Sustainability Expert
$\langle 0.65, 0.30\rangle$	$\langle 0.60, 0.35\rangle$	$\langle 0.45, 0.50\rangle$

*Step 4.4:*In this stage, the initial weight of an criteria for each decision-maker is calculated using Equation (20).

$$Q_j = \begin{cases} 1 & \text{if } j = 1 \\ \dfrac{Q_j}{D_j} & \text{if } j > 1 \end{cases} \qquad j = 1, \ldots, s \tag{20}$$

Step 4.5 The determination of the relative weight of an criteria for each decision-maker is carried out by applying Equation (21).

$$W_j = \frac{Q_j}{\sum_{j=1}^{n} Q_j}, \quad j = 1, 2, \ldots, s; \tag{21}$$

B. AROMAN

Step 5: Standardize the input data in the decision-making matrix through normalization. Once the matrix is established with input data, the next step involves structuring the data within intervals from 0 to 1. There are two commonly used methods for data standardization. Equation (22) and (23).

Step 5.1: Normalization 1 (**Linear**):

$$\beth_{ij} = \frac{\omega_{ij} - min(\omega_{ij})}{max(\omega_{ij}) - min(\omega_{ij})}, \; i = 1, 2, \ldots, r; \; j = 1, 2, \ldots, s; \tag{22}$$

Step 5.2: Normalization 2 (**Vector**):

$$\beth^*_{ij} = \frac{\omega_{ij}}{\sqrt{\sum_{i=1}^{m} \omega_{ij}^2}}, \quad i = 1, 2, \ldots, r; \; j = 1, 2, \ldots, s; \tag{23}$$

Step 6: Apply Averaged Aggregation Normalization to standardize the input data. This method offers a systematic approach to ensure consistency and enable meaningful comparisons across various criteria. The process of aggregated averaged normalization is carried out by utilizing

$$\mathrm{IFDWG}(\tilde{\alpha}_1, \tilde{\alpha}_2, \ldots, \tilde{\alpha}_n) = \bigotimes_{i=1}^{n} (\tilde{\alpha}_i)^{\theta^{\gamma}{}_i} = \left(\frac{1}{1 + \left\{ \sum_{i=1}^{n} \theta^{\gamma}{}_i \left(\frac{1-\xi^{\gamma}{}_i}{\xi^{\gamma}{}_i} \right)^m \right\}^{\frac{1}{m}}}, 1 - \frac{1}{1 + \left\{ \sum_{i=1}^{n} \theta^{\gamma}{}_i \left(\frac{\omega^{\gamma}{}_i}{1-\omega^{\gamma}{}_i} \right)^m \right\}^{\frac{1}{m}}} \right) \tag{15}$$

$$= \left(1 - \frac{1}{1 + \left\{ \sum_{i=1}^{n} \theta^{\gamma}{}_i \left(\frac{\xi^{\gamma}{}_i}{1-\xi^{\gamma}{}_i} \right)^m \right\}^{\frac{1}{m}}}, \; \frac{1}{1 + \left\{ \sum_{i=1}^{n} \theta^{\gamma}{}_i \left(\frac{1-\omega^{\gamma}{}_i}{\omega^{\gamma}{}_i} \right)^m \right\}^{\frac{1}{m}}} \right) \tag{17}$$

Equation (24).

$$\beth_{ij}^{\text{norm}} = \frac{\beta \beth_{ij} + (1-\beta)\beth_{ij}^{*}}{2}, \ i = 1, 2, \ldots, r; \ j = 1, 2, \ldots, s; \tag{24}$$

where $\beth_{ij}^{\text{norm}}$ represents the aggregated average normalization, where β acts as a weighting factor within the range of 0 to 1. In our specific context, we assign β a value of 0.5.

Step 7: Multiply the decision-making matrix, which has been normalized through aggregated averaging, by the respective criteria weights. This process yields a weighted decision-making matrix, as indicated by Equation (25).

$$\hat{\beth}_{ij} = W_{ij} \cdot \beth_{ij}^{\text{norm}}, \quad i = 1, 2, \ldots, r; \ j = 1, 2, \ldots, s \tag{25}$$

Step 8: Represent the normalized weighted values separately for the criteria type min($\xi^{\gamma}{}_i$) and the max type (υ_i^{γ}) using Equation (26).

$$\xi^{\gamma} = \sum_{j=1}^{n} \widehat{\beth}_{ij}^{(\text{min})}, \quad i = 1, 2, \ldots, r; \ j = 1, 2, \ldots, s;$$
$$\upsilon_i^{\gamma} = \sum_{j=1}^{n} \widehat{\beth}_{ij}^{(\text{max})}, \quad i = 1, 2, \ldots, r; \ j = 1, 2, \ldots, s; \tag{26}$$

Step 9: Determine the final ranking of alternatives:

$$\widehat{R}_i = \xi^{\gamma\lambda} + \upsilon_i^{\gamma(1-\lambda)}, \quad i = 1, 2, \ldots, r; \tag{27}$$

The figure 1 breaks down the entire algorithm step by step, giving you a clear and detailed look at how the process unfolds. In this context, $\widehat{R}$ represents the label of the ranked alternatives, and $\lambda \in [0, 1]$ signifies the coefficient degree associated with the criterion type. The figure breaks down the entire algorithm step by step, giving you a clear and detailed look at how the process unfolds.

IV. APPLICATIONS OF THE PROPOSED FRAMEWORK

In the ever-changing world of sports event management, the decision to pick the perfect host city for a global sports event has become quite a sophisticated process. This case study really dives into the complexities of a major global sports event, highlighting that choosing the host city is not as simple as it used to be. It is a big deal, not just for the success of the event but also for how the participants experience it and the lasting impact on the chosen host city. At the core of this story are the decision-makers, regular folks dealing with a challenging task that requires a departure from the usual ways of handling sports events. This perspective turns the event from a mere series of games into an immersive experience that fits with what people care about nowadays things like cultural values and being environmentally aware. As we get into the nitty-gritty of picking a city, the story unfolds, showing the journey decision-makers go on. The intricate challenge of selecting an best host city for a global sports event extends beyond routine logistical considerations. It requires a strategic assessment and ranking of alternative cities, considering a tapestry of uncertainties and qualitative nuances inherent in city selection. The criteria for evaluation, ranging from accessibility and facilities to community engagement, weather conditions, economic viability, safety and security, cultural fit, and environmental impact, reflect a contemporary shift in sports event management philosophy. The five alternative cities, each with its unique strengths and criteria, exemplify the diverse considerations that decision-makers must weigh. As sports events continue to evolve as integral components of societal dynamics, the case study serves as a compass, guiding decision-makers through the complexities to make informed, strategic choices that resonate with the evolving landscape of sports events on a global scale. It introduces five alternative cities, labeled A to E, each with its own vibe. City A might have great infrastructure and a lively sports culture, while City B stands out for its economic strength and a community that really supports sports. These cities are not just names on a list; they represent real options, reflecting the nuanced factors decision-makers need to think about in the complex world of city selection.

A. DEFINITION OF ALTERNATIVES

1) *City A* (A_{Δ})*:* The vibrant urban experience of City A is enhanced by its sports culture, which combines strong infrastructure with inclusively. Here, athletic events are not only staged; they are enthusiastically welcomed and woven into the rich tapestry of city life.
2) *City B* (A_{Θ})*:* City B intertwines economic viability with unwavering community support for sports, showcasing vibrant economic strength through global sports events while prioritizing safety and engagement for an enriched sports experience.
3) *City C* (A_{Λ})*:* City C blends heritage, modern sports, and green ethos, fostering inclusive sports with eco-focus. Global events embody holistic values of culture and environment.
4) *City D*(A_{Ξ})*:* Fantastic weather all year round, a safe environment, and a booming economy. Bringing together developed infrastructure and robust economies to elevate the worldwide spectator experience.
5) *City E*(A_{Π})*:* City E champions eco-friendly urban planning, serving as both a host and defender of sustainability. Its dedication to environmental stewardship is exemplified through global sporting events, showcasing its progressive ideology.

B. DEFINITION OF CRITERIA

Accessibility (C_{Δ})*:* Accessibility in the context of selecting a host city for a global sports event extends beyond physical transportation infrastructure. It encompasses the reliability, affordability, and inclusivity of the entire transportation network, aiming to ensure a seamless and equitable travel experience for athletes, spectators, and stakeholders. This criterion acknowledges that the journey to the event is as crucial as the event itself, contributing to the overall success and inclusivity of the sports experience.

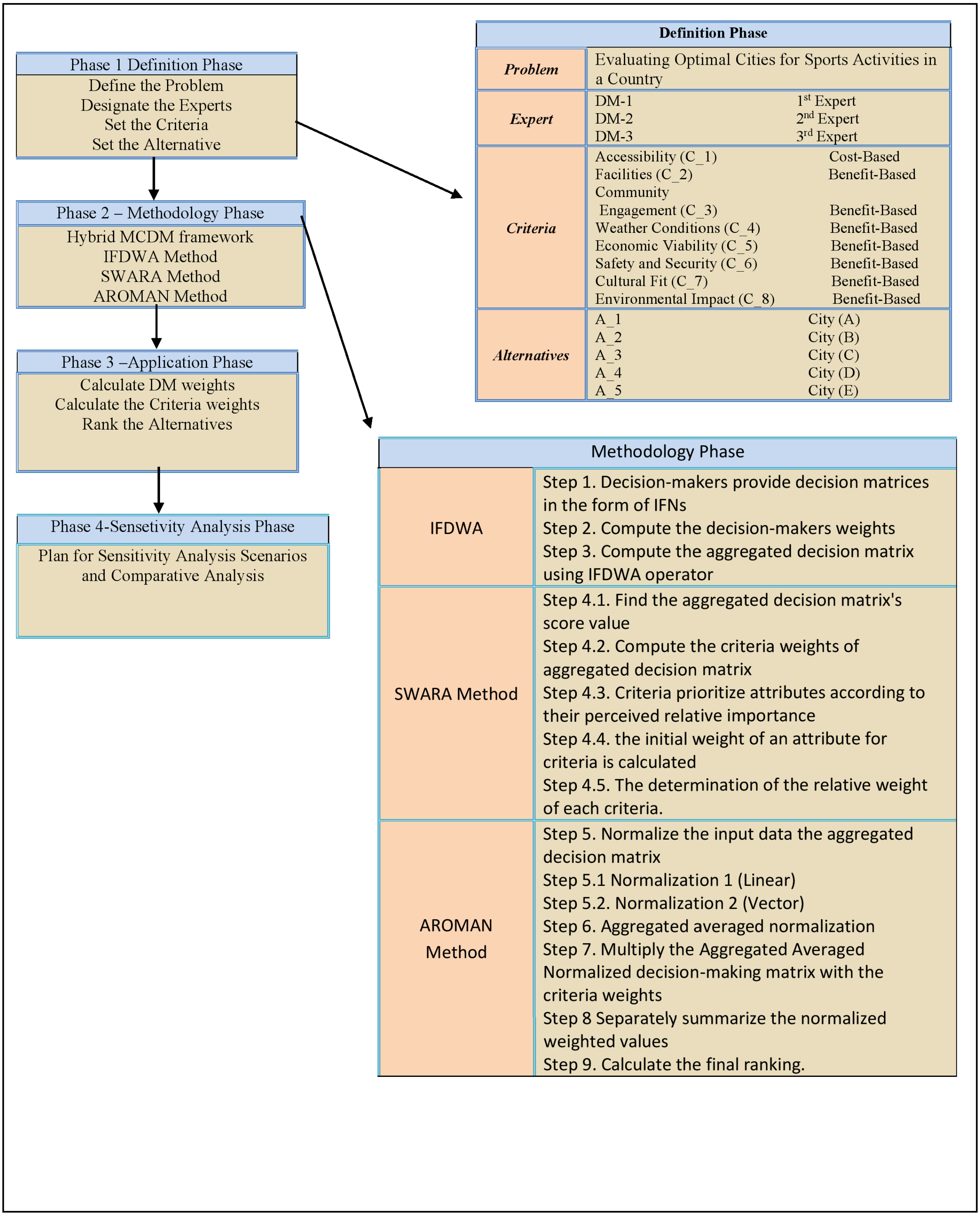

FIGURE 1. **The entire algorithm step by step process.**

Facilities (C_{Θ})*:* The assessment of sports facilities goes beyond a mere inventory check. This criterion delves into the qualitative aspects, evaluating the adaptability and technological advancements of facilities. The objective is to provide an inclusive environment that caters to a spectrum of sports activities, fostering an atmosphere of excellence. It recognizes that the quality and adaptability of facilities significantly contribute to the overall success and prestige of the sports event.

Community Engagement (C_Λ)*:* Community support for sports activities is a dynamic facet that requires a nuanced evaluation. This criterion delves into the qualitative aspects of engagement, scrutinizing not just the numbers but the depth of participation, local enthusiasm, and the extent to which sports are ingrained in the city's social fabric. It acknowledges that a supportive and engaged community not only enhances the overall atmosphere of the event but also ensures its long-term success by fostering a sustainable sports culture.

Weather Conditions (C_Ξ)*:* Analyzing climatic conditions encompasses more than suitability for sports. It involves a comprehensive study of climate patterns, potential impact on sports scheduling, and proactive measures in place to mitigate weather-related challenges. The objective is to ensure a predictable and favorable environment for athletes and spectators, acknowledging that weather can profoundly impact the scheduling and success of sports events.

Economic Viability (C_Π)*:* Evaluating economic factors necessitates a holistic examination. This criterion delves into a city's capacity to create a sustainable economic ecosystem around sports. Beyond immediate financial contributions, it explores the city's ability to attract investments, generate revenue, and foster entrepreneurship within the sports industry. This recognizes that the economic health of the host city is intricately linked to the overall success and legacy of the sports event.

Safety and Security (C_Σ)*:* Ensuring the safety of athletes and spectators requires a comprehensive approach. This criterion assesses not only the crime rates and emergency response capabilities but also the city's commitment to creating a secure and welcoming environment. It focuses on proactive measures that contribute to the overall safety of the sports community, acknowledging that a secure environment is fundamental for the success and reputation of the event.

Cultural Fit (C_Υ)*:* The integration of sports culture with the overall cultural atmosphere is a delicate balance. This criterion examines not just the coexistence but the synergy between sports and culture, ensuring that sports events resonate with local traditions, values, and contribute positively to the cultural identity of the city. It emphasizes that the harmonious blending of sports with cultural elements enhances the overall experience for participants and spectators.

Environmental Impact (C_Φ)*:* Environmental sustainability in sports activities goes beyond token gestures. This criterion evaluates the city's commitment to eco-friendly practices, waste management, and overall environmental consciousness in sports development. It aims to align sports activities with broader sustainability goals, contributing to a greener and healthier community. This criterion underscores the importance of integrating sports events with responsible environmental practices for a positive and lasting impact.

TABLE 4. **DM's evaluation table with 5 alternatives and 8 criteria.**

DMs	Alternatives	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
DM_1	A_1	E	S	U	U	A	AD	P	AD
	A_2	M	S	U	M	AD	A	P	AD
	A_3	AD	P	M	G	E	A	G	U
	A_4	A	S	P	A	AD	M	G	AD
	A_5	E	A	AD	P	G	U	S	U
DM_2	A_1	P	A	AD	E	M	U	S	U
	A_2	S	AD	P	G	M	A	E	U
	A_3	G	M	S	AD	P	U	A	U
	A_4	A	AD	U	M	E	P	S	U
	A_5	P	G	U	S	A	E	M	E
DM_3	A_1	AD	P	U	A	S	E	M	P
	A_2	S	AD	A	P	M	G	P	U
	A_3	G	P	U	M	S	A	AD	M
	A_4	A	M	S	AD	G	E	P	U
	A_5	U	S	A	E	AD	M	U	P

Step 1: Experts utilize the IFNs dataset, incorporating linguistic terms from Table 2 for each alternative A_i where $i = 1, 2, \ldots, r$, taking into account various criteria C_j, where $j = 1, 2, \ldots, s$, as detailed in Table 4.

Step 2: Establish the weights of decision-makers (DMs) by employing the scoring function specified in Equation (2). Subsequently, apply the obtained scores in Equation (16) and present the resulting values in Table 5.

Step 3: Calculate the aggregated decision matrix $M = \left[M_{ij}\right]_{r \times s}$ using Equation (17), and display the results in Table 6.

Step 4.1: The aggregated decision matrix's score value using Equation (2) is given as shown in the equation at the bottom of the next page.

Step 4.2: Compute the criteria weights of the aggregated decision matrix by utilizing the scoring function outlined in Equation (2), and subsequently, incorporate these scores into the specified Equation (18). As shown in the equation at the bottom of the next page.

Step 4.3: The calculation of the criteria coefficient D for each criteria is determined using Equation (19). As shown in the equation at the bottom of the next page.

Step 4.4: Weight of each criteria is calculated using Equation (20). As shown in the equation at the bottom of the next page.

Step 4.5 The determination of the relative weight of each criteria is carried out by applying Equation (21). As shown in the equation at the bottom of the next page. **Step 5:**
Step 5.1: Normalization 1 (**Linear**) utilizing Equation (22). As shown in the equation at the bottom of the next page.

Step 5.2: Normalization 2 (**Vector**) utilizing Equation (23). As shown in the equation at the bottom of the next page.

Step 6: In the aggregated averaged normalization process, we apply the Equation (24), as depicted in Table 7. *Step 7:* Multiply the aggregated averaged normalized decision-making matrix by the criteria weights to derive

TABLE 5. Decision-makers weight.

	Profession	Role	Expertise	Weight
DM_1	Sports Event Manager	Planner	Coordinator, Evaluator, Collaborator	
	⟨0.90, 0.05⟩	⟨0.85, 0.10⟩	⟨0.80, 0.15⟩	0.3913
DM_2	Urban Planner	Designer	Assessor, Analyst, Developer	
	⟨0.85, 0.10⟩	⟨0.80, 0.15⟩	⟨0.65, 0.30⟩	0.3391
DM_3	Environmental Specialist	Advisor	Evaluator, Advisor, Sustainability Expert	
	⟨0.65, 0.30⟩	⟨0.60, 0.35⟩	⟨0.45, 0.50⟩	0.2696

a weighted decision-making matrix, as per Equation (25) shown in Table 8.

Step 8,9: Express the normalized weighted values distinctly for the criteria type min(ω_i) and the max type (Ω_i) by using Equation (26). Determine the final ranking of alternatives by using Equation (27) in Table 9.

C. SENSITIVITY ANALYSIS

The sensitivity analysis of decision outcomes in Table 10 unveils a consistent ranking of alternatives, denoted as A_Δ to A_Π, as the parameter λ fluctuates from 0.1 to 0.8. The graphical representation in Figure 2 and Table 10 illustrates the nuanced impact of different λ values on the decision-making

$$\text{Score} = \begin{bmatrix} 0.6344 & 0.1090 & -0.0347 & 0.4458 & 0.7257 & 0.7574 & 0.2838 & 0.0765 \\ 0.7341 & 0.5611 & 0.3470 & 0.0897 & 0.2601 & 0.6332 & 0.2474 & -0.0319 \\ 0.6458 & 0.0853 & -0.0120 & 0.2769 & 0.7861 & 0.3429 & 0.5487 & 0.2396 \\ 0.3500 & 0.2861 & 0.7264 & 0.5374 & 0.7019 & 0.7597 & 0.1298 & -0.0319 \\ 0.1700 & 0.7326 & 0.3489 & 0.7720 & 0.5487 & 0.3643 & -0.0074 & 0.2158 \end{bmatrix}$$

$$\text{initial weights} = \begin{pmatrix} 0.1650 & 0.1155 & 0.0896 & 0.1382 & 0.1968 & 0.1861 & 0.0783 & 0.0305 \end{pmatrix}$$

$$D = \begin{bmatrix} 1.0000 & 1.1155 & 1.0896 & 1.1382 & 1.1968 & 1.1861 & 1.0783 & 1.0305 \end{bmatrix}$$

$$\begin{bmatrix} 1.0000 & 0.8965 & 0.8227 & 0.7228 & 0.6040 & 0.5092 & 0.4722 & 0.4583 \end{bmatrix}$$

$$\text{Weights} = \begin{bmatrix} 0.1823 & 0.1634 & 0.1500 & 0.1318 & 0.1101 & 0.0928 & 0.0861 & 0.0835 \end{bmatrix}$$

$$T(i,j) = \begin{bmatrix} 0.8447 & 0.1814 & 0 & 0.6066 & 0.9600 & 1 & 0.4021 & 0.1404 \\ 1 & 0.7742 & 0.4946 & 0.1587 & 0.3812 & 0.8683 & 0.3646 & 0 \\ 0.8242 & 0.1219 & 0 & 0.3620 & 1 & 0.4447 & 0.7025 & 0.3152 \\ 0.4824 & 0.4017 & 0.9579 & 0.7192 & 0.9270 & 1 & 0.2043 & 0 \\ 0.2276 & 0.9494 & 0.4571 & 1 & 0.7135 & 0.4769 & 0 & 0.2864 \end{bmatrix}$$

$$F(i,j) = \begin{bmatrix} 0.2548 & 0.7805 & 0.9160 & 0.7702 & 0.1759 & 0.6074 & 0.2691 & 0.5762 \\ 0.2240 & 0.6753 & 0.0012 & 0.3225 & 0.7218 & 0.1917 & 0.7655 & 0.6834 \\ 0.6678 & 0.0067 & 0.4624 & 0.7847 & 0.4735 & 0.7384 & 0.1887 & 0.5466 \\ 0.8444 & 0.6022 & 0.4243 & 0.4714 & 0.1527 & 0.2428 & 0.2875 & 0.4257 \\ 0.3445 & 0.3868 & 0.4609 & 0.0358 & 0.3411 & 0.9174 & 0.0911 & 0.6444 \end{bmatrix}$$

TABLE 6. Aggregated decision matrix.

C_i	A_1	A_2	A_3	A_4	A_5
C_1	⟨0.7867, 0.1523⟩	⟨0.8500, 0.1159⟩	⟨0.800, 0.1542⟩	⟨0.6500, 0.3000⟩	⟨0.5307, 0.3607⟩
C_2	⟨0.5000, 0.3910⟩	⟨0.7500, 0.1889⟩	⟨0.5000, 0.4147⟩	⟨0.6000, 0.3139⟩	⟨0.8500, 0.1174⟩
C_3	⟨0.4500, 0.4847⟩	⟨0.6500, 0.3030⟩	⟨0.4500, 0.4620⟩	⟨0.8500, 0.1236⟩	⟨0.6500, 0.3011⟩
C_4	⟨0.6950, 0.2492⟩	⟨0.5000, 0.4103⟩	⟨0.6000, 0.3231⟩	⟨0.7500, 0.2126⟩	⟨0.8655, 0.0935⟩
C_5	⟨0.8500, 0.1243⟩	⟨0.8000, 0.3399⟩	⟨0.6500, 0.0859⟩	⟨0.0.8257, 0.1238⟩	⟨0.7500, 0.2013⟩
C_6	⟨0.8655, 0.1081⟩	⟨0.8000, 0.1668⟩	⟨0.6500, 0.3071⟩	⟨0.8655, 0.1058⟩	⟨0.6514, 0.2871⟩
C_7	⟨0.6000, 0.3162⟩	⟨0.5642, 0.3169⟩	⟨0.7500, 0.2013⟩	⟨0.5000, 0.3702⟩	⟨0.4500, 0.4574⟩
C_8	⟨0.5000, 0.4235⟩	⟨0.4500, 0.4819⟩	⟨0.6000, 0.3604⟩	⟨0.4500, 0.4819⟩	⟨0.5642, 0.3484⟩

TABLE 7. Aggregated averaged normalization.

Alternative	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.3403	0.0733	-0.0099	0.2548	0.3681	0.3911	0.2052	0.0923
A_2	0.3994	0.3373	0.2224	0.0604	0.1412	0.3350	0.1824	-0.0238
A_3	0.3374	0.0523	-0.0034	0.1545	0.3888	0.1750	0.3780	0.2579
A_4	0.1918	0.1737	0.4463	0.3041	0.3556	0.3915	0.0989	-0.0238
A_5	0.0915	0.4250	0.2136	0.4286	0.2752	0.1871	-0.0027	0.2329

TABLE 8. Weighted aggregated averaged normalization.

Alternative	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.0620	0.0120	-0.0015	0.0336	0.0405	0.0363	0.0177	0.0077
A_2	0.0728	0.0551	0.0334	0.0080	0.0155	0.0311	0.0157	-0.0020
A_3	0.0615	0.0086	-0.0005	0.0204	0.0428	0.0162	0.0325	0.0215
A_4	0.0350	0.0284	0.0669	0.0401	0.0392	0.0363	0.0085	-0.0020
A_5	0.0167	0.0695	0.0320	0.0565	0.0303	0.0174	-0.0002	0.0195

TABLE 9. Final ranking of alterntives.

Alternatives	sum of all min criteria	sum of all max criteria	final ranking of alternatives
A_1	0.1220	0.4131	0.5351
A_2	0.1768	0.2182	0.3950
A_3	0.2615	0.4254	0.6869
A_4	0.0950	-0.0320	0.0630
A_5	0.0167	0.0225	0.0790

process within the IF framework, emphasizing the model's adaptability. Overall, these findings underscore the reliability and versatility of the decision-making model across a range of λ values.

This ranking information provides decision-makers with an understanding of how the alternatives respond to changes in the importance assigned to decision criteria. It highlights the consistent and robust performance of A_3 across different decision scenarios, offering valuable guidance for selecting the most suitable alternative based on specific decision-making priorities.

D. COMPARATIVE ANALYSIS

In our extensive comparative research, we systematically examined the feasibility and effectiveness of decision-making procedures within IFNs. The meticulous scrutiny of each element, combined with rigorous validation and robustness checks throughout the study, significantly enhances the reliability and consistency of our results. These methodological aspects not only contribute to the comprehensiveness of our research but also serve as the bedrock for our conclusive insights. The pivotal findings are succinctly presented in Table 11, offering a compelling overview of our investigation. The nuanced insights derived from our thorough analysis enable a comprehensive understanding of both the benefits and drawbacks associated with various decision-making procedures within IFNs. In essence, our research provides decision-makers with reliable insights, strategically guiding the integration of IFs and enriching our collective comprehension of decision-making within the IF framework.

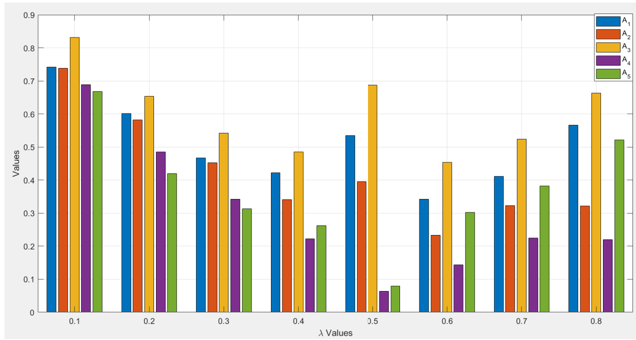

FIGURE 2. Visualizing Variations with Changing Parameter λ.

TABLE 10. The influence of the parameter λ on the outcome of the decision.

λ	A_1	A_2	A_3	A_4	A_5	Ranking
λ = 0.1	0.7423	0.7380	0.8321	0.6887	0.6681	$A_3 > A_1 > A_2 > A_4 > A_5$
λ = 0.2	0.6020	0.5821	0.6531	0.4853	0.4193	$A_3 > A_1 > A_2 > A_4 > A_5$
λ = 0.3	0.4671	0.4521	0.5423	0.3421	0.3134	$A_3 > A_1 > A_2 > A_4 > A_5$
λ = 0.4	0.4218	0.3411	0.4850	0.2219	0.2618	$A_3 > A_1 > A_2 > A_5 > A_4$
λ = 0.5	0.5351	0.3950	0.6869	0.0630	0.0790	$A_3 > A_1 > A_2 > A_4 > A_5$
λ = 0.6	0.3421	0.2335	0.4542	0.1433	0.3022	$A_3 > A_1 > A_5 > A_2 > A_4$
λ = 0.7	0.4111	0.3228	0.5234	0.2249	0.3827	$A_3 > A_1 > A_5 > A_2 > A_4$
λ = 0.8	0.5661	0.3212	0.6626	0.2194	0.5214	$A_3 > A_1 > A_5 > A_2 > A_4$

TABLE 11. Comparison of newly proposed with already existing when λ = 0.5.

Authors	Methodology	Ranking of alternatives	best alternative
Rouyendegh [69]	ELECTRE model	$A_3 > A_1 > A_2 > A_4 > A_5$	A_3
Stanujkić and Karabašević [70]	WASPAS method	$A_3 > A_2 > A_1 > A_4 > A_5$	A_3
Kumari and Mishra [71]	COPRAS method	$A_3 > A_1 > A_5 > A_4 > A_2$	A_3
Yazdi [72]	TOPSIS method	$A_3 > A_1 > A_2 > A_5 > A_4$	A_3
Govindan et al. [73]	DEMATEL method	$A_3 > A_1 > A_5 > A_2 > A_4$	A_3
Roy and Garai [74]	delphi method	$A_3 > A_1 > A_4 > A_2 > A_5$	A_3
Proposed	IF-SWARA-AROMAN	$A_3 > A_1 > A_2 > A_4 > A_5$	A_3

In contrast to alternative methodologies, IF-SWARA-AROMAN consistently demonstrates superior performance in evaluating and ranking predictive maintenance models within the manufacturing sector. It outshines well-established methods like delphi method, TOPSIS,WASPAS, COPRAS method, ELECTRE model and DEMATEL across various criteria in a comprehensive comparison. Notably, A_Λ consistently emerges as the top-rated alternative, emphasizing the effectiveness of IF-SWARA-AROMAN in guiding decision-making for predictive maintenance model selection. This underscores its practicality and reliability, establishing it as a superior approach in this domain.

E. DISCUSSION

Our narrative unfolds organically, much like a compelling story, beginning with the recognition of a distinct research gap in the realm of selecting cities for hosting sports events.

It becomes evident that existing studies often overlook crucial qualitative dimensions in this process. To address this void, we introduce a comprehensive evaluation framework that extends beyond the mere efficiency of logistics, considering the intricate interplay of social, economic, cultural, and environmental factors. As we immerse ourselves in the case study, we take the time to meticulously unpack the distinct characteristics of each alternative city, shedding light on the unique criteria that make them suitable for hosting sports events. The narrative gains depth as we introduce the IF-SWARA-AROMAN methodology, positioning it as a reliable guide in our analytical journey. This method does not just streamline the decision-making process; it empowers decision-makers to thoroughly assess the strengths and weaknesses of each city, acknowledging the complexity of the factors at play. The crescendo of our discussion reveals City C as the standout choice for hosting sports events. it is crucial to emphasize that this decision transcends numerical metrics, taking into account the qualitative aspects that profoundly impact the success and resonance of a sports event. Our discussion aims to underscore that choosing the right host city is not a mere logistical decision; it has a far-reaching impact on the sports community and the chosen city itself. In essence, our endeavor extends beyond addressing a research gap; it aspires to set a new standard in sports event management. We aim to spotlight the holistic impact of a well-chosen host city, propelling the discourse towards a more nuanced and comprehensive understanding of the dynamics involved in this decision-making process.

F. LIMITATIONS

In the exploration and application of the IF-SWARA-AROMAN methodology for selecting best host cities in sports events, it is crucial to acknowledge certain limitations that require thoughtful consideration.

- *Data Reliability:* The methodology heavily relies on the availability and accuracy of data for diverse criteria, potentially compromising decision-making in cases where comprehensive and up-to-date information is lacking. This limitation becomes particularly challenging when certain criteria demand real-time or context-specific data that might be difficult to obtain.
- *Subjectivity in Qualitative Assessments:* The inclusion of qualitative aspects, especially in criteria like cultural fit and community engagement, introduces interpretation bias. This may lead to variations in the final decision, impacting the consistency of decision-making across different evaluators.
- *Comprehensive Coverage of Criteria:* Assuming that the identified criteria adequately cover all relevant aspects influencing host city selection might overlook emerging factors or fail to capture subtle nuances. As the sports landscape evolves, periodic reassessment of the criteria set may be necessary to ensure its continued relevance and comprehensiveness.
- *Uniform Significance of Criteria:* The methodology presupposes that criteria hold the same level of significance across different sports events and contexts. However, the unique nature of each event and location may require adjusting the weightage of certain criteria for specific circumstances. A one-size-fits-all approach might not fully account for the dynamic nature of sports events.
- *Adaptability to Changes Over Time:* Challenges may arise in accommodating dynamic changes over time, as the methodology may not adequately address factors such as evolving economic conditions, shifting cultural landscapes, or sudden environmental developments. Future iterations of the methodology should incorporate mechanisms for continuous adaptation to ensure its ongoing relevance and effectiveness.

V. CONCLUSION

The application of the IF-SWARA-AROMAN methodology to assess the suitability of alternative cities for hosting sports events has culminated in a compelling conclusion. Among the contenders, City C emerges as the most fitting choice, underlining the robustness and efficacy of the applied evaluation framework. The in-depth examination of accessibility, facilities, community engagement, weather conditions, economic viability, safety and security, cultural fit, and environmental impact through the IF-SWARA-AROMAN lens has provided a nuanced understanding of each city's strengths and weaknesses. City C, with its unique blend of preserving rich cultural heritage, embracing advanced sports facilities, and a steadfast commitment to environmental sustainability, stands out as the best host. This result not only validates the practical utility of the IF-SWARA-AROMAN methodology but also underscores the significance of considering a diverse array of factors in the decision-making process for sports event management. The implications of this conclusion extend beyond the immediate context, emphasizing the need for a holistic and strategic approach to city selection that aligns seamlessly with broader socio-economic, cultural, and environmental considerations, ensuring a positive and enduring impact on the sports community and the hosting city itself.

Looking ahead, future research in sports event management could focus on refining and expanding the IF-SWARA-AROMAN methodology, adapting it to diverse contexts and scales, and exploring the integration of emerging technologies like data analytics and artificial intelligence. Additionally, there is potential for investigating the long-term impacts of hosting sports events on cities, considering economic, social, and environmental outcomes. By incorporating diverse cultural contexts and geographic locations into comparative analyses of various sporting events and their host cities, a more comprehensive understanding of the determinants of successful event hosting could be attained. The establishment of comprehensive frameworks through interdisciplinary collaboration involving stakeholders from the sports management, urban planning, and sustainability sectors may result in the identification of appropriate host cities in a more informed and comprehensive manner.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

COMPETING INTEREST

The authors declare that they have no competing interest.

AUTHORS CONTRIBUTIONS

The authors contributed to each part of this paper equally. The authors read and approved the final manuscript.

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