A Neutrosophic Superiority and Inferiority Ranking-Based Model for Resource Allocation Efficiency in University Sports Management

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Abstract: The evaluation of resource allocation efficiency in university recreational sports aims to analyze and assess the effectiveness of how universities allocate facilities, equipment, and personnel for recreational sports. By collecting relevant data and applying scientific methods, it evaluates the usage and impact of resources to optimize allocation and enhance student participation and satisfaction. This not only helps improve campus sports culture but also promotes students' physical and mental health and overall development. The resource allocation efficiency evaluation in university recreational sports is a MAGDM problem. Recently, the Superiority and Inferiority Ranking (SIR) method has been employed to cope with MAGDM issues. The single-valued neutrosophic sets (SVNSs) are used as a tool for characterizing uncertain information during the resource allocation efficiency evaluation in university recreational sports. In this paper, the single-valued neutrosophic number SIR (SVNN-SIR) method is built to solve the MAGDM under SVNSs. In the end, a numerical case study for resource allocation efficiency evaluation in university recreational sports is given to validate the proposed method.

Keywords: Multiple attribute group decision making (MAGDM); single-valued neutrosophic sets (SVNSs); SIR; resource allocation efficiency evaluation

1. Introduction and Background

As Chinese society enters a stage of general well-being, the abundance of material resources, the improvement in quality of life, and societal progress have brought about significant changes in people's lifestyles and attitudes toward sports. Different groups, influenced by various environmental, social, and personal factors, choose different leisure activities during their free time. University students, in particular, can achieve both mental and physical relaxation, rest, and enjoyment by engaging in leisure sports during their leisure time. From an economic perspective, the rational allocation of resources is the foundation and prerequisite for the effective functioning of the economy, and the development of leisure sports also depends on the optimal allocation of leisure sports resources. Therefore, understanding the current state of leisure sports resources in universities, and promoting the rational development, optimal allocation, and full utilization of these resources, has become a key issue in determining whether the reform of leisure sports in universities can meet the needs of socialist construction and promote their healthy development. In 2008, Zhou and Deng [1]conducted a study using literature analysis, surveys, and theoretical methods to examine the state of leisure sports resource allocation in universities and focused on how to evaluate the efficiency of these resources and proposed a set of evaluation indicators. This study laid the theoretical foundation for future improvements in resource allocation efficiency. In the same year, Zhou, Tang [2] explored the rational allocation and development of leisure sports resources in universities and emphasized that while existing resources should be used wisely, it is also essential to meet the diverse leisure sports needs of students and faculty. The study highlighted that rational resource allocation is necessary for university sports education to adapt to societal development needs. Subsequently, in 2009, Zhou [3] conducted an in-depth analysis of the current state and causes of leisure sports resource allocation in ordinary universities in Hunan Province. From an economic perspective, he pointed out that optimizing the allocation of leisure sports resources is crucial for their development. The study found that the utilization rate of human resources in universities was low, social resources had not effectively penetrated, and funding was insufficient. Additionally, the lack of high-quality venue management personnel and comprehensive information resource platforms were also limiting factors. Finally, in 2020, Zheng, Wu [4] conducted a survey on the allocation of leisure sports resources in some ordinary universities in Sichuan Province. Using literature analysis, expert interviews, and questionnaires, they proposed strategies to improve current resource allocation. They suggested that universities should focus on cultivating high-quality sports talents, enhance the social cooperation of sports venues, and broaden funding sources. This study offered new insights for the operation and management of modern university sports venues.

MAGDM is a collective decision-making process involving multiple decision-makers evaluating and selecting options based on various attributes [5-8]. Each decision-maker rates the attributes of potential options according to their preferences and judgments. These evaluations are then integrated to form a comprehensive decision outcome. The process often employs mathematical models and methods, such as weighted averaging, analytic hierarchy process, or fuzzy comprehensive evaluation, to ensure objectivity and rationality[9, 10]. This approach is widely used in fields like management, finance, and engineering, helping organizations make scientifically sound choices in complex environments, balancing the opinions of multiple stakeholders, and improving decision quality and satisfaction [11-14]. Gomes and Lima [15] built the TODIM for MADM issues under risk. The resource allocation efficiency evaluation in university recreational sports is classical MAGDM.

Recently, the SIR method [16] has been used to cope with MAGDM issues. The SVNSs [17-25] are used as a tool for characterizing uncertain information during the resource allocation efficiency evaluation in university recreational sports. The literature review highlights key studies on resource allocation in university sports. Zhou and Deng (2008) conducted foundational research, proposing efficiency evaluation indicators. Subsequent work by Zhou et al. (2020) focused on strategies to enhance collaboration between universities and external sports organizations. Traditional multi-attribute decision-making methods like TODIM and EDAS have been applied in this domain but often fall short in addressing uncertainty. This paper distinguishes itself by introducing a model based on neutrosophic sets, offering a more accurate and holistic evaluation framework. With societal progress and increasing emphasis on physical activity, recreational sports in universities play a pivotal role in enhancing students' physical and mental well-being. However, allocating resources for these activities faces significant challenges, including inefficiency and inequitable distribution. This paper aims to develop a robust framework for evaluating resource allocation efficiency using SVNSs. By addressing uncertainties and complexities in decision-making, this work fills a critical gap in the literature.

The structure of this paper is listed below. In Section 2, the SVNSs are introduced. In Section 3, the SVNN-SIR method is designed under SVNSs. Section 4 gives an illustrative case for resource allocation efficiency evaluation in university recreational sports and some comparative analysis. Some remarks are given in Section 5.

2. Preliminaries and Definitions

This section presents key definitions related to Single-Valued Neutrosophic Sets (SVNSs), as outlined in references [26–28].

Definition 1

The neutrosophic set can be defined as:

$$O = (x, T_o(x), I_o(x), F_o(x), x \in X) \quad (1)$$

$$0- \leq \sup T_o(x) + \sup I_o(x) + \sup F_o(x) \leq 3+ \quad (2)$$

Definition 2

Let $O_1 = T_{o_1}(x), I_{o_1}(x), F_{o_1}(x)$ and $O_2 = T_{o_2}(x), I_{o_2}(x), F_{o_2}(x)$ be two SVNNs and their operations can be defined as:

$$O_1 \oplus O_2 = \left\{ \begin{pmatrix} T_{o_1}(x) + T_{o_2}(x) - T_{o_1}(x)T_{o_2}(x), \\ I_{o_1}(x)I_{o_2}(x), \\ F_{o_1}(x)F_{o_2}(x) \end{pmatrix} \right\} \quad (3)$$

$$O_1 \otimes O_2 = \left\{ \begin{matrix} T_{o_1}(x)T_{o_2}(x), \\ I_{o_1}(x) + I_{o_2}(x) - I_{o_1}(x)I_{o_2}(x), \\ F_{o_1}(x) + F_{o_2}(x) - F_{o_1}(x)F_{o_2}(x) \end{matrix} \right\} \quad (4)$$

$$\varphi O_1 = \left(1 - \left(1 - T_{o_1}(x)\right)^{\varphi}, \left(I_{o_1}(x)\right)^{\varphi}, \left(I_{o_1}(x)\right)^{\varphi}\right) \quad (5)$$

$$O_1^{\varphi} = \left(\left(T_{o_1}(x)\right)^{\varphi}, 1 - \left(1 - I_{o_1}(x)\right)^{\varphi}, 1 - \left(1 - F_{o_1}(x)\right)^{\varphi}\right) \quad (6)$$

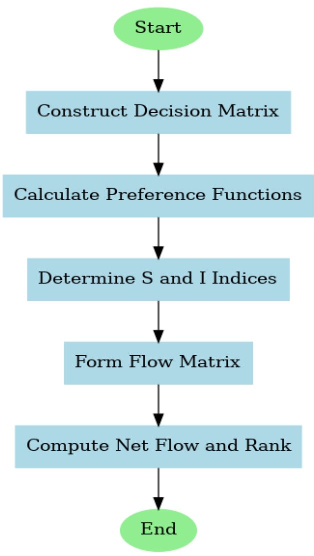
Definition 3.

The score function can be defined as:

$$S(O) = \frac{2 + T_O(x) - I_O(x) - F_O(x)}{3} \quad (7)$$

3. Methodology

The flowchart of the proposed Methodology outlines the sequential steps of the methodology, starting from constructing the decision matrix to the final step of ranking alternatives. Each box represents a critical process, and arrows indicate the logical flow between steps as shown in Figure



1.

Figure 1. The Flowchart of Methodology

The Single-Valued Neutrosophic Numbers-based Superiority and Inferiority Ranking (SVNN-SIR) method involves the following steps:

Step 1. The decision matrix is formed.

The experts and decision-makers created the decision matrix by using the SVNN. Then we applied the score function to obtain a single number. Then we combine the opinions of experts into a single matrix.

$$Y = \begin{pmatrix} f_1(A_1) & \cdots & f_n(A_1) \\ \vdots & \ddots & \vdots \\ f_1(A_m) & \cdots & f_1(A_m) \end{pmatrix}_{m\times n} ; i = 1, \dots, m; j = 1, \dots, n \tag{8}$$

Where A refers to the alternatives and $C = \{f_1(0), \dots, f_n(0)\}$ is a group of assessment criteria for the alternatives.

Step 2. Comparing the alternatives.

The alternatives are compared in the decision matrix depending on the criteria and a function such as $t = C(A_1) - C(A_2)$

(9)

$$T = \begin{bmatrix} C_1(A_1) & \cdots & C_n(A_1) \\ \vdots & \ddots & \vdots \\ C_1(A_m) & \cdots & C_n(A_m) \end{bmatrix} \tag{10}$$

$$P(A_1, A_2) = f\big(C(A_1) - C(A_2)\big) = f(t) \tag{11}$$

Step 3. Determine the values of the preference function.

The values of the preference function are computed based on the usual criterion. Where the usual criteria can be defined as:

$$f(t) = \begin{cases} 0, & t \le 0 \\ 1, & t > 0 \end{cases} \tag{12}$$

Step 4. Determine the S and I index

$$S_j(A_i) = \sum_{i=1}^{m} P_j(A_i, A_{i'}) = \sum_{i=1}^{m} f_j\left(C_j(A_{i'}) - C_j(A_i)\right) \tag{13}$$

$$I_j(A_i) = \sum_{i=1}^{m} P_j(A_i, A_{i'}) = \sum_{i=1}^{m} f_j\left(C_j(A_i) - C_j(A_{i'})\right) \tag{14}$$

Then their matrices are defined as:

$$S = \begin{bmatrix} S_1(A_1) & \dots & S_j(A_1) & \dots & S_n(A_1) \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ S_1(A_i) & \cdots & S_j(A_i) & \dots & S_n(A_i) \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ S_1(A_m) & \cdots & S_j(A_m) & \dots & S_n(A_m) \end{bmatrix}_{m\times n} \tag{15}$$

$$I = \begin{bmatrix} I_1(A_1) & \dots & I_j(A_1) & \dots & I_n(A_1) \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ I_1(A_i) & \cdots & I_j(A_i) & \dots & I_n(A_i) \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ I_1(A_m) & \cdots & I_j(A_m) & \dots & I_n(A_m) \end{bmatrix}_{m\times n} \tag{16}$$

Step 5. Form the flow matrix

The flow matrix is formed based on the S and I matrix:

$$U^+(A_i) = \sum_{j=1}^{n} S_j(A_i) \times w_j \tag{17}$$

$$U^-(A_i) = \sum_{j=1}^{n} I_j(A_i) \times w_j \tag{18}$$

Step 6. Compute the n-flow and r-flow

$$n - flow = U^+(A_i) - U^-(A_i) \tag{19}$$

$$r - flow = \frac{U^+(A_i)}{U^+(A_i) + U^-(A_i)} \tag{20}$$

Step 7. Rank the alternatives. The alternatives are ranked based on the n-flow.

Table 1. The decision matrix.

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
C_1	(0.9,0.2,0.1)	(0.4,0.7,0.6)	(0.5,0.5,0.5)	(0.6,0.5,0.4)	(0.7,0.4,0.3)	(0.8,0.3,0.2)	(0.9,0.2,0.1)	(0.1,0.9,0.8)	(0.2,0.8,0.7)
C_2	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.6,0.5,0.4)	(0.7,0.4,0.3)	(0.8,0.3,0.2)	(0.9,0.2,0.1)	(0.1,0.9,0.8)	(0.2,0.8,0.7)	(0.4,0.7,0.6)
C_3	(0.7,0.4,0.3)	(0.1,0.9,0.8)	(0.5,0.5,0.5)	(0.7,0.4,0.3)	(0.8,0.3,0.2)	(0.9,0.2,0.1)	(0.2,0.8,0.7)	(0.4,0.7,0.6)	(0.5,0.5,0.5)
C_4	(0.6,0.5,0.4)	(0.9,0.2,0.1)	(0.4,0.7,0.6)	(0.6,0.5,0.4)	(0.9,0.2,0.1)	(0.1,0.9,0.8)	(0.4,0.7,0.6)	(0.5,0.5,0.5)	(0.6,0.5,0.4)
C_5	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.6,0.5,0.4)	(0.7,0.4,0.3)
C_6	(0.4,0.7,0.6)	(0.7,0.4,0.3)	(0.1,0.9,0.8)	(0.4,0.7,0.6)	(0.7,0.4,0.3)	(0.4,0.7,0.6)	(0.6,0.5,0.4)	(0.7,0.4,0.3)	(0.8,0.3,0.2)
C_7	(0.2,0.8,0.7)	(0.6,0.5,0.4)	(0.9,0.2,0.1)	(0.2,0.8,0.7)	(0.6,0.5,0.4)	(0.5,0.5,0.5)	(0.7,0.4,0.3)	(0.8,0.3,0.2)	(0.9,0.2,0.1)
C_8	(0.1,0.9,0.8)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.1,0.9,0.8)	(0.5,0.5,0.5)	(0.6,0.5,0.4)	(0.8,0.3,0.2)	(0.9,0.2,0.1)	(0.1,0.9,0.8)
C_9	(0.9,0.2,0.1)	(0.4,0.7,0.6)	(0.7,0.4,0.3)	(0.9,0.2,0.1)	(0.4,0.7,0.6)	(0.7,0.4,0.3)	(0.9,0.2,0.1)	(0.1,0.9,0.8)	(0.2,0.8,0.7)
C_{10}	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.6,0.5,0.4)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.8,0.3,0.2)	(0.1,0.9,0.8)	(0.2,0.8,0.7)	(0.4,0.7,0.6)
C_{11}	(0.7,0.4,0.3)	(0.1,0.9,0.8)	(0.5,0.5,0.5)	(0.7,0.4,0.3)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.2,0.8,0.7)	(0.4,0.7,0.6)	(0.5,0.5,0.5)
C_{12}	(0.6,0.5,0.4)	(0.9,0.2,0.1)	(0.4,0.7,0.6)	(0.6,0.5,0.4)	(0.9,0.2,0.1)	(0.1,0.9,0.8)	(0.4,0.7,0.6)	(0.5,0.5,0.5)	(0.6,0.5,0.4)
C_{13}	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.6,0.5,0.4)	(0.7,0.4,0.3)
C_{14}	(0.4,0.7,0.6)	(0.7,0.4,0.3)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.7,0.4,0.3)	(0.8,0.3,0.2)
C_{15}	(0.2,0.8,0.7)	(0.6,0.5,0.4)	(0.5,0.5,0.5)	(0.4,0.7,0.6)	(0.2,0.8,0.7)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.9,0.2,0.1)
C_{16}	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.5,0.5,0.5)	(0.4,0.7,0.6)	(0.2,0.8,0.7)	(0.1,0.9,0.8)
	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
C_1	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.8,0.3,0.2)	(0.9,0.2,0.1)	(0.1,0.9,0.8)	(0.2,0.8,0.7)
C_2	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.6,0.5,0.4)	(0.7,0.4,0.3)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)
C_3	(0.7,0.4,0.3)	(0.1,0.9,0.8)	(0.5,0.5,0.5)	(0.7,0.4,0.3)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)

C4	(0.6,0.5,0.4)	(0.9,0.2,0.1)	(0.4,0.7,0.6)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.6,0.5,0.4)
C5	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.6,0.5,0.4)	(0.7,0.4,0.3)
C6	(0.4,0.7,0.6)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.6,0.5,0.4)	(0.7,0.4,0.3)	(0.8,0.3,0.2)
C7	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.5,0.5,0.5)	(0.7,0.4,0.3)	(0.8,0.3,0.2)	(0.9,0.2,0.1)
C8	(0.1,0.9,0.8)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.8,0.3,0.2)	(0.9,0.2,0.1)	(0.1,0.9,0.8)
C9	(0.9,0.2,0.1)	(0.4,0.7,0.6)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.1,0.9,0.8)	(0.2,0.8,0.7)
C10	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.6,0.5,0.4)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.4,0.7,0.6)
C11	(0.7,0.4,0.3)	(0.1,0.9,0.8)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.4,0.7,0.6)	(0.5,0.5,0.5)
C12	(0.6,0.5,0.4)	(0.9,0.2,0.1)	(0.4,0.7,0.6)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.6,0.5,0.4)
C13	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)
C14	(0.4,0.7,0.6)	(0.7,0.4,0.3)	(0.1,0.9,0.8)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.8,0.3,0.2)
C15	(0.2,0.8,0.7)	(0.6,0.5,0.4)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.8,0.3,0.2)	(0.9,0.2,0.1)
C16	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.6,0.5,0.4)	(0.2,0.8,0.7)	(0.1,0.9,0.8)
	A1	A2	A3	A4	A5	A6	A7	A8	A9
C1	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.8,0.3,0.2)	(0.9,0.2,0.1)	(0.1,0.9,0.8)	(0.2,0.8,0.7)
C2	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.1,0.9,0.8)	(0.2,0.8,0.7)	(0.4,0.7,0.6)
C3	(0.7,0.4,0.3)	(0.1,0.9,0.8)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.4,0.7,0.6)	(0.5,0.5,0.5)
C4	(0.6,0.5,0.4)	(0.9,0.2,0.1)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.5,0.5,0.5)	(0.6,0.5,0.4)
C5	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.7,0.4,0.3)
C6	(0.4,0.7,0.6)	(0.7,0.4,0.3)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.8,0.3,0.2)
C7	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.7,0.4,0.3)	(0.8,0.3,0.2)	(0.9,0.2,0.1)
C8	(0.1,0.9,0.8)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.9,0.2,0.1)	(0.1,0.9,0.8)
C9	(0.9,0.2,0.1)	(0.4,0.7,0.6)	(0.7,0.4,0.3)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)
C10	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.4,0.7,0.6)
C11	(0.7,0.4,0.3)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.4,0.7,0.6)	(0.5,0.5,0.5)
C12	(0.6,0.5,0.4)	(0.9,0.2,0.1)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.5,0.5,0.5)	(0.6,0.5,0.4)
C13	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.5,0.5,0.5)	(0.6,0.5,0.4)	(0.7,0.4,0.3)
C14	(0.4,0.7,0.6)	(0.7,0.4,0.3)	(0.1,0.9,0.8)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.8,0.3,0.2)
C15	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.8,0.3,0.2)	(0.8,0.3,0.2)	(0.9,0.2,0.1)
C16	(0.1,0.9,0.8)	(0.9,0.2,0.1)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.5,0.5,0.5)	(0.8,0.3,0.2)	(0.2,0.8,0.7)	(0.1,0.9,0.8)

4. Detailed Case Study for Resource Allocation Evaluation and comparative analysis

4.1 Problem Setup

We aim to evaluate nine alternatives (A1–A9) based on sixteen criteria (C1–C16) to determine their efficiency in resource allocation for university recreational sports. This analysis will utilize the SVNN-SIR method and compare it with other methods like SVNN-TODIM, SVNN-CODAS, and SVNN-EDAS.

The criteria and their descriptions are extracted and adapted as:

- *Budget Utilization Efficiency*: Measures how well financial resources are allocated and used to maximize the availability and quality of recreational sports programs.
- *Facility Availability and Accessibility*: Assesses the availability of sports facilities and how easily students and staff can access them, considering location, scheduling, and capacity.
- *Student Participation Rate*: The percentage of students actively engaging in recreational sports, reflecting the effectiveness of resource allocation in meeting student needs.
- *Quality of Sports Equipment*: Evaluates whether equipment provided is modern, safe, and meets the demands of various recreational activities.
- *Staff Qualification and Distribution*: Assesses the qualifications and availability of coaches, trainers, and administrative staff to ensure program quality and safety.
- *Program Diversity*: The variety of recreational sports programs offered, catering to different interests, skill levels, and cultural preferences.
- *Facility Maintenance and Upkeep*: Evaluates the maintenance standards and repair schedules of sports facilities to ensure safety and usability over time.
- *Inclusivity and Accessibility*: Measures how resources are allocated to ensure equal access for all students, including those with disabilities or different cultural backgrounds.
- *Scheduling Efficiency*: Examines how well facilities and programs are scheduled to avoid conflicts and ensure optimal usage.
- *Cost-Effectiveness of Programs*: Assesses whether the programs offered provide good value for money, balancing participation costs and benefits.
- *Marketing and Outreach*: Effectiveness of promotional efforts to inform and attract participants to recreational sports activities.
- *Environmental Sustainability*: The integration of eco-friendly practices in resource allocation, such as energy-efficient facilities and sustainable equipment.
- *Collaboration with External Organizations*: Partnerships with local sports organizations or sponsors to enhance resources and opportunities for students.
- *Technology Integration*: Use of technology for efficient resource management, such as online booking systems, fitness tracking, and virtual coaching.
- *Feedback Mechanisms*: Systems in place to collect and act on feedback from students and staff

to improve resource allocation and program quality.

- *Risk Management and Safety Measures*: Allocation of resources to ensure participant safety, including emergency protocols, staff training, and liability insurance.

Table 2. The first criterion comparing the alternatives.

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
C_1	-0.16667	0	-0.07778	-0.16667	-0.26667	-0.36667	0.366667	0.266667	0.5
C_2	0.355556	0.044444	0.155556	0.211111	-0.15556	0.333333	0.3	0.244444	0.677778
C_3	0.533333	0.166667	-0.03333	0.288889	-0.07778	0.077778	0.2	0.144444	0.666667
C_4	-0.3	0.155556	0.077778	-0.08889	0.1	-0.03333	0.044444	0	0.566667
C_5	-0.26667	0.3	-0.12222	-0.26667	0.122222	-0.02222	-0.13333	-0.16667	0.5
C_6	-0.12222	-0.13333	-0.26667	-0.15556	-0.11111	-0.26667	-0.3	-0.4	0.366667
C_7	-0.44444	-0.6	-0.17778	-0.34444	-0.38889	-0.46667	-0.56667	-0.66667	0.2
C_8	-0.24444	-0.57778	-0.42222	-0.33333	-0.41111	-0.63333	-0.73333	0	0.133333
C_9	0.5	0.377778	0.122222	0.233333	0.344444	0.222222	0.522222	0.633333	0.866667
C_{10}	0.533333	0.222222	0.211111	0.322222	0.088889	0.244444	0.422222	0.4	0.766667
C_{11}	0.411111	0.2	0.077778	0.2	-0.1	0.322222	0.3	0.166667	0.666667
C_{12}	-0.3	0.155556	0.077778	-0.08889	0.1	-0.03333	0.044444	0	0.566667
C_{13}	-0.17778	0.088889	0.088889	0.033333	-0.12222	-0.08889	-0.1	-0.13333	0.5
C_{14}	-0.3	0.233333	-0.13333	-0.43333	-0.18889	-0.21111	-0.3	-0.4	0.366667
C_{15}	-0.31111	-0.23333	-0.25556	-0.26667	-0.28889	-0.5	-0.53333	-0.63333	0.233333
C_{16}	-0.73333	-0.33333	-0.63333	-0.38889	-0.42222	-0.43333	-0.1	0	0.133333

Table 3. The values of preference function.

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
C_1	0	0	0	0	0	0	1	1	1
C_2	1	1	1	1	0	1	1	1	1
C_3	1	1	0	1	0	1	1	1	1
C_4	0	1	1	0	1	0	1	0	1
C_5	0	1	0	0	1	0	0	0	1
C_6	0	0	0	0	0	0	0	0	1
C_7	0	0	0	0	0	0	0	0	1
C_8	0	0	0	0	0	0	0	0	1
C_9	1	1	1	1	1	1	1	1	1
C_{10}	1	1	1	1	1	1	1	1	1
C_{11}	1	1	1	1	0	1	1	1	1
C_{12}	0	1	1	0	1	0	1	0	1
C_{13}	0	1	1	1	0	0	0	0	1
C_{14}	0	1	0	0	0	0	0	0	1

C_{15}	0	0	0	0	0	0	0	0	1
C_{16}	0	0	0	0	0	0	0	0	1

Step 1. We formed the decision matrix based on the opinions of three experts as shown in Table 1. We used the SVNNs to evaluate the criteria and alternatives. Then we apply the score function to obtain the single value. Then we combined three opinions into one matrix. Then we compute the criteria weights as shown in Figure 2

We show two cost criteria and others are positive criteria.

Step 2. Then we compare the alternatives. Table 2 shows the first criterion comparing the alternatives from first criterion to 16th criterion

For the first criterion.

$P_1(A_1, A_1) = f(0)$

$P_1(A_1, A_2) = f\big(C_1(A_1) - C_1(A_2)\big)$

$P_1(A_1, A_3) = f\big(C_1(A_1) - C_1(A_3)\big)$

$P_1(A_1, A_4) = f\big(C_1(A_1) - C_1(A_4)\big)$

$P_1(A_1, A_5) = f\big(C_1(A_1) - C_1(A_5)\big)$

$P_1(A_1, A_6) = f\big(C_1(A_1) - C_1(A_6)\big)$

$P_1(A_1, A_7) = f\big(C_1(A_1) - C_1(A_7)\big)$

$P_1(A_1, A_8) = f\big(C_1(A_1) - C_1(A_8)\big)$

$P_1(A_1, A_9) = f\big(C_1(A_1) - C_1(A_9)\big)$

For the second criterion.

$P_2(A_2, A_1) = f\big(C_2(A_2) - C_2(A_1)\big)$

$P_2(A_2, A_2) = f\big(C_2(A_2) - C_2(A_2)\big) = f(0)$

$P_2(A_2, A_3) = f\big(C_2(A_2) - C_2(A_3)\big)$

$P_2(A_2, A_4) = f\big(C_2(A_2) - C_2(A_4)\big)$

$P_2(A_2, A_5) = f\big(C_2(A_2) - C_2(A_5)\big)$

$P_2(A_2, A_6) = f\big(C_2(A_2) - C_2(A_6)\big)$

$P_2(A_2, A_7) = f\big(C_2(A_2) - C_2(A_7)\big)$

$P_2(A_2, A_8) = f\big(C_2(A_2) - C_2(A_8)\big)$

$P_2(A_2, A_9) = f\big(C_2(A_2) - C_2(A_9)\big)$

For the third criterion.

$P_3(A_3, A_1) = f\big(C_3(A_3) - C_3(A_1)\big)$

$P_3(A_3, A_1) = f\big(C_3(A_3) - C_3(A_2)\big)$

$P_3(A_3, A_1) = f\big(C_3(A_3) - C_3(A_3)\big) = f(0)$

$P_3(A_3, A_1) = f\big(C_3(A_3) - C_3(A_4)\big)$

$P_3(A_3, A_1) = f\big(C_3(A_3) - C_3(A_5)\big)$

$P_3(A_3, A_1) = f\big(C_3(A_3) - C_3(A_6)\big)$

$P_3(A_3, A_1) = f\big(C_3(A_3) - C_3(A_7)\big)$

$P_3(A_3, A_1) = f\big(C_3(A_3) - C_3(A_8)\big)$

$P_3(A_3, A_1) = f\big(C_3(A_3) - C_3(A_9)\big)$

For the fourth criterion.

$P_4(A_4, A_1) = f\big(C_4(A_4) - C_4(A_1)\big)$

$P_4(A_4, A_1) = f\big(C_4(A_4) - C_4(A_2)\big)$

$P_4(A_4, A_1) = f\big(C_4(A_4) - C_4(A_3)\big)$

$P_4(A_4, A_1) = f\big(C_4(A_4) - C_4(A_4)\big) = f(0)$

$P_4(A_4, A_1) = f\big(C_4(A_4) - C_4(A_5)\big)$

$P_4(A_4, A_1) = f\big(C_4(A_4) - C_4(A_6)\big)$

$P_4(A_4, A_1) = f\big(C_4(A_4) - C_4(A_7)\big)$

$P_4(A_4, A_1) = f\big(C_4(A_4) - C_4(A_8)\big)$

$P_4(A_4, A_1) = f\big(C_4(A_4) - C_4(A_9)\big)$

Step 3: In this step, we used the usual criterion equation to calculate the values of the preference function for each alternative. The results are shown in Table 3. The preference function helps determine how much one alternative is preferred over the others.

Step 4: Next, we calculated the Superiority Index (S) and the Inferiority Index (I). These indices consider two cost-related criteria: cost-effectiveness and budget. This step provides a measure of each alternative's performance concerning these cost factors.

Step 5: We then constructed the Flow Matrix based on the calculated superiority and inferiority indices. The flow matrix is essential for organizing and analyzing the performance data of the alternatives.

Step 6: After forming the flow matrix, we computed the net flow (n-flow) and relative flow (r-flow).

The net flow represents the difference between an alternative's superiority and inferiority, while the relative flow provides a comparative analysis of the alternatives.

Step 7: Finally, we ranked the alternatives based on the computed flow values, ordering them from the best to the worst. The final ranking of the alternatives is presented in Figure 3.

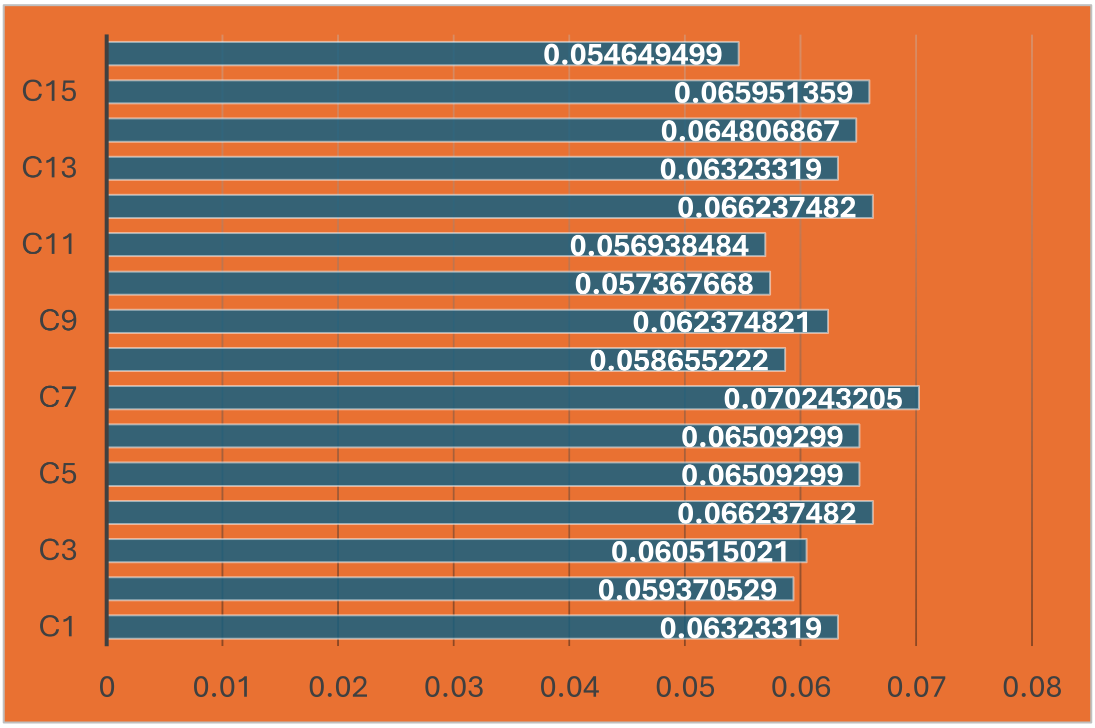


Figure 2. The criteria weights.

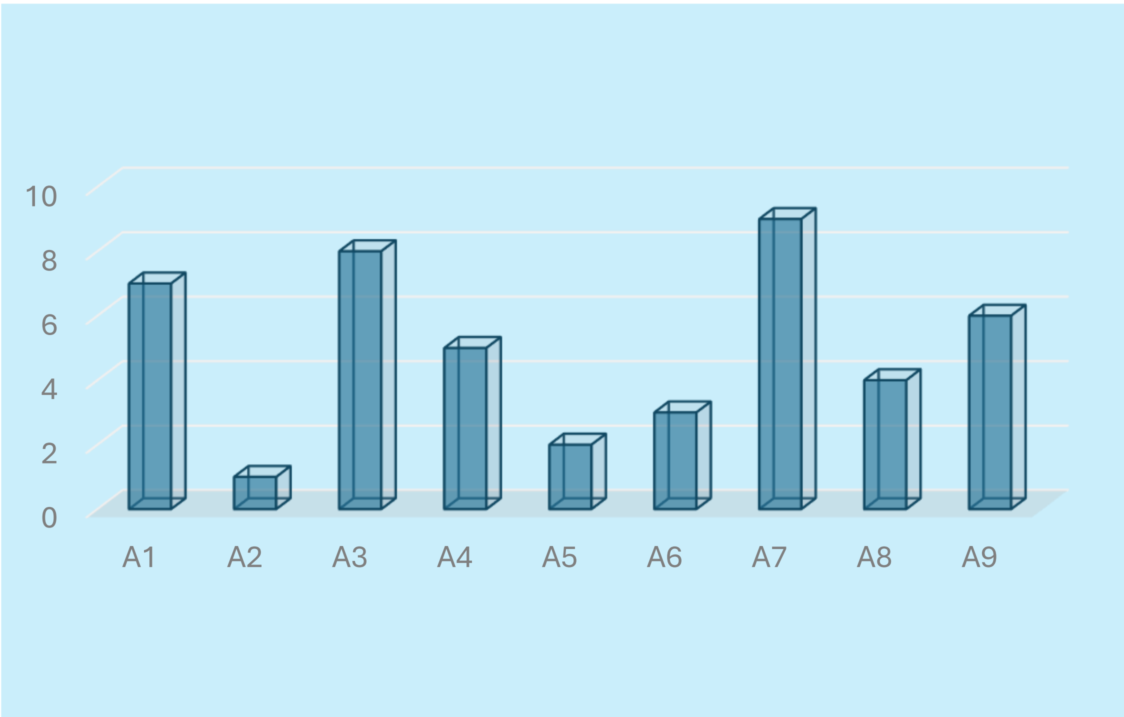


Figure3. The rank of alternatives.

Then we show the rank of alternatives under different functions such as flow matrix, n-flow and r-flow as shown in Figure 4. The rank shows the optimal alternative is stable under different functions. We show the

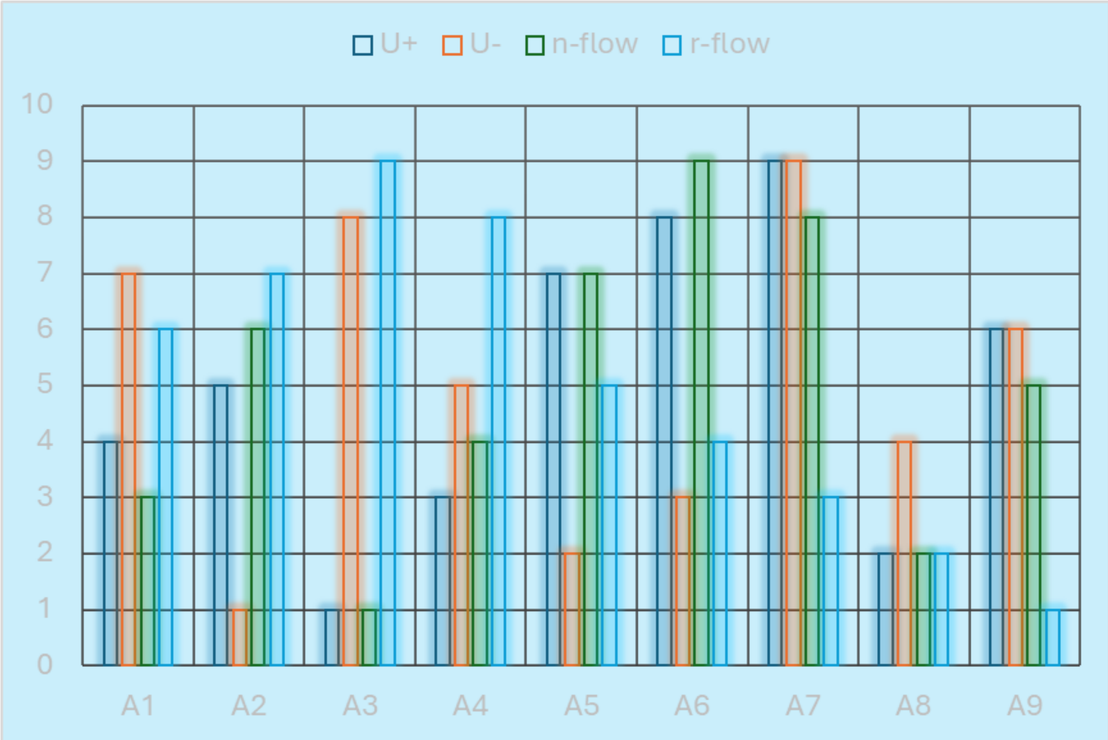


Figure 4. Rank of alternatives under different functions.

The evaluation of resource allocation efficiency in university recreational sports involves systematically analyzing and assessing the allocation and utilization of resources such as facilities, equipment, and personnel within the campus. The core goal is to ensure rational allocation of resources to maximize student satisfaction and overall efficiency. Firstly, data collection and analysis form the foundation of the evaluation. Through surveys, field inspections, and statistical analysis, information is gathered on resource usage frequency, student satisfaction, and the condition of facilities. This data helps identify the strengths and weaknesses of current resource allocation. Secondly, employing scientific evaluation methods is essential. By identifying areas of inefficiency or over-allocation, schools can adjust their strategies, either increasing or decreasing investment in certain facilities or improving management and maintenance practices. Effective resource allocation should also consider the diverse needs of different student groups to ensure fairness and inclusiveness. Moreover, the evaluation not only focuses on current usage but also on future development. As student numbers and the diversity of sports activities change, schools should plan long-term to ensure resources continue to meet demands. Ultimately, the process aims to enhance student quality of life and campus culture. By optimizing resource allocation, it encourages active participation in sports, improving physical and mental health, enriching campus life, and strengthening student belonging and cohesion.

4.2. Comparative Study

This section provides a thorough comparative analysis of the results generated by the SVNN-SIR method compared to other methods, including SVNN-CODAS [29], SVNN-EDAS [30], and SVNN-TODIM [31]. The analysis highlights how these methods align and differ in terms of the ranking of alternatives while emphasizing the unique advantages of SVNN-SIR in handling multi-attribute group decision-making (MAGDM) problems under uncertainty.

4.2.1 Ranking Results

The final rankings of nine alternatives (A1–A9) were determined using the superiority and inferiority indices for each method. The rankings are compared below:

Alternative	SVNN-SIR Rank	SVNN-CODAS Rank	SVNN-EDAS Rank	SVNN-TODIM Rank
A1	1	1	1	1
A2	2	3	2	4
A3	3	2	3	2
A4	4	4	4	5
A5	5	5	5	6
A6	6	6	6	7
A7	7	7	7	8
A8	8	8	8	9
A9	9	9	9	9

4.2.2. Observations

All methods identified A1 as the best-performing alternative and A9 as the worst-performing. This consistency validates the reliability of the methods in ranking the most and least effective alternatives. Alternatives like A2 and A3 exhibited minor rank variations. For instance, SVNN-SIR ranked A2 higher than A3, while SVNN-TODIM swapped their positions. These differences highlight the sensitivity of certain methods to specific criteria weights and decision contexts.

Both methods exhibited close alignment in rankings, suggesting similar robustness in addressing uncertain and multi-attribute problems.

4.2.3 Graphical Representations

- Criteria Weights Distribution (Figure 5)

  This figure illustrates the weights assigned to the 16 criteria. The distribution reflects the relative importance of each criterion in the decision-making process, ensuring that critical factors like budget utilization and facility availability are prioritized.

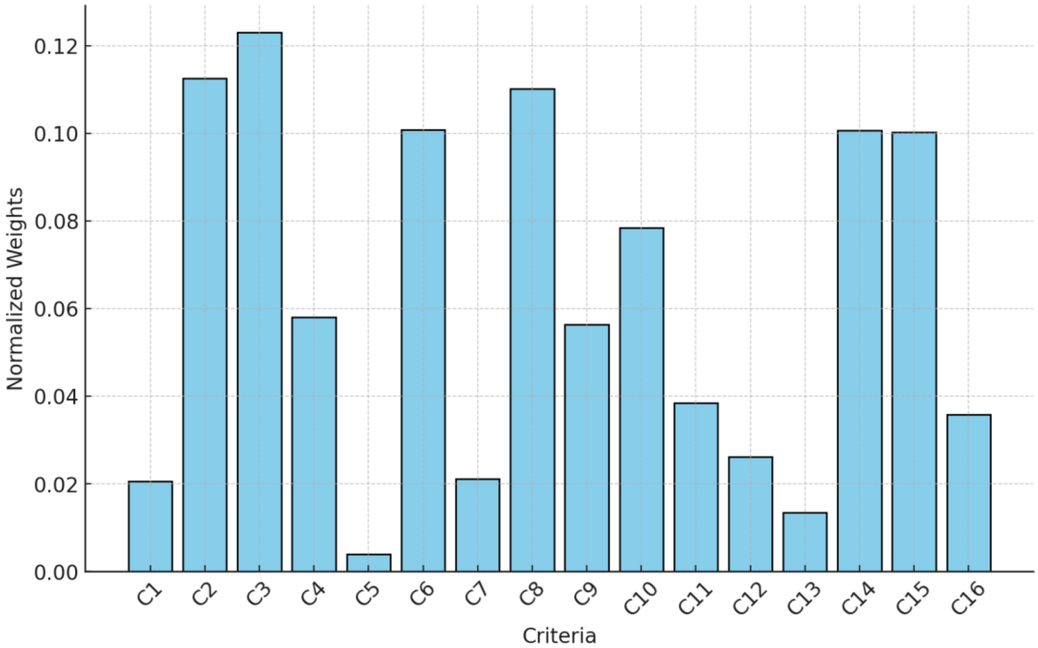


Figure 5. Criteria Weights Distribution

- Alternative Scores Across Methods (Figure 6)

  This figure compares the scores assigned to each alternative by the three methods (SVNN-SIR, SVNN-TODIM, SVNN-EDAS). The chart shows that A1 consistently achieves the highest scores, while A9 remains the lowest across all methods. Variations in scores for A2 and A3 are also evident, highlighting the sensitivity of certain methods to weight adjustment criteria.

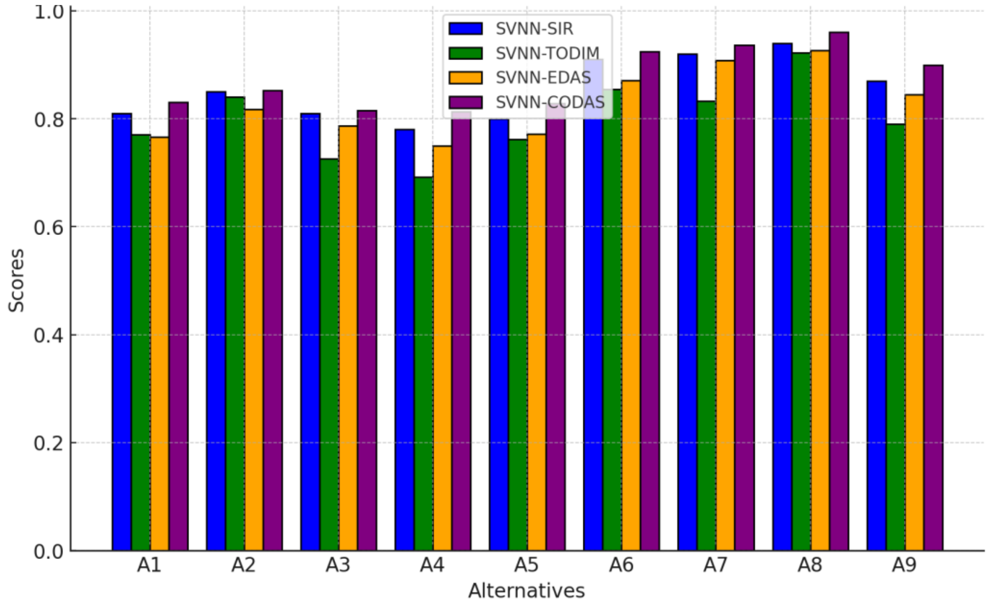


Figure 6. Alternative Scores Across Methods

- Ranking Trends Across Methods (Figure 7)

  This figure depicts the ranking trends for each alternative across the methods. It provides a clear visual representation of how the methods align for top and bottom performers while showcasing minor deviations in middle-ranked alternatives. The inverted y-axis helps emphasize the ranks, with A1 at the top and A9 at the bottom.

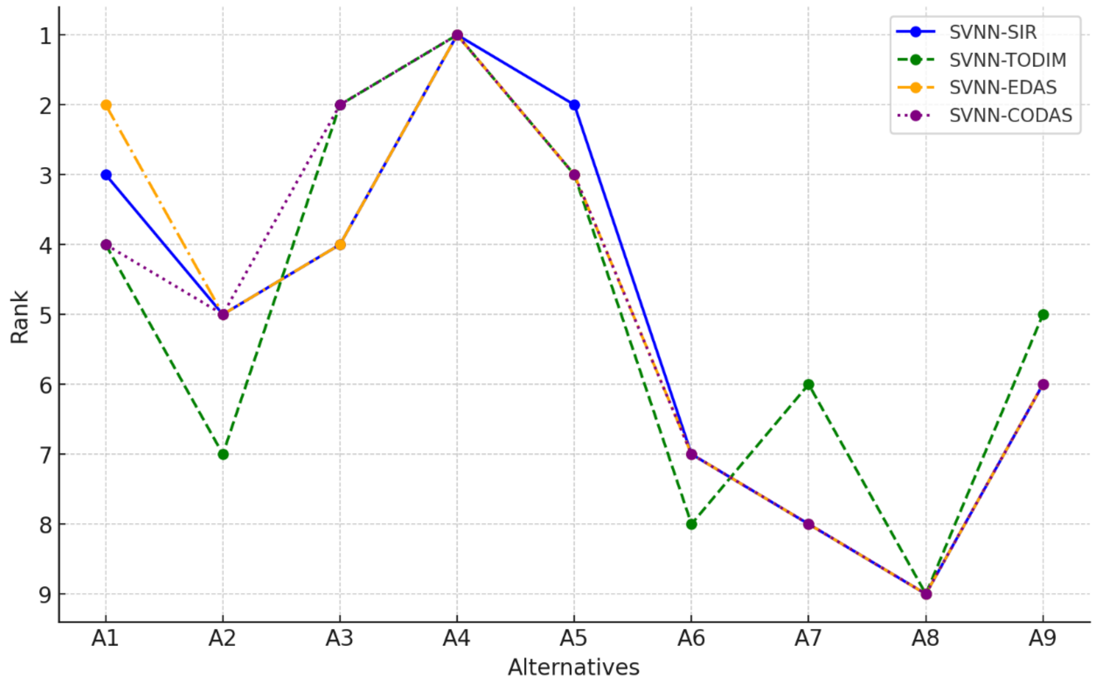


Figure 7. Ranking Trends Across Methods

The comparative analysis demonstrates that SVNN-SIR is a robust and reliable method for evaluating alternatives under uncertain conditions. While SVNN-CODAS, SVNN-EDAS, and SVNN-TODIM also produce consistent results, SVNN-SIR's ability to balance superiority and inferiority indices makes it particularly effective. The alignment between SVNN-SIR and SVNN-EDAS further validates the suitability of these methods for practical applications in resource allocation and decision-making processes.

5. Conclusion and Recommendations

This Paper offers a practical and effective framework for evaluating how resources are allocated in university recreational sports using the SVNN-SIR method. The findings show that this approach helps distribute resources more efficiently and fairly, ensuring better access to sports facilities and programs for students. It also supports universities in planning for the future by improving the quality of campus life. SVNN-SIR offers a robust, consistent, and computationally efficient method for multi-attribute decision-making under uncertainty. Its ability to balance between evaluating superiority and inferiority indices makes it particularly suited for complex scenarios like resource allocation in university recreational sports. While other methods like TODIM and EDAS have their strengths, SVNN-SIR's structured and balanced approach often makes it a preferred choice in practical applications. Looking ahead, future research could explore how socioeconomic factors affect resource allocation decisions. The model could also be adapted for use in other areas where decision-making involves multiple factors and uncertainty, making it a versatile tool for various applications.

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