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A Multi-Criteria Evaluation of Sustainable Olympic Events: Integrating AHP, EWM, and Natural Breaks

Victor Niu Young *, #, Forest Niu Young #

Skyline High School, Salt Lake City, Utah, U.S.A., 84109

* Corresponding Author Email: niuqiong1970@gmail.com

#These authors contributed equally.

Abstract. Facing the sustainable development challenges of Olympics, this study aims to identify the Sports, Disciplines, or Events (SDEs) that best align with the Olympic spirit and the International Olympic Committee's (IOC) long-term strategy. All 47 SDEs held between 1896 and 2028 were evaluated using the IOC's six Sports Inclusion Criteria (C1–C6) as primary indicators, each subdivided into 3-4 secondary factors (21 total). Subjective weights for P1–P21 were derived via the Analytic Hierarchy Process (AHP), objective weights via the Entropy Weight Method (EWM), and comprehensive weights using the Linear Weighted Average Method (LWAM, α = 0.5). Normalized indicator data were used to compute overall SDE scores, which were then classified into 5 strategic groups using the Natural Breaks (NB) method. Breakpoints were identified at 0.7823, 0.7689, 0.6503, 0.5983, and 0.3128. Swimming ranked highest (0.7823) as an elite event, followed by gymnastics (0.7689) and athletics (0.7641), while Roque (0.3128) and Basque Pelota (0.5326) were considered outdated or alternative. This study introduces the AHP-EWM approach to sports event evaluation for the first time, creating the AHP-EWM-NB comprehensive model for sustainable assessment and strategic grouping of Olympic SDEs. The model fills a research gap and provides a data-driven decision-making tool, expanding the application of multi-criteria decision-making (MCDM) in sports management.

Keywords: Analytic Hierarchy Process; Entropy Weight Method; Natural Breaks Classification; Sport; Discipline; or Event.

1. Introduction

The Olympic Games is the largest and most influential sports event in the world. To achieve the sustainable development [1] of the Olympics, the International Olympic Committee (IOC) has been constantly innovating its sports, disciplines, and events (SDEs), striving to resonate with modern values and appeal to a global audience. Throughout Olympic history, SDEs have been introduced, removed, or even reintroduced to reflect the times [2]. For example, in 2020, Karate, Sport Climbing, Surfing, and Skateboarding made their Olympic debut. However, Karate was no longer included in the 2024 Paris Olympics [3], while Breaking (also known as Breakdancing) was introduced [4]. In this context, the question of how to select SDEs that best align with the Olympic spirit and the IOC's long-term development strategy has emerged as an urgent practical issue.

To support such decisions, the IOC has developed 6 Sports Inclusion Criteria to ensure each sport reflects Olympic values. These criteria are adopted in this study as the primary indicators (C1–C6). Under these, each primary indicator was further subdivided and 21 secondary factors (P1–P21) were identified. Then, pairwise comparison judgment matrices were listed for each evaluation index within the same level, and scores were given according to the Saaty 1-9 scale. After determining ωCi and ωPi using AHP, the subjective weights of all secondary factors were calculated by multiplying each secondary factor's weight by the weight of its corresponding primary indicator. Next, select all 47 SDEs that have appeared at the Olympic Games from 1896 to 2028 and collected a large amount of their actual data. After the negative data were converted into positive phase data and normalized, the EWM was used to determine the objective weights. To comprehensively consider the influence of subjective judgment and objective data, this study adopted the Linear Weighted Average Method

(LWAM) to conduct fusion processing on the two. Set the balance coefficient α = 0.5 and calculated the comprehensive weights of each evaluation index. Finally, based on the comprehensive weights, the scores of the 47 SDEs were calculated and ranked. The scores of 47 SDEs were classified into 5 categories in descending order by using the Natural Breaks Classification (NB). This study focused on analyzing and discussing the results of each group. By comparing the strengths and weaknesses of each group, a applicable and scientific strategy for introducing or removing SDEs was proposed. While existing research has applied AHP and EWM separately, this study is the first in the public literature to combine AHP, EWM, and NB grouping into a single AHP–EWM–NB model for the optimization evaluation and strategic grouping of SDEs. By introducing NB grouping, the methodology not only enhances scientific rigor and reproducibility but also provides a robust, data-driven basis for IOC decision-making and sports management.

2. Framework for Olympic Sports Selection and Evaluation

2.1. The Primary Indicators (C): C1-C6

The primary indicators C1-C6 of this study were based on 6 core criteria set by the IOC's Olympic Programme Commission to help ensure that each sport aligned with Olympic values. IOC Criteria for Sports Inclusion is summarized below:

C1: Safety and Fair Play [5], maintains high standards for athlete protection and anti-doping.

C2: Gender Equity [6-7], ensures that both men and women athletes have equal opportunity to participate.

C3: Relevance and Innovation, the sport must appeal to younger audiences, reflect modern trends, and incorporate innovations including physical virtual sports where appropriate while respecting Olympic traditions.

C4: Popularity and Accessibility, enhances the Olympic Games' appeal and global interest without excessively increasing costs or logistical demands.

C5: Inclusivity, represents diverse cultures and promotes global participation (at least 75 countries across four continents practicing the sport).

C6: Sustainability [1], promotes environmental and social responsibility.

2.2. The Secondary Factors (P): P1-P21

This study adopted a hierarchical index system to construct an evaluation framework [8-9]. The selection of secondary factors P1-P21 aimed to refine, specify, and expand the primary indicators. By analyzing the key factors that can directly influence or represent the evaluation criteria, 3 to 4 secondary evaluation factors were determined for each primary indicator, totaling 21. These secondary indicators was guided by relevance, measurability, and data availability to ensure a more comprehensive and scientific coverage of the evaluation dimensions of the Olympic Games. This evaluation framework focused on attracting more people, especially young people, and expanding global influence. While fulfilling its environmental and social responsibilities, they also took into account various factors such as geographical distribution, cultural diversity, inclusiveness for people with disabilities, and economic adaptability [10-11]. The primary criteria and their corresponding secondary indicators are listed in Table 1.

Table 1. The primary and secondary evaluation indicators derived from IOC criteria

Primary Indicators	Secondary Indicators
C1：Safety and Fair Play	P1: Athlete safety, P2: Anti-doping measures, P3: Emergency Response System, P4: Accident rate
C2: Gender Equity	P5: Gender participation ratio (F/M), P6: Gender event setting, P7: Gender ratio of the audience (F/M)
C3: Relevance and Innovation	P8: Young audience appeal, P9: Sports form diversity, P10: Technological innovation
C4: Popularity and Accessibility	P11: Global participation, P12: Audience appeal, P13: Infrastructure requirements, P14: Convenience
C5: Inclusivity	P15: Geographical distribution, P16: Cultural diversity, P17: PWD Inclusion, P18: Econ Adapt(GDP %)
C6: Sustainability	P19: Venue reuse rate, P20: Environmental impact, P21: Waste management

2.3. Selection and data foundation of 47 SDEs for evaluation

Furthermore, to ensure the representativeness and consistency of the evaluation, a total of 47 Olympic SDEs [12-13] were selected as evaluation objects. These SDEs have all been featured in the Olympic Games from 1896 to 2028, providing a rich and continuous historical basis for analysis. A large volume of actual performance, participation, and contextual data related to these 47 SDEs was collected to support the subsequent objective weighting and quantitative evaluation process.

3. AHP-based Weight Determination Method

3.1. Determine the weight of the primary indicators

To determine the weights of the primary indicators *Ci*, a pairwise comparison matrix *Ai* (of size 6×6) was constructed for each primary indicators. The corresponding eigenvector ωi and maximum eigenvalue λ_{max} were calculated using AHP formulas. The eigenvector was then normalized to obtain the weight vector of criterion *Ci*. Next, the Consistency Index (CI) and the Random Consistency Ratio (CR) were computed to verify the matrix's consistency, where: $CR = CI/RI$. If $CR<0.1$, the matrix *Ai* is considered to exhibit acceptable consistency. The consistency verification results for all matrices are shown in Table 2.

Table 2. The analysis result of the primary indicators - AHP

	Weight Vector	Weight value (%)	λmax	CI value	RI value	CR value	Consistency Check
C1	2.276	37.936	6.122	0.024	1.25	0.02	pass
C2	1.493	24.883					
C3	0.963	16.043					
C4	1.963	10.244					
C5	0.393	6.549					
C6	0.261	4.344					

3.2. Determine the weight of the Secondary Factors

Based on the primary indicators described above, the weights of the secondary factors *Bi* under each primary indicators *Ci* were determined using the AHP, following the same procedure. Each pairwise comparison matrix for *Bi* underwent a consistency check to ensure the validity of the results. The final normalized weights of the 21 secondary factors Bp_1 to Bp_{21} are summarized in Table 3 below.

Table 3. The analysis result of the secondary factors - AHP

Ci	*Bi*	Weight Vector	Weight value (%)	λ_{max}	*CI* value	*RI* value	*CR* value	Consistency Check
C1	P1	2.354	58.854	4.152	0.051	0.882	0.057	pass
	P2	0.846	21.155					
	P3	0.516	12.897					
	P4	0.284	7.093					
C2	P5	1.714	57.143	3	0	0.525	0	pass
	P6	0.857	28.571					
	P7	0.429	14.286					
C3	P8	1.744	58.126	3.004	0.002	0.525	0.004	pass
	P9	0.927	30.915					
	P10	0.329	10.959					
C4	P11	1.863	46.582	4.031	0.01	0.882	0.012	pass
	P12	1.109	27.714					
	P13	0.644	16.107					
	P14	0.384	9.597					
C5	P15	1.863	46.582	4.031	0.01	0.882	0.012	pass
	P16	1.109	27.714					
	P17	0.644	16.107					
	P18	0.384	9.597					
C6	P19	1.714	57.143	3	0	0.525	0	Pass
	P20	0.857	28.571					
	P21	0.429	14.286					

3.3. Obtain the Subjective Weight

In order to integrate the subjective local judgments at the two levels into a unified global subjective weight, the weight of the primary indicator *ωCi* was multiplied by the weight of its corresponding secondary factor *ωPi,* thereby obtaining a clear, consistent, and comparable subjective priority structure. This step demonstrates the unique advantages of the AHP model in hierarchical aggregation. The results obtained by this method are shown in Figure 1 below.

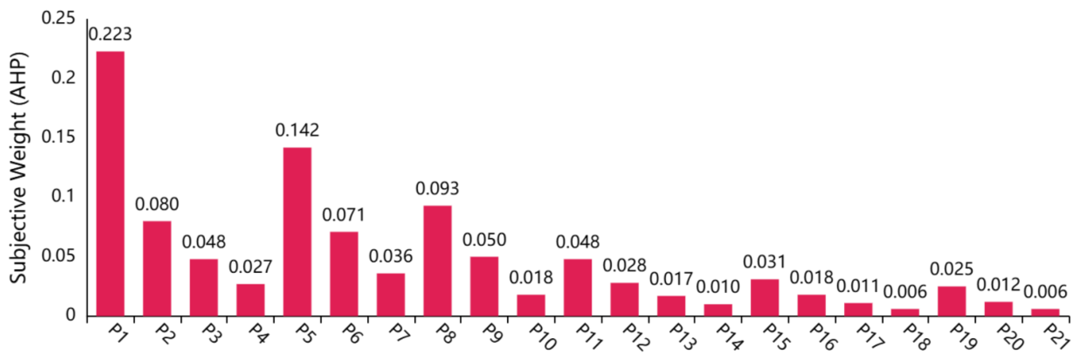

Figure 1. AHP subjective weights of secondary factors

4. EWM-based Weight Determination Method and Comprehensive Scores

4.1. Determine the Objective Weigh

This study collected real data on 21 secondary factors (P1-P21) of all 47 SDEs during the Olympic Games from 1896 to 2028. To maintain consistency, before normalization, the 4 negative factors Accident rate (P4), Infrastructure requirements (P13), Environmental impact (P20) [14], and Waste management (P21), which had negative impacts, were converted to positive values. After completing the data normalization processing, the objective weights of each *Pi* were calculated using EWM, as shown in Figure 2 below.

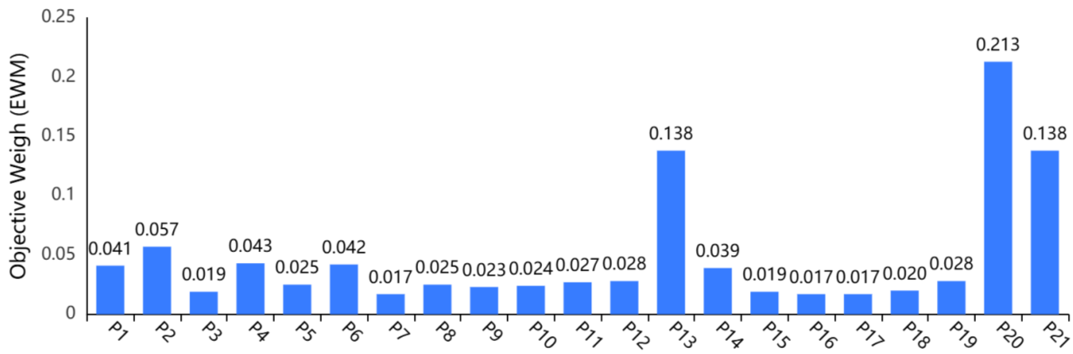

Figure 2. EWM objective weights of secondary factors

4.2. Calculate the Comprehensive Weight

The Linear Weighted Average Method (LWAM) has the characteristics of simplicity, intuitiveness and effective combination of multiple information sources, and is suitable for multi-criteria decision analysis. In this study, LWAM was adopted to calculate the comprehensive weight. The parameter α was set to 0.5, which reflected the relative importance of the subjective and objective weights. The specific calculation is shown in Formula 1, and the comprehensive weights are shown in Figure 3 below.

$$\omega_{j}^{\text{comprehensive}} = \alpha \cdot \omega_{j}^{\text{AHP}} + (1-\alpha) \cdot \omega_{j}^{\text{EMW}}, \alpha = 0.5 \tag{1}$$

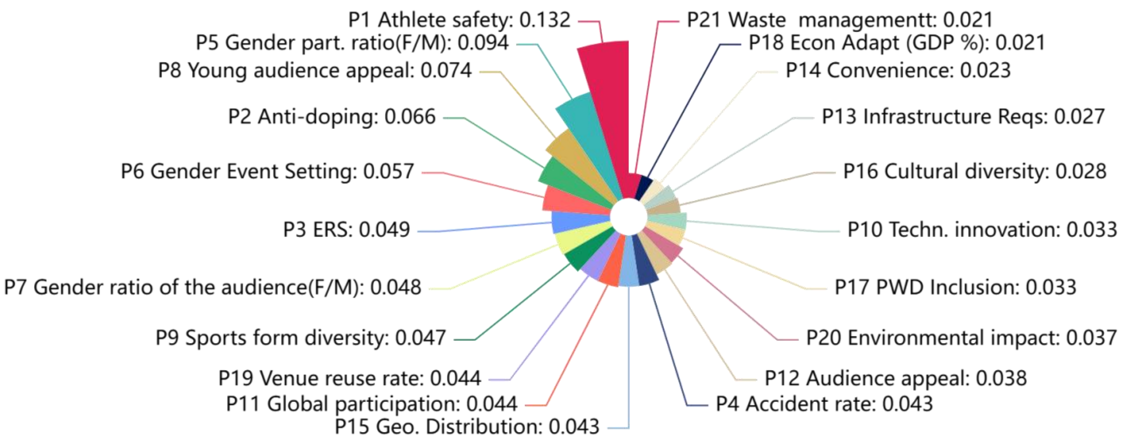

Figure 3. Comprehensive weight based on LWAM (α = 0.5)

4.3. Obtain the Comprehensive Scores

In this study, the normalized index values of P1-P21 of 47 SDEs were multiplied by the comprehensive weights to calculate the comprehensive scores of each SDE. Thus, a ranking based on the comprehensive evaluation results has been achieved, which can reflect the level of superiority and inferiority. The higher the score, the stronger the overall contribution and comprehensive performance based on expert judgment and actual data-driven evaluation. As shown in Figure 4, swimming achieved the highest score of 0.7823, indicating that it performed the best under the selected evaluation criteria.

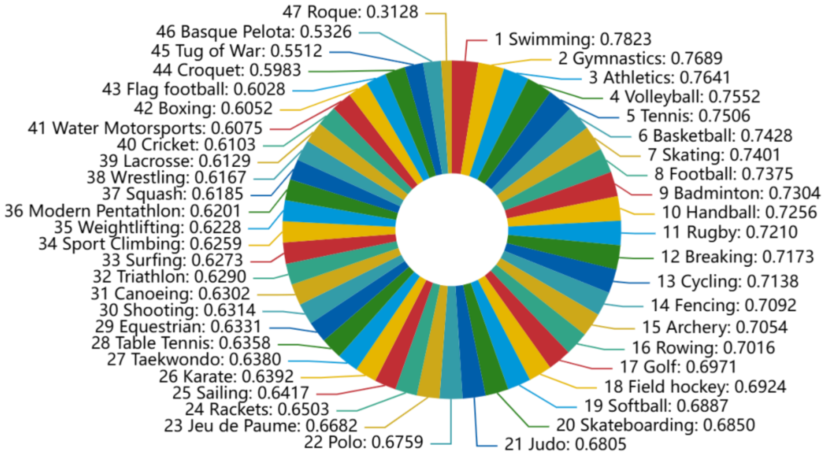

Figure 4. The comprehensive score and ranking of 47 SDFs

4.4. Score-Based Grouping Using Natural Breaks Classification (NB)

To further reveal the natural aggregation characteristics of the comprehensive scores and divide them into several grade intervals, this study applied the Natural Breaks Classification (NB) to group the comprehensive scores of 47 SDEs. The natural breakpoint method is a data-driven hierarchical approach that can identify natural aggregation patterns in data by minimizing intra-group variance and maximizing inter-group differences. This method is based on the Jenks optimal classification algorithm. Through iterative optimization, numerical continuous variables are divided into several groups to achieve the optimal boundary division between groups. Based on the calculation results of the natural breakpoint method, the comprehensive score is divided into five grade intervals, providing a basis for the subsequent analysis and the proposal of the selection decision of SDEs, as shown in Table 4 below.

Table 4. Olympic SDEs Natural Breaks Grouping

Group name	Breakpoints start score	SDE index range	Grouping rationale
1 Elite Standalone	0.7823	1	Swimming stands out with a significantly higher score due to its numerous medal events, global popularity, and media appeal. Its score gap from the next sport warrants a separate category.
2 Core Olympic Sports	0.7689	2–23	These sports are well-established with high scores, representing traditional Olympic pillars with widespread participation and consistent global viewership.
3 Watchlist – Stable	0.6503	24–43	These sports have moderate scores, showing regional popularity or limited growth. They are viable but require monitoring to ensure continued relevance.
4 Replaceable	0.5983	44–46	These sports have low scores with declining visibility or minimal international engagement. Consider phasing out or replacing them.
5 Obsolete	0.3128	47	This sport scores significantly lower than all others and lacks contemporary relevance, suggesting it should be removed from Olympic consideration.

5. Results and Discussion

5.1. Results

This study produced significant gaps in the comprehensive evaluation results of the 47 Olympic SDEs, and distinguishable performance stratifications emerged. First of all, Swimming ranked first with a comprehensive score of 0.7823. It is not difficult to see from the normalized standard data of 47 SDEs that swimming performs well in terms of gender participation rate (P5=0.9178) and appeal to young audiences (P8=1.0000). Meanwhile, Swimming also ranked high in sports form diversity, Econ Adapt (GDP %), and venue reuse rate. This also confirms that Swimming is a perennial, stable and, indispensable SDE in the Olympic Games, which is loved by people all over the world. Following closely behind were Gymnastics (0.7689) and Athletics (0.7641), both of which performed well in terms of safety and audience engagement indicators. The comprehensive scoring data showed that the team sports events of the Olympic Games demonstrated strong competitiveness. Volleyball (4^{th} place), tennis (5^{th} place) and basketball (6^{th} place) occupied the top positions, mainly due to the high court venue reuse rate (P19>0.8) and the gender part. ratio (P5>0.79).

It is worth noting that emerging sports show polarized results: Breakdancing ranks 12th (P8=1.0) due to its outstanding appeal to young people, while skateboarding ranks 20th (P10=1.0) despite its technological innovation advantages. Traditional niche sports occupied the last quarter. Basque Pelota (ranked 46th) and Roque (ranked 47th) scored less than 0.55 due to the severe insufficiency of anti-doping measures (P2=0) and the extremely low Venue reuse rate (P19=0).

5.2. Discussions

The results of this study showed that Swimming, Gymnastics, and Athletics, ranking in the top echelon of the comprehensive score, dominate the Olympic landscape. This aligns with their global participation (P1=1) and audience appeal (P12 =1). This finding resonates with Richard Giulianotti's cultural critique of modern sports consumption, where sports with strong visual expressiveness tend to attract broader audiences due to their aesthetic appeal [15]. They showed multi-dimensional advantages in terms of Gender Event Settings (P6=1), Gender audience (P7>0.77), Econ Adapt (P18>0.88), and Venue reuse rate (P19>0.67). However, high-risk sports such as boxing (ranked 42nd), despite their cultural significance, performed poorly, highlighting the increasing weight of athlete protection standards in contemporary assessment frameworks (P1=0). This study showed that the complete ranking distribution presents a rightward bias, indicating that the scores of sports events with lower rankings were more dispersed. Considering the country that hosts each Olympic Games, the sports culture, and the local traditional SDEs with a broad foundation, the IOC allows the organizers to add and remove some SDEs to a limited extent. Some SDEs with lower scores were regions replaced by SDEs that were evaluated and received higher comprehensive scores.

5.2.1. Analyze the Natural Breakpoints Between Swimming and Athletics

Swimming and Athletics have long been at the core of the super SDEs. They are both mega-events with the highest number of Olympic medals [16-17] and possess an irreplaceable international influence. Swimming stood out because it featured a wide range of events, strong visual impact, low participation threshold, high global popularity, and significant star effect. It performed exceptionally well in almost all rating dimensions. Swimming and Athletics are only two places apart, but there is a first breakpoint between them, with a gap of 0.0182. The reasons why Athletics are not in the first group are shown in Table 5 below. It is extremely rare but not impossible for a mainstream sport like swimming to emerge. For a new project to rise to become a super SDE, it must simultaneously meet multiple core criteria: high entertainment value, a rich competition system, a broad popularity base, and good infrastructure adaptability. In other words, it must perform well in almost all evaluation dimensions. Only when these advantages work in synergy can it stand out in the highly competitive sports ecosystem and become an innovative, sustainable super SDE.

However, with the transformation of the sports industry ecosystem and the change in the audience structure, even super sports like swimming and Athletics must proactively adapt to the requirements of the new era if they are to continue to lead and achieve new glories in the future Olympic system. This has become a key point in the Olympic reform and communication strategy. On the basis of maintaining the traditional competitive spirit, it will rejuvenate its vitality through modern technological and cultural means, truly achieving an upgrade from a "core project" to a "global resonance".

Table 5. Analysis and Comparison of Swimming and Athletics

Dimension	Swimming	Athletics
Event Density	Athletes can participate in multiple events (e.g., Phelps won 8 golds in one Olympics)	Events vary greatly in technique; hard to compete across (e.g., sprint vs. marathon)
Gender Symmetry[6-7]	Complete gender symmetry, equal number of events for men and women	Some women's events are relatively recent, differences in viewing appeal remain
Scheduling Exposure	Mostly scheduled in the first half of the Olympics, high media exposure	Spread out in the second half, some events (e.g., racewalking, field events) have lower visibility
Venue Reusability	Swimming venues are also used for diving, water polo, synchronized swimming	Primarily uses the main stadium, limited reuse for other sports
Aesthetic Appeal	Emphasizes streamlined motion, visually appealing in slow-motion shots	Mostly functional movements, only a few (e.g., high jump[18]) are visually striking

5.2.2. Add and remove SDEs reasonably and scientifically

As the Olympics evolve, the IOC aims to keep the Games both relevant and impactful by adding SDEs that resonate with modern values and appeal to a global audience. Throughout Olympic history, SDEs have been introduced, removed, or even reintroduced to reflect the times. For example, in 2020, Karate, Sport Climbing, Surfing, and Skateboarding made their Olympic debut. However, Karate was no longer included in the 2024 Paris Olympics, while Breaking was introduced. Looking forward to the 2028 Los Angeles Olympics, Flag Football, Lacrosse, and Coastal Rowing will be added, while Baseball and Softball will return to be contested in the 2028 Games after a 20-year absence. This research can provide a scientific decision-making approach for the future Olympic Games. Assist the IOC in selecting SDEs with modern values and a global audience appeal to replace and substitute those with lower overall scores. This not only contributes to the optimization and update of SDEs, but also promotes the system construction and development in the field of sports management [19] in terms of SDEs selection, promotion strategies, and international cooperation.

6. Conclusions

This study presents a comprehensive, data-driven framework and constructs a robust AHP-EWM-NB multi-criteria decision-making (MCDM) model for the evaluation and strategic classification of Olympic movements, disciplines and programs (SDEs). This framework is closely related to the six sports inclusion standards formulated by the IOC and provides a replicable approach for the evaluation of strategic projects. The results show that swimming is the top event with the highest total score (0.7823), followed by gymnastics (0.7689) and track and field (0.7641). These projects performed well in all assessment dimensions, demonstrating their significance within the Olympic framework. On the contrary, traditional sports such as Roque (0.3128) and the Basque Pelotta (0.5326) are classified as "outdated" or "alternative", indicating that they no longer align with the vision of the modern Olympics. This article does not take into account the preferences, unique cultures, and geopolitical factors of the host countries of the Olympic Games. Future research that can incorporate machine learning techniques or natural language processing (NLP) and expand datasets to emerging global sports (for instance, e-sports and breakdancing before entering the Olympics) will be more conducive to predicting future candidate SDEs.

The model developed in this study - the AHP-EWM-NB comprehensive evaluation model - fills a significant gap in the existing literature and compensates for and expands the application scope of the multi-criteria Decision (MCDM) method in the analysis of sports events. This mode of thinking has the potential to become an important tool for guiding and applying in the related fields of sports management, catering to the rapid evolution of the global sports development trajectory.

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