

Olympic Sports Evaluation Model Based on Entropy Weight Method and Improved TOPSIS

Qiaoyi Zhang¹, Yunkun Song², Yuxuan Fei^{3*} and Gongchao Wan⁴

¹Sendelta International Academy, China

²Asia Technology Research Institute, China

³Beijing Haijia School, China

⁴Hanyang University, Republic of Korea

*Corresponding author: Yuxuan Fei

Abstract

Since the revival of the Olympic Games in 1896, the Olympics has evolved into one of the most important global sporting events. With the passage of time, the International Olympic Committee (IOC) has worked continuously to maintain the relevance and influence of the Games, introducing, adjusting, or removing sports to ensure that the competition aligns with the needs and expectations of global audiences. As such, developing a scientific and rational evaluation framework to determine whether a sport should be added or removed from the Olympic Games is crucial. This paper proposes a sports evaluation model to assess whether Olympic sports align with the core values of the Games. The model is based on six key evaluation dimensions: Popularity and Accessibility, Gender Equity, Sustainability, Inclusivity, Relevance and Innovation, and Safety and Fair Play. It combines 12 quantitative indicators and 10 qualitative indicators to construct a 22-element evaluation matrix. The entropy weight method is then used to calculate the weights of each indicator, followed by the application of the TOPSIS method to determine the ideal and negative ideal solutions. The sports are then evaluated by calculating the distance between each sport's score and the ideal solution. The higher the score, the more aligned the sport is with the Olympic core values.

Keywords

Olympic Games, Sports Evaluation, Entropy Weight Method, TOPSIS, Sustainability, Inclusivity, Gender Equity, Innovation

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Introduction

Background

Since its revival in 1896, the Olympic Games have become one of the most important sporting events in the world, not only as a display of athleticism, but also as a symbol of cultural exchange, peaceful coexistence and global solidarity. Each Olympic Games has carried deep historical significance and served as a meeting point for cultures and values from around the world. From the first ancient Olympic Games to the modern Olympic Games, the Olympic Movement has always advocated the sports spirit of 'faster, higher, stronger', and has demonstrated the progress of human civilisation through the continuous innovation and development of sports events. The history and evolution of the Olympic Games have reflected the changes in global sports, culture and social values. As time progresses, the International Olympic Committee (IOC) is committed to keeping the Olympic Games relevant and influential, and therefore continues to introduce, adapt or delete sports to ensure that the content of the games matches the needs and expectations of the global audience.

As globalisation accelerates, the Olympic Games are not only a showcase for competitive sport, but also a beacon of progress and innovation for the global community, as exemplified by the introduction of BREAKDANCE at the Paris 2024 Games, a youthful, street-culture-inspired sport that has attracted a large youth demographic, a trend that mirrors the ongoing diversification of sports in the context of globalisation. This trend reflects the increasing diversification of sports in the context of globalisation.

Determination of Factors Affecting IOC Criteria

Variables

Table 1: Notations

Symbols	Descriptions
$N_{countries}$	Number of participating countries
$N_{participants}$	Number of participants worldwide
$A_{attendance}$	Number of spectators during the match
L_{social}	Social media likes
$L_{logistics}$	Organisational costs
A_{global}	Global appeal
P_{women}	Percentage of female athletes
P_{prizes}	Percentage of female awards
F_{fair}	Fairness in Women’s Game
$E_{sustainability}$	Economic sustainability
T_{rent}	Duration of the lease of the premises
$I_{environment}$	Impact of the environment
$S_{responsibility}$	Social responsibility
$D_{cultural}$	Cultural Diversity
$A_{accessibility}$	Universality
D_{social}	Number of video plays
$I_{innovation}$	Innovativeness
$N_{accidents}$	Number of accidents
s_{judge}	Fairness of adjudication
s_{safe}	Security measures for the project
$D_{anti-doping}$	Anti-doping measures
w_i	Weighting of indicators
$R_{weighted}$	Weighting matrix
f_i	Evaluation scores for projects

Key Factors Affecting IOC Standards

This paper looks at the IOC’s criteria for evaluating the entry of new sports into the Olympic Games, which are not only based on event-specific data, but also involve a variety of qualitative and quantitative factors. These factors help the IOC to assess whether a sport is in keeping with the spirit of the modern Olympics, while at the same time attracting a wide audience, maintaining impartiality, and ensuring the health and safety of the athletes. The IOC’s evaluation criteria and the methodology for calculating the weights are shown in the figure 1 below.

Quantitative factors: $N_{countries}$ $N_{participants}$ $A_{attendance}$ L_{social}

Number of Countries Participating: Reflects the global popularity and internationalisation of a sport, which should cover at least the four continents of the world to ensure the global appeal of the Olympic Games. The symbol for the total number of participating countries is $N_{countries}$.

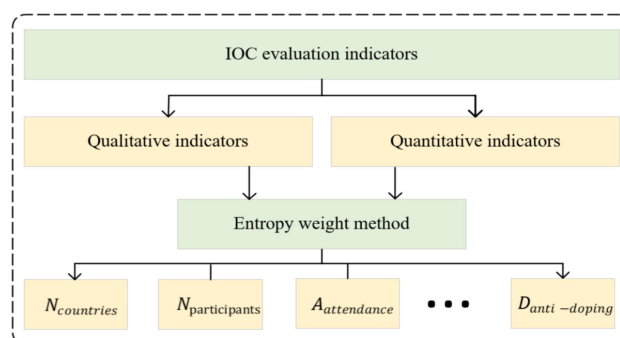


Figure 1: Assessment of indicator maps

Number of Global Participants: Measures the number of participants from all over the world, indicating the global popularity of the sport. The symbol for the number of Global Participants is **Nparticipants**.

Attendance Numbers: Measures the popularity of the sport, especially the live participation of spectators, which can affect the ticket revenue and audience reach of the Olympic Games. A attendance denotes the number of spectators during the competition.

Numbers of Likes on Social Media (e.g. on Twitter): quantifies the level of interest and buzz around a sport on a global scale. The symbol for the number of Likes on Social Media is denoted as **L social**.

Qualitative Factors: L logistics, A global.

Logistical Demands: assesses whether the campaign requires excessive resources or high organisational costs. For example, if the campaign requires complex site construction or high equipment costs, this may limit its feasibility. The organisational cost symbol is indicated as **L logistics**.

Global Appeal: How the popularity and popularity of the sport affects the global appeal of the Games. The Global Appeal score is denoted as **A global**.

Quantitative factors:pwomen ,pprizes.

Participation Rates (percentage of women): This is the most direct indicator of gender balance and is usually measured by counting the percentage of male and female athletes participating in an event. If the percentage of women's participation in an event is too low, it may affect their chances of being selected for the Olympic Games, and vice versa. Ensuring a balanced participation ratio of male and female athletes in sports is in line with the general demand for gender equality in modern society. The symbol is denoted as **pwomen**.

$$P_{\text{women}} = \left(\frac{N_{\text{women}}}{N_{\text{total}}} \right) \times 100 \quad (1)$$

Where Nwomen is the number of female athletes and Ntotal is the total number of athletes.

Percentage of Prizes Awarded to Men and Women: This indicator is used to assess whether there is a gender bias in the distribution of awards at events. If there is an imbalance in the distribution of awards between male and female athletes, this may lead to gender injustice. Therefore, ensuring that awards are distributed fairly between men and women can demonstrate the sport's respect and recognition of gender equality.

$$P_{\text{prizes}} = \left(\frac{N_{\text{prizes,women}}}{N_{\text{prizes,total}}} \right) \times 100 \quad (2)$$

Where Nprizes,women is the number of female awards and Nprizes,total is the total number of awards.

Qualitative Factors:Ffair.

Fairness in Competition: This factor assesses whether the rules and opportunities for competition are equal for male and female athletes and whether there is any gender bias or injustice. For example, in some sports, male and female athletes may face different rules or equipment requirements, or there may be gender differences in the organisation and management of the event. Ensuring the fairness of the competition is an important part of gender equality. The competition rules fairness rating symbol is denoted as **Ffair**.

Quantitative factors:E sustainability,Trent .

Economy Sustainability: This indicator measures the economic sustainability of the event, looking at whether the event will contribute to the long-term development of the local economy. For example, whether the event attracts a large number of tourists, drives spending and provides long-term employment opportunities. In addition, the event should be assessed to see if it uses sustainable venue construction materials and complies with environmental standards. The measurement of these factors enables a judgement to be made as to whether the sport will be able to economically support the long-term development of the Games. The symbol indicates **Esustainability**.

Time Needed to Rent: This indicator measures the length of time that sports facilities and venues are rented, reflecting the amount of resources needed to stage the event. A sport that rents venues for too long may result in a waste of resources or an impact on other events. Therefore, reasonable venue usage and resource arrangement can help enhance the resource utilisation efficiency and sustainability of the Olympic Games. The symbol is denoted as **Trent**.

Qualitative Factors: Ienvironment , sresponsibility

Environmental Impact: This factor evaluates the impact of the sport itself on the environment, especially in terms of energy consumption, pollution emission, etc. For example, certain sports may require large amounts of water, electricity or fuel resources, or may have irreversible impacts on the natural environment. A sport with a significant environmental impact may influence whether it meets the sustainability criteria of the Olympic Games. Reducing the carbon footprint and environmental pollution of an event is therefore key to achieving sustainability. Symbolised as **Ienvironment**.

Social Responsibility: This factor considers whether the event gives back to the community through charitable or other socially responsible activities. For example, whether the event is able to providesup- port to the local community in terms of education, health, poverty alleviation, or whether it promotes social equity and inclusiveness. The social responsibility of a sports event can enhance its global recog- nition and respect, while promoting sustainable social development. Symbolised as sresponsibility.

Qualitative factors:D cultural ,Accessibility .

Cultural Diversity: This factor assesses whether a sport is able to attract athletes and spectators from different cultural backgrounds and promote cross-cultural communication and understanding. A cul- turally diverse sport demonstrates multicultural integration and coexistence and builds bridges between cultures through sport. For example, some sports have a long tradition and influence in different coun- tries, which can attract athletes from all continents and demonstrate the uniqueness of each country’s culture through the events. The symbols are represented as D cultural.

Accessibility Across Regions: This factor looks at whether the sport can be replicated in different countries and regions around the globe, especially if there are no major constraints in terms of resources, language or geographical location. Some sports may require higher economic costs or specific venue facilities, which may limit their popularity in some economically underdeveloped regions or resource- poor countries. In contrast, sports that can be played widely in different regions and are not subject to significant economic, linguistic or geographic barriers are better able to reflect the inclusiveness and fairness of the Olympic Games. The symbols are denoted as Accessibility .

Quantitative factors:Dsocial.

Top Views on Social Media (e.g. tweets): This metric measures the popularity of a sport amongst younger viewers, particularly in terms of the amount of interaction on social media platforms. A high number of views and interactions tends to indicate that the sport is popular with a younger demographic, inline with modern trends. Social media reach is a direct reflection of the penetration and breadth of the sport among young audiences, and is an important quantitative indicator for assessing the modernity and relevance of a sport. Number of social media views D social.

Qualitative Factors:Iinnovation.

Incorporation of Innovation: this factor assesses whether the sport has adopted new technologies or formats that meet the need for innovation in the digital age. For example, virtual sports (e.g., virtual track riding) or eSports (e.g., cybersports) are part of the innovation in sports that can bridge the gap between traditional sports and digital entertainment. Adopting innovative forms of sport not only en- hances the spectacle of the game, but also sets future sports trends and creates a new viewing experience through the combination of technology and entertainment. The symbols are denoted as Iinnovation.

Quantitative Factors: Naccidents,s judge.

Events Not Containing Accidents: This indicator measures the safety record of an event, reflecting whether or not the sport has a high level of risk and the likelihood of accidents occurring. By counting the incidence of accidents in the Olympic Games for each sport, it is possible to evaluate the safety and security of the sport for athletes. If a sport has frequent cases of accidents or injuries, this may affect its continued eligibility as an Olympic sport. The number of accidents is symbolised as Naccidents.

Effect on Score by Judges: Measures the fairness of the judging system. This indicator quantifies the fairness of judges’ scoring and assesses whether there is any human bias or unfairness. If the judges’ scoring is highly biased, it may lead to athletes feeling unfairly treated, which in turn affects the trust of athletes and spectators. The symbols are denoted as s judge.

$$S_{\text{judge}} = \frac{1}{N_{\text{events}}} \sum_{i=1}^{N_{\text{events}}} (S_{\text{judge},i} - S_{\text{standard},i}) \tag{3}$$

Where s_{judge,i} is the ith rating, s_{standard,i} is the standardised rating, and N_{events} is the number of ratings.

Qualitative Factors: s safe ,D anti-doping.

Athlete Safety Standards: whether the sport has strict safety measures in place to safeguard athletes, e.g., pre-competition health screening, necessary protective equipment during competition, accessibil- ity of medical services, etc. For more dangerous sports (e.g., equestrian, wrestling, etc.), additional safety measures must be taken to protect athletes from injury. The symbol is s safe.

Anti-Doping Practices: Whether the sport has rigorous anti-doping measures in place to ensure that athletes are able to compete on a fair and level playing field. A rigorous anti-doping detection and monitoring system helps to maintain the integrity of the sport and prevents any athlete from enhancing performance through illegal means. This is not only about the health of the athletes, but also ensures a level playing field for all participants. Symbolised as D anti-doping .

Access to quantitative factors

This paper collects a large amount of information, and the percentage of female participation pwomen in each sport is roughly the same, at around 50 per cent, suggesting that each of these sports maintains a relatively equitable situation in terms of gender balance. For example, Rhythmic Gymnastics is 50.3 per cent, Mountain Bike is 50 per cent and Diving is 50 per cent. This means that the gender ratio is relatively balanced across the disciplines, in line with the IOC's requirements for gender equality. The indicator pprizes is 1 in all disciplines, which means that the awards are distributed equally between male and female athletes, with no gender bias. This is in line with the IOC's expectations for gender equality.

Table 2: Data sheet for each quantitative factor

Sport	pwomen	pprizes	E _{sustainability}	L _{logistics}	A _{attendance}	D _{social}
Mountain Bike	50	1	28	206	72	2.1
Rhythmic (Gymnastic)	50.3	1	40	470	191	1.3
...
Diving	50	1	120	675	136	5
Fencing	50	1	128	462	260	1.8
Weightlifting	50	1	128	394	122	7.5

Sport	N _{countries}	N _{participants}	I _{environment}	T _{rent}	A _{attendance}	S _{judge}
Mountain Bike	36	70	32400	19	2	8
Rhythmic (Gymnastic)	21	94	1433	19	6	6
...
Diving	32	135	125	19	16	6
Fencing	53	260	221	19	72	8
Weightlifting	59	122	16	19	10	7

E_{sustainability} reflects the economic sustainability of the different sports, the data shows that Diving and Fencing have high economic sustainability, at 120 and 128 respectively, which may be due to the broader audience base of these sports or the higher degree of commercialisation of the events, which attracts more spectators and sponsors. Mountain Bike, on the other hand, has an economic sustainability of 28, which may be due to the relatively low economic benefits of the programme due to its more specific audience and the higher costs of running the event.

L_{social} reflects the influence of each event on social platforms. Diving (Diving) received 6.75 million views, demonstrating its widespread social media following and popularity particularly amongst the younger demographic. Gymnastics (Rhythmic Gymnastics) also had a high number of views (4.7 million), while Mountain Bike had a relatively low number of views (2.06 million), possibly reflecting the sport's low level of discussion on social media or its more niche audience.

The number of likes on social media D_{social} is also an important indicator of social influence. Diving received the most likes (191), which is further evidence of its high social media following. Mountain Biking (Mountain Bike), on the other hand, received only 21,000 likes, suggesting that it is less interactive on social media and may need more publicity and promotion.

Audience engagement A_{attendance} is an important indicator of the popularity of sports. Diving (Diving) and Rhythmic Gymnastics (Gymnastics) had relatively high audience numbers of 675 and 470 respectively. This suggests that these disciplines are capable of attracting large numbers of spectators and that the events may have a high potential for ticket revenue. Mountain Bike had a relatively low attendance of 72, suggesting that it has a limited audience.

The number of participating countries N_{countries} shows how international the events are. Fencing has the highest number of participating countries at 260, reflecting the sport's global reach. Diving also has a high number of participating countries (135), indicating its strong international appeal. Mountain Biking has the lowest number of participating countries (36), which may be an indication of the relatively low popularity of the sport, especially in non-Western countries.

The number of global participants N_{participants} is another key indicator of a programme's international popularity. Diving and Rhythmic Gymnastics have a high number of global participants, 136 and 94 respectively, compared to Mountain Bike, which has a lower number of global participants, 70, indicating a lower level of international participation.

Venue requirements I_{environment} varied considerably between the different disciplines. Mountain Bike's venue requirements of 32,400 square metres are much higher than those of other disciplines, reflecting the fact that the sport can require larger spaces for events, often involving longer courses or special facilities. Other disciplines, such as Rhythmic Gymnastics (Gymnastics) and Diving (Diving), have smaller venue requirements of 1,433 square metres and 125 square

metres respectively. This suggests that mountain biking is more resource intensive and may impose higher venue rental costs on organisers.

Rental time Trent is an important indicator of a programme’s consumption of resources. Diving (Diving) has a rental time of 16 hours and Fencing (Fencing) has a rental time of 72 hours, which suggests that Fencing has a higher demand for venues. In contrast, Mountain Bike and Rhythmic Gym- nastics have shorter rental times of 19 hours and 19 hours respectively.

Safety is one of the most important criteria for evaluating the programmes. The data for all sports show that they have a low accident rate A attendance . Diving (Diving) and Rhythmic Gymnastics (Rhyth- mic Gymnastics) had 6 and 6 no accidents respectively, reflecting the high level of safety in these sports. Mountain Bike, on the other hand, had no major accidents, but it had more frequent accidents (8) and requires more safety measures.

The impact of judges’ ratings s judge also varied across disciplines. Fencing had a large deviation in ratings (72), probably due to the highly subjective judgemental nature of the sport. Comparatively, Mountain Bike and Rhythmic Gymnastics had less impact in judges’ ratings, 2 and 6 respectively, indicating that these events rely more on objective criteria for judging.

Access to qualitative factors

In the course of this paper, we extensively reviewed relevant literature, official reports and various academic studies to analyse in detail the qualitative factors affecting the assessment of Olympic sports. By comparing the performance of different sports under each criterion, we set up a scoring system for each qualitative factor, and assigned scores to each sport based on the available data and expert opin- ions. These qualitative factors not only cover dimensions such as cultural inclusiveness, innovation, and global appeal of the sports, but also consider key aspects such as their impact on the environment and society, as well as athlete safety and fairness. In order to ensure the objectivity and accuracy of the results, we also used qualitative analyses to comprehensively assess the performance of each type of sport, taking into account the official evaluation criteria of the International Olympic Committee (IOC). Through this scoring and assignment method, we are able to assess more systematically and compre- hensively the overall competence of each sport in the Olympic Games, so as to provide a scientific basis for the final decision.

Table 3: Data table for each qualitative factor

Sport	S safe	D anti-doping	I innovation	D cultural	A accessibility
Mountain Bike	3	10	1	4	1
Rhythmic (Gymnastic)	4	10	2	2	1
...
Diving	5	10	4	3	1
Fencing	5	10	5	5	1
Weightlifting	5	10	5	6	1

Sport	I environment	S responsibility	F fair	L logistics	A global
Mountain Bike	0	1	8	3	2.1
Rhythmic (Gymnastic)	5	0	6	10	1.3
...
Diving	5	0	6	10	5
Fencing	4	1	8	10	1.8
Weightlifting	4	0	7	8	7

The scoring of each qualitative factor follows a scale from 1 to 10, with a score of 1-3 indicating poor performance and significant deficiencies; 4-6 indicating moderate performance and some room for improvement; 7-8 indicating good performance and close to best practice; and 9-10 indicating excellent performance and compliance with virtually all relevant criteria. Such a qualitative assessment enables a comprehensive assessment of whether each sport meets all the requirements of the Olympic Movement.

Use entropy weighting to find the weight of each indicator

Entropy Weight Method [1] is an objective method for determining the weight of each indicator, which is commonly used in multi-indicator decision analysis. In Entropy Weight Method, the informa- tion entropy of each indicator is calculated to determine the relative importance of the indicator. The larger the information entropy, the less information

the indicator provides and the smaller its weight; on the contrary, the smaller the information entropy, the more information the indicator provides and the larger its weight. This paper adopts the entropy weight method to find out the weight of each factor.

Data standardisation

Because different indicators may have different scales, the raw data first need to be standardised to make the data for each indicator comparable, for example, the data for Ienvironment and pprizes are obviously not in the same scale. Common standardisation methods include extreme variance standardi- sation,Z-score standardisation and so on. It is assumed here that the extreme difference standardisation method is used.

For each indicator x_{ij} , the following formula can be used for standardisation:

$$z_{ij} = \frac{x_{ij} - \min(x_i)}{\max(x_i) - \min(x_i)} \tag{4}$$

Where x_{ij} is the original value of the i th sample under the j th indicator. $\min(x_i)$ and $\max(x_i)$ are the minimum and maximum values of the j th indicator respectively.

Calculate the proportion of each indicator. $p_{ij} = \frac{z_{ij}}{\sum_{i=1}^m z_{ij}}$. Calculate the proportion value of the normalised data $p_{ij} = \frac{z_{ij}}{\sum_{i=1}^m z_{ij}}$ It indicates the proportion of the i th sample on the j th indicator. The formula for its calculation is:

$$p_{ij} = \frac{z_{ij}}{\sum_{i=1}^m z_{ij}} \tag{5}$$

Where: z_{ij} is the standardised value. m is the total number of samples and $\sum_{i=1}^m z_{ij}$ is the sum of the standardised values of all samples under the j th indicator.

Calculating information entropy

The entropy value e_j of each indicator is used to measure the information uncertainty of the indicator; the greater the information entropy, the less information the indicator provides. Its calculation formula is:

$$e_j = -\frac{1}{\ln(m)} \sum_{i=1}^m p_{ij} \ln(p_{ij}) \tag{6}$$

Where: p_{ij} is the proportion value of the i th sample on the j th indicator. m is the number of samples. \ln denotes the natural logarithm.

The complementary degree of entropy value d_j reflects the amount of valid information of the indicator, which is calculated by the formula:

$$d_j = 1 - e_j \tag{7}$$

Where: e_j is the entropy value of the j th indicator.

Calculate the weight of each indicator w_j . Finally, the weight of the indicator w_j can be obtained by calculating the ratio of the complement of entropy value to the total complement. Its calculation formula is:

$$w_j = \frac{d_j}{\sum_{j=1}^c d_j} \tag{8}$$

Where: d_j is the degree of complementarity of the j th indicator. $\sum_{j=1}^c d_j$ is the sum of the degrees of complementarity of all indicators.

Weighting of quantitative and qualitative factors

In this paper, the weights of quantitative and qualitative factors affecting the evaluation criteria of the Olympic programme are calculated through the entropy weight method. The entropy weight method is an objective method of determining the weights of indicators, which reflects the relative importance of each indicator by quantifying its information entropy. Firstly, all the raw data are standardised to eliminate the influence of the difference in the quantitative scale between different indicators. Then, the information entropy of each indicator is further derived by calculating the scale value of each indicator. The information entropy reflects the uncertainty of the indicator, the larger the entropy value, the smaller the change of the indicator, the less information, and the lower the weight accordingly; the smaller the entropy value, the larger the change of the indicator, the more information, and the higher the weight.

Eventually, the weight of each indicator is derived by calculating the entropy complement of each indicator, and the quantitative and qualitative factors are comprehensively assessed based on the weights, which provides a more scientific and objective basis for the assessment of the Olympic programme. As shown in the table, the weights of 12 quantitative factors and 10 qualitative factors are shown.

Table 4: Table of weights of quantitative factors

Pwomen	Pprizes	Esustainability	Lsocial	Aattendance	Dsocial
0.038	0.040	0.063	0.067	0.055	0.049
Ncountries	Nparticipants	Ienvironment	Trent	Aattendance	Sjudge
0.053	0.058	0.062	0.053	0.055	0.045

Table 5: Table of weights of qualitative factors

Ssafe	Danti-doping	Ienvironment	Dcultural	Aaccessibility
0.061	0.038	0.063	0.067	0.055
Ienvironment	Sresponsibility	Ffair	Llogistics	Aglobal
0.062	0.058	0.061	0.045	0.040

Restatement of the problem

First, we were asked to define the factors that impact the IOC's criteria within the guideline topics of popularity and accessibility, gender equity, sustainability, inclusivity, relevance and innovation, and safety and fair play. We were also advised that the factors themselves should be carefully selected, while ensuring the units of measurement are consistent and standardized.

Second, we were instructed to develop a model—or a set of models—to evaluate the best SDEs (Sports or Disciplines of Excellence) for inclusion in the Olympics, using the factors identified within the IOC's criteria.

Third, we were asked to test our finalized model on at least six SDEs: three that have been added or will be removed from the Olympics in the years 2020, 2024, and 2028, and three that have been part of the Olympic program since 1988. We were further instructed to ensure our selection of SDEs reflects diversity in order to produce more generalizable results. Additionally, we were asked to discuss how the model affirms or challenges the current status of SDEs in the Olympics.

Fourth, we were tasked with identifying three new SDEs for potential inclusion in the 2032 Olympics, ranking them as the best, second-best, and third-best choices. We were then asked to evaluate whether any of these SDEs could be considered for inclusion in future Olympic Games.

Fifth, we were asked to assess the strengths and weaknesses of our model, identifying how different aspects of the decision-making process contribute to either the strengths or limitations of the model.

Finally, we were asked to write a one- or two-page letter to the IOC, presenting the results of our SDE evaluation, including our recommendations on whether or not certain SDEs should be included in the upcoming Olympics, with clear support for our positions based on the results of our model.

Assumptions and justification

- Assumption 1: All sports assessed have a significant impact on participation globally.
- Assumption 2: The athlete's experience of the game is linked to the long-term development of the programme.
- Assumption 3: The degree of internationalisation and global promotion of the project has a significant impact on its success in being selected for the Olympic Games.
- Assumption 4: The construction of the project's facilities and logistical requirements directly affect the feasibility of its introduction.
- Assumption 5: The cultural adaptability of a project determines its broad acceptance on a global scale.

Evaluation model for SDEs based on tosis

In this paper, the TOPSIS method (Technique for Order of Preference by Similarity to Ideal Solution) was used to scientifically score and evaluate each sport by comprehensively analysing 12 quantitative and 10 qualitative indicators of the sport. The TOPSIS method is a multi-attribute decision analysis method, the basic principle of which is to determine the degree of superiority or inferiority of each alternative by calculating the distance between each alternative and the ideal solution and the negative ideal solution.

Data preparation

The rating data for each indicator for all sports were collated into a $m \times n$ decision matrix. This matrix is a matrix where m denotes the number of sports and n denotes the number of indicators, i.e. 71×22 . In this paper there are $m = 71$

sports, and $n = 12$ quantitative indicators and 10 qualitative indicators. We can construct a matrix containing all the data x_{ij} .

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{9}$$

Where x_{ij} denotes the value of the i th sport under the j th indicator. The value of the indicator for each sport can be obtained from actual data collection (e.g., the number of spectators at competitions, the number of participating countries, etc.) or from expert ratings (e.g., cultural diversity, global appeal, etc.).

Data standardisation

Since the units of each indicator are different (e.g. "economic sustainability" is expressed in monetary units, while "audience" is measured in numbers of people), it is important to standardise these data. In this paper, the Z-Score [3] standardisation method is used, which is standardised by subtracting the mean and dividing by the standard deviation.

$$r_{ij} = \frac{x_{ij} - \mu_j}{\sigma_j} \tag{10}$$

Where μ_j is the mean of the j th indicator and σ_j is the standard deviation of the j th indicator.

Standardised data eliminate differences between units and scales, allowing all indicators to be compared on the same scale. The standardised data form the decision matrix R , i.e.:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \tag{11}$$

As different indicators have different scales, the decision matrix needs to be normalised. The standardisation process uses the following formula.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \tag{12}$$

The normalised matrix $R = [r_{ij}]$ is obtained:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \tag{13}$$

Establishing the ideal solution to the sports programme matrix

Based on the weighted normalised decision matrix A^+ , the ideal and negative ideal solutions A^- are determined.

Ideal Solution A^+ : Optimal values for each indicator:

$$A^+ = (v_{1+}, v_{2+}, \dots, v_{n+}) \tag{14}$$

Where $v_{j+} = \max(v_{ij})$, the maximum value of each column.

Negative ideal solution A^- : the worst value of each indicator:

$$A^- = (v_{1-}, v_{2-}, \dots, v_{n-}) \tag{15}$$

Where $v_{j-} = \min(v_{ij})$, the minimum value of each column.

In the TOPSIS method, calculating the distance of each scenario to the ideal and negative ideal solutions is one of the key steps. The method measures the relative merits of the scenarios by calculating the distance between the scenarios and the ideal solution (best scenario) and the negative ideal solution (worst scenario).

For each scenario i , its distance to the ideal solution S_i^+ is calculated using the Euclidean distance with the following formula:

$$S_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^+)^2} \tag{16}$$

Where: v_{ij} is the normalised value of scenario i on indicator j . v_j^+ is the ideal solution value of indicator j , i.e. the maximum value of this indicator across all scenarios. n is the number of indicators.

By calculating the Euclidean distance from the ideal solution for each scenario, we are able to obtain a distance metric value that indicates how close the sports programme is to the ideal solution. The smaller the distance, the closer the sports programme is to the ideal solution, the better.

For each scenario i , its distance to the negative ideal solution s_i^- is also calculated using the Euclidean distance with the following formula:

$$S_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2} \quad (17)$$

Where: v_{ij} is the normalised value of scenario i on indicator i . v_j^- is the value of the negative ideal solution for indicator j , i.e. the smallest value of this indicator among all scenarios. n is the number of indicators.

A negative ideal solution reflects the worst performance of all the scenarios on some indicator, indicating a least ideal scenario. Calculating the distance of each scenario to the negative ideal solution can help us assess the disadvantage of the sport.

Calculating assessment scores for SDEs

In the TOPSIS method, calculating the relative proximity¹ of each solution is an important step in comparing the advantages and disadvantages of different solutions. The relative proximity reflects the relative proximity of solution i to the ideal solution, and its value is in the range of [0, 1], with larger values indicating that the solution is closer to the ideal solution and is superior. The next calculation step explains how to derive this relative proximity.

The relative proximity f_i of each scenario is calculated by the following formula:

$$f_i = \frac{S_i^-}{S_i^+ + S_i^-} \quad (18)$$

Where: s_i^+ denotes the distance from scenario i to the ideal solution (calculated as described earlier and obtained through the Euclidean distance formula). s_i^- denotes the distance from scenario i to the negative ideal solution (also calculated using the Euclidean distance formula). f_i denotes the relative proximity of scenario i .

In this section, this paper uses the TOPSIS assessment methodology to provide a comprehensive assessment of each programme through 12 quantitative indicators and 10 qualitative indicators for Olympic sports. First, we calculate the SDEs assessment scores for each sport based on these indicators, which reflect the performance and strengths of each sport under each criterion. The weights of each indicator were derived through the entropy weighting method in the previous analyses, ensuring the objectivity and scientificity of the weights.

Evaluation of SDEs based on entropy weight method and TOP-SIS

Determine the SDEs to be assessed

This paper analyses the HiMCMolympic Data.xlsx table and selects six representative Olympic sports for a comprehensive evaluation to assess whether they meet the criteria for Olympic sports and to provide data support for decision-making on future Olympic sports. The selected projects include:

Added/Removed Items:

Skateboarding: The introduction of skateboarding to the Olympic Games as a new sport at the 2020 Tokyo Games signalled the Games' focus on the youth demographic and extreme sports. By assessing skateboarding's participation, global impact, and its environmental and sustainability implications, this paper aims to understand its potential to remain in the Olympics for the long term.

Baseball: Baseball was removed after the 2008 Beijing Olympics and will not return until the 2020 Tokyo Olympics. The return of baseball reflects the openness of the Olympic Games to different cultures and sports. This paper will assess the global popularity of baseball, the number of participating countries and regions, as well as its historical and cultural value in the Olympic Games, to further explore its future prospects.

Cricket: Cricket is a traditionally global sport, but its popularity and global participation is relatively low compared to other Olympic sports. Although cricket has a large spectator base in countries such as India and Australia, this paper will use the TOPSIS methodology to assess whether cricket has what it takes to join the Olympics, and to analyse its potential for global development and the challenges it may face.

Persistent sports:

Swimming: Swimming has been one of the most iconic core sports since the inception of the modern Olympic Games. Swimming not only has a global participation base, but also attracts a large number of spectators due to its high spectator and competitive nature. This paper will analyse the quantitative and qualitative indicators of swimming to assess whether it continues to be at the heart of the Olympic Games.

Athletics: As one of the oldest Olympic sports, athletics is the soul of the Games. Its global popularity and diversity make it an important part of the Olympic Games. This paper assesses the sustainability, spectator appeal, and compliance of track and field with the standards of the modern Olympic Games.

Football: Football is one of the world’s most popular sports and has been a core sport since the beginning of the modern Olympic Games. This paper analyses football’s performance at the Olympic.

Games, including its global participation, the complexity of event organisation and the challenges it may face in the modern Olympic Games, and assesses the need for its continuation as an Olympic sport.

Through a comprehensive assessment of the six sports, the individual indicators of the six sports will be standardised by analysing 12 quantitative and 10 qualitative indicators.

Table 6: Quantitative analysis of indicators

Sport	Pwomen	Pprizes	E _{sustainability}	L _{social}	A _{attendance}	D _{social}
Baseball	0.1177	0.1076	0.1269	0.3294	0.3671	0.1174
Skateboarding	0.2893	0.2866	0.1352	0.2008	0.1764	0.3909
Cricket	0.3724	0.2522	0.1038	0.3243	0.3319	0.3452
Swimming	0.9424	0.9887	0.7077	0.8227	0.9104	0.9538
Athletics	0.9137	0.8763	0.8361	0.8027	0.8129	0.7595
Football	0.8388	0.9860	0.8998	0.7054	0.8266	0.9073

Sport	Ncountries	Nparticipants	Ienvironment	Trent	Aattendance	sjudge
Baseball	0.3214	0.2115	0.3133	0.3642	0.2223	0.3401
Skateboarding	0.2860	0.3552	0.3513	0.1629	0.1136	0.2502
Cricket	0.2738	0.2413	0.21302	0.3533	0.3632	0.1292
Swimming	0.8788	0.9699	0.9027	0.8757	0.8975	0.9742
Athletics	0.8235	0.7504	0.8243	0.9353	0.9697	0.7821
Football	0.9771	0.9703	0.8694	0.7606	0.9206	0.7077

Table 7: Data table for each qualitative factor

Sport	ssafe	Danti-doping	Iinnovation	Dcultural	Aaccessibility
Baseball	0.36463	0.142023	0.368992	0.334242	0.160647
Skateboarding	0.399967	0.208924	0.30569	0.341762	0.210758
Cricket	0.1894	0.3013	0.1483	0.1242	0.1805
Swimming	0.9051	0.9485	0.9851	0.7967	0.9327
Athletics	0.7639	0.8571	0.7876	0.9114	0.7175
Football	0.8935	0.7234	0.9897	0.9556	0.7787

Sport	Ienvironment	sresponsibility	Ffair	Llogistics	Aglobal
Baseball	0.1416	0.1816	0.2604	0.2152	0.1924
Skateboarding	0.1784	0.2801	0.1037	0.1492	0.3934
Cricket	0.1282	0.1361	0.1732	0.1864	0.3892
Swimming	0.7199	0.9056	0.7653	0.7959	0.7294
Athletics	0.9467	0.9881	0.7208	0.9324	0.7537
Football	0.9742	0.9158	0.8159	0.8187	0.774

This is converted into a matrix denoted as R, where n is 22:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \quad (19)$$

The projects will be assessed on the basis of a combination of 12 quantitative and 10 qualitative indicators. The core of the assessment will be the TOPSIS methodology, which will help to determine whether the projects meet the Olympic criteria and provide decision-makers with an objective and quantitative basis.

Calculate the score of the project

Multiply the matrix R by the weights to obtain the weighting matrix:

$$|R_{\text{weighted}} = \begin{bmatrix} r_{11} \cdot w_1 & r_{12} \cdot w_2 & \dots & r_{1n} \cdot w_n \\ r_{21} \cdot w_1 & r_{22} \cdot w_2 & \dots & r_{2n} \cdot w_n \\ r_{31} \cdot w_1 & r_{32} \cdot w_2 & \dots & r_{3n} \cdot w_n \end{bmatrix} \quad (20)$$

The positive and negative ideal solutions of the weighting matrix, as well as the Euclidean distance of each scenario from the ideal solution, are then computed by means of TOPSIS, and finally the evaluation scores for each SDE project f_i are computed.

Candidate SDE for 2032 Olympics in Brisbane

What about this paper after reviewing the information to analyse three possible new or reintroduced projects that would be suitable for inclusion in the Brisbane 2032 Olympic Games and deciding on the priority based on the model analysis (i.e. which projects should be considered first and which could be ranked second and third). Consideration was also given to whether any other sports would be suitable for inclusion in the 2036 or later Games.

Selection of potential new or reintroduced projects

When selecting new programmes, we need to consider market demand, consistency with Olympic values, and innovativeness.

Based on these criteria, we have selected three sports:

SDE	f_i
Swimming	0. 9531
Athletics	0. 9322
Football	0. 9123
Skateboarding	0. 3461
Baseball	0. 2864
Cricket	0. 2434

Electronic Sports (Esports)

In recent years, eSports has become very popular worldwide, especially among young people, and has a global participation base.

Relevance and innovation: eSports combines traditional sports and virtual platforms, making it a very innovative option that can attract a large young audience.

Inclusivity and accessibility: eSports are not restricted by gender, age, physical condition, etc. and are accessible to young people from almost all countries around the world.

Gender equality: Many eSports competitions have no significant gender gap and are open to both male and female players.

Disadvantages: eSports are less ‘sporty’ than traditional sports and some may question whether they are in line with traditional Olympic sportsmanship.

Futsal (3x3 basketball)

Futsal has been added as a new sport at the 2020 Tokyo Olympics and has received good feedback. With a shorter pace of play, a more compact tournament schedule, and easier promotion, this sport meets the needs of modern young people for sporting events.

Popularity: Basketball has a wide audience around the world, especially in the United States, Europe and Asia.

Gender Equality: Futsal is already well established in terms of gender equality and Futsal has been included in the 2024 Olympic programme, demonstrating its sustainability.

Sustainability and innovation: The game is faster paced and suitable for a global audience, especially a younger demographic.

Sailing (Coastal Rowing)

This is a newer form of water sport that is expected to be featured at the 2028 Olympic Games in Los Angeles. Its best features are its low environmental impact and its appeal to coastal countries around the globe.

Popularity: Sailing has gained popularity in coastal countries, particularly in Europe and the Americas.

Sustainability: Sailing itself meets the requirements of sustainable development and has a high potential for low-carbon environmental protection in particular.

Inclusiveness: the sport can be played across several continents and is particularly suited to countries that are closely associated with waters and oceans.

The 12 quantitative indicators for the three sports are standardised as shown in the table below.

Table 8: Quantitative indicators for candidate projects

Sport	Pwomen	Pprizes	Esustainability	Lsocial	Aattendance	Dsocial
Esports	0.6824	0.9044	0.7487	0.8723	0.8102	0.8368
3x3 basketball	0.6189	0.7074	0.8388	0.9271	0.6435	0.7905
Coastal Rowing	0.8929	0.9379	0.8405	0.9336	0.7658	0.8493

Sport	Ncountries	Nparticipants	Ienvironment	Trent	Aattendance	sjudge
Esports	0.8216	0.7483	0.6343	0.6605	0.7245	0.7425
3x3 basketball	0.7266	0.6342	0.8521	0.6893	0.8469	0.6247
Coastal Rowing	0.7514	0.6695	0.9486	0.8443	0.8381	0.6392

The standardised qualitative indicators for the three projects are shown in the table below:

Table 9: Qualitative indicators for candidate projects

Sport	ssafe	Danti-doping	Iinnovation	Dcultural	Aaccessibility
Esports	0.8704	0.8522	0.7843	0.8532	0.8011
3x3 basketball	0.9298	0.7516	0.6877	0.8471	0.8793
Coastal Rowing	0.6238	0.7911	0.688	0.6684	0.8804

Sport	Ienvironment	Sresponsibility	Ffair	Llogistics	Aglobal
Esports	0.8765	0.7993	0.6468	0.9894	0.7925
3x3 basketball	0.7913	0.7849	0.8617	0.7907	0.7978
Coastal Rowing	0.8217	0.8139	0.6222	0.7888	0.8543

Prioritisation

Based on the model evaluation projects in this paper, these projects can be prioritised based on several factors:

Esports

Reason for prioritisation: Esports is very popular and meets the criteria of 'relevance and innovation'. It attracts a young audience and has a global reach. Although it is different from traditional sports, its innovation and global reach make it an important candidate.

Futsal Basketball (3x3 Basketball)

Reason for preference: Futsal basketball has already been successful at the Tokyo 2020 Olympic Games and is suited to the diverse needs of future Olympic Games due to its fast pace and ease of promotion. In addition, five-a-side basketball has advantages in terms of gender equality and inclusiveness, making it a very suitable candidate.

Sailing (Coastal Rowing)

Reason for Priority: Although it is a relatively new sport, it meets the need for environmental sustainability and global popularity, particularly in areas where water sports are more prevalent. Its inclusion in the Brisbane 2032 Olympic Games could enhance the environmental profile of the Games.

Table 10: Evaluation scores for candidate projects

SDE	fi
Esports	0.8326
3x3 basketball	0.7854
Coastal Rowing	0.7538

Potential future projects after 2036

With the development of technology and changes in social demands, future Olympic events may gradually adapt to new trends. For the 2036 and future Olympic Games, the following potential new events have a certain possibility.

Robotics Sports. With the continuous development of robotics technology, there may be competitive events dominated by robots in the future. The performance of robots in terms of strength, speed, and accuracy may make these projects new faces in the arena. Future robot sports may include robot soccer, robot wrestling, and so on.

Street Sports. Street sports usually have strong freedom and innovation, which can reflect the personality and creativity of participants. With the acceptance of multiculturalism in society, projects such as street dance and street basketball may receive wider attention and recognition in the future, becoming Olympic events.

Sensitivity Analysis

This paper explores the impact of these two different assessment methods on the model results by applying quantitative indicator analysis and qualitative indicator sensitivity analysis respectively. Quantitative indicator analysis focuses on the use of quantifiable data, such as number of participants, number of events, global audience statistics, etc., to assess how well each programme meets each criterion. In contrast, qualitative analysis focuses on the subjective evaluation of programme characteristics, including the cultural significance, innovativeness, and historical context of the sport. Although these factors are more difficult to quantify, they play a crucial role in Olympic programme selection.

Sensitivity analysis of qualitative indicators

In this paper, we have chosen to conduct a sensitivity analysis of the effect of the number of quantitative indicators on the model's assessment of mean scores, in order to explore the effects of variations in the decision-making process produced by different numbers of quantitative indicators. In that analysis, we examined the stability and sensitivity of the quantitative indicators on the model output results by systematically adjusting their number and weights. This approach is able to reveal how the increase or decrease of quantitative indicators affects the change in the final assessment scores during the assessment process, which in turn provides validation of the accuracy and reliability of the model. As shown in Figure 2.

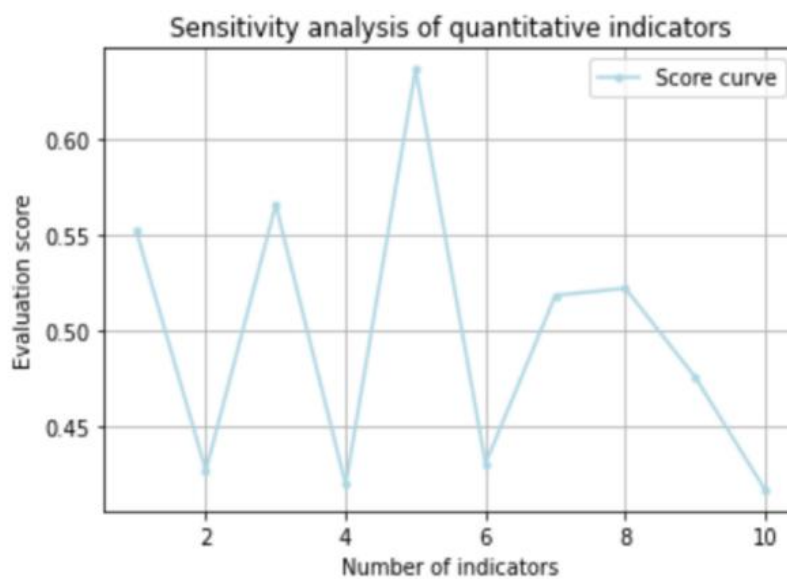


Figure 2: Sensitivity analysis of quantitative indicators

Sensitivity analysis of quantitative indicators

By testing the sensitivity to changes in the number of quantitative indicators, this paper not only evaluates the responsiveness of the model to changes in data input, but also further explores how to balance the weights of different indicators in the model design to ensure the scientific and reasonable nature of the final assessment results.

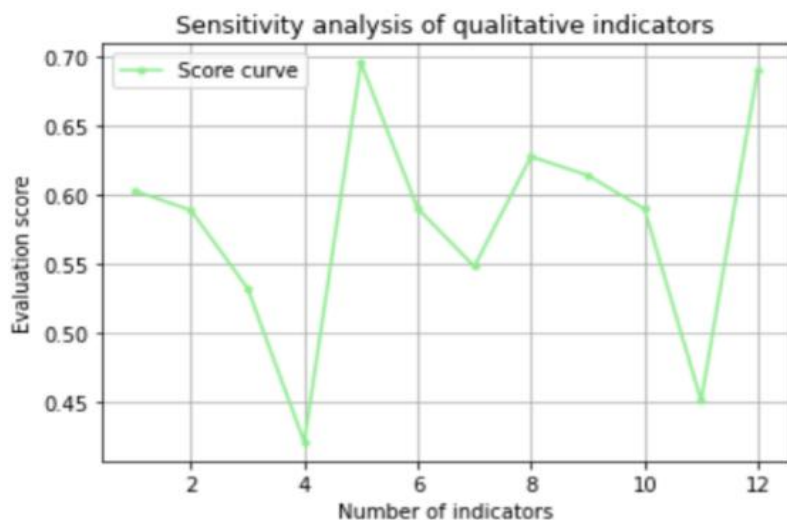


Figure 3: Sensitivity analysis of qualitative indicators

In this paper, we aim to provide insight into the role of qualitative factors in model decision-making and their sensitivity to assessment results by conducting a sensitivity analysis of the impact of the number of qualitative indicators on the assessment scores of the model. In the process, we analyse how changes in the number and weight of qualitative indicators affect the assessment scores output by the model by systematically adjusting them. This approach can reveal the stability and change pattern of the assessment results when facing different numbers of qualitative factors, and thus provide a theoretical basis for the improvement of the model. As shown in Figure 3.

Conclusion

The purpose of this project was to help the IOC judge which sports should be added to or removed from the Olympic Games by combining quantitative and qualitative data. We used an evaluation model that combines a number of criteria based on the core values of the Olympic Movement and assesses a number of factors such as the popularity, gender balance, sustainability, inclusiveness, relevance, innovation, and safety of individual sports.

In order to comprehensively assess the proposed projects, we used a multi-criteria decision analysis (MCDA) methodology, the Technique of Ideal Solutions (TOPSIS), a widely used model for complex decision-making problems that is capable of considering multiple evaluation criteria simultaneously. Our analysis combines subjective (qualitative) and objective (quantitative) metrics to measure how close each project is to the Ideal Olympic Project. Using this methodology, we calculated a score for each programme and ranked them accordingly. The top-ranked sports were recommended to be retained in the Olympic Games, while those with lower scores were considered for removal.

Three sports were evaluated; The results of our analyses show that Esports scores highly on popularity, young audience appeal and gender balance, particularly its growing popularity among younger groups and international participation. Esports' overall score supports its continued existence as an Olympic sport. 3x3 basketball performs strongly on popularity, inclusiveness and gender balance, particularly has a large fan base in countries such as Japan and the United States. However, 3x3 basketball's sustainability score is low, largely due to the high energy consumption associated with large stadiums and events. In addition, the relatively limited global popularity of 3x3 basketball affects its relevance and innovation in the Olympic Games. Based on these factors, the model suggests further scrutiny of 3x3 basketball's Olympic status. Coastal Rowing scores highly in terms of inclusivity, gender balance, and accessibility, particularly in terms of broad participation and low environmental impact amongst female athletes.

Despite this, Coastal Rowing's global popularity is low and its appeal to younger audiences is less favourable than other emerging sports. Based on these assessments, the model suggests that softball should remain an Olympic sport, but that continued attention needs to be paid to its future global popularity.

The model in this paper supports the flexibility and dynamism of Olympic programme selection. It emphasises sports that resonate with a global audience, promote gender balance, drive sustainability and ensure inclusivity and innovation. We believe that this analysis can provide a valuable reference for the IOC in its future Olympic programme decisions.

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