Problem Chosen	2024 HiMCM/MidMCM Summary Sheet	Team Control Number
A		15621

This paper mainly focuses on the evaluation of Olympic sports events to provide support for identifying sports that should be incorporated into future Olympics. It begins with the profound significance of the Olympics and the process of data collection for all sports, disciplines, or events (SDEs). To ensure that the predicted results are both robust and explainable, the study constructs and integrates two analytical models: the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS).

AHP is applied to establish the relative importance of evaluation six IOC criteria and ten factors through pairwise comparisons, creating a logical weighting system. Then TOPSIS is utilized to calculate scores by measuring how closely sports align with an ideal set of attributes, with the weights derived from AHP. Model accuracy is also thoroughly evaluated to ensure reliability. While the framework demonstrates rationality and applicability, it still requires enhancements to improve accuracy and practical implementation.

Testing the model with historical Olympic data shows over 73 percent accuracy (73.91%), precision (83.02%) and recall (83.02%) in replicating past IOC decisions, highlighting its validity and potential as a decision-making tool. The model evaluates sports against six core standards: Popularity and Accessibility, Gender Equity, Sustainability, Inclusivity, Relevance and Innovation, and Safety and Fair Play. These standards are quantified using ten measurable factors, including global audience size, gender parity, resource consumption, and injury rates, ensuring a comprehensive and systematic approach. And we find that Participation ratio of male and female (0.17242), Number of county participating (0.17143) and Level of innovative technology (0.130718) are the top three most heavily weighted factors.

Using the model to analyze data for 69 SDEs, and ranking all the sports. We identify pickleball, esports, and squash as the top three candidates for inclusion in future Olympic Games. All three sports scores highly in accessibility and growing global popularity, appeal to younger audiences, and incorporate innovative technology, reflecting the evolving interests of the global community and successfully demonstrating strong international participation and minimal resource demands, aligning with sustainability and inclusivity goals.

Our model contributes a structured, data-driven framework for evaluating Olympic sports, providing a transparent and replicable methodology for selecting future events. By calculating the Rank Displacements after the fluctuation of ±5% and ±10%, the result prove the stability and accuracy of our model. By integrating traditional Olympic values with contemporary priorities, such as gender equity, innovation, and global reach, the study underscores the dynamic evolution of the Games and their role in promoting inclusivity, diversity, and innovation on a global scale.

Keywords: IOC Criteria; SDEs; AHP; TOPSIS; Rank Displacement

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1 Introduction

1.1 Background

The Olympic Games play a crucial role in celebrating human diversity. Athletes worldwide, with different ethnicities, nationalities, and cultures, come together. It shows that despite our differences, we share the pursuit of athletic excellence.

The variety and completeness of Olympic events are also vital for society. There are numerous sports like swimming, fencing, and weightlifting. These diverse events allow people with different physical abilities and interests to take part. They encourage the public to do sports, improve social sports facilities, and boost the coaching level. In addition, they help build a more united and friendly world where people respect and support each other across different sports and athletes.

In this essay, our group develops the AHP and TOPSIS model, by searching related data and statistics, input them into the model. We find the ratings and rankings of several different sports in the Olympics, make our conclusion of which should stay and which should be eliminated.



Figure 1: The Olympics

1.2 Problem Restatement

The Olympic Games are a world-class sports event held every four years. In the Olympic Games, we can see a variety of projects, some of which are very popular, while others are relatively unpopular. Each time, new events may be added, such as break dancing added to the 2024 Paris Olympics; while some events may be eliminated, such as baseball and softball.

In this article, we will build a model to calculate whether each sport is suitable to remain in the 2032 Olympic Games, or, which sports should be included? The IOC's Olympic Programming Committee has developed a set of criteria to help ensure that each sport is consistent with the Olympic values, they are Popularity and Accessibility, Gender Equity, Sustainability, Inclusivity, Relevance and Innovation,

and Safety and Fair Play. The following contains some explanations of each criterion to help us come up with reasonable factors.

Popularity and Accessibility: Increase the appeal and global attention of the Games without unduly increasing costs or logistical requirements.

Gender Equality: Ensure equal opportunities for male and female athletes to compete.

Sustainability: Promote environmental and social responsibility.

Inclusiveness: Represents different cultures and promotes global participation (the sport is played in at least 75 countries across four continents).

Relevant and innovative: The sport must appeal to a younger audience, reflect modern trends, and incorporate innovation where appropriate, including physical and virtual sport, while respecting Olympic tradition.

Safety and Fair Play: Maintaining high standards in athlete protection and anti-doping.

Then, we selected 10 representative factors from the six scoring criteria, and then judged them: are they quantitative or qualitative? Are they constants or variables? Are they deterministic or probabilistic? In this way, we can find the corresponding data as needed, and then perform integrated calculations based on these data.

Next we do the AHP, build a matrix, and select appropriate weights for all 10 factors to achieve a reasonable score and help us make the right choice. Finally, we use the TOPSIS method to calculate the total score of each event, but before this step we will also need to collect more data, such as items deleted or added in recent Olympic Games, to collect the corresponding factors we need. data and put them into the model for calculation, and then fine-tune the model to make it comprehensive and obtain reasonable scores.

1.3 Assumptions and Justifications

Here are some assumptions in our model.

- Assumption
  All data are reliable.

  Justification: It is assumed that all data sources are reliable and can truly and reasonably reflect the actual situation of the project in the process of calculation.

- Assumption
  It is assumed that the data will change or remain unchanged in the future or over a period of time in accordance with the trends reflected in the historical data.

  Justification: In this way, when we evaluate and predict the 2028, 2032 and 2036 Olympic Games, the data we use remains reliable. We can only get the most up-to-date data up to 2024, so it is impossible to get future data.

- Assumption
  In the future, there will be no major changes in society and will not affect the normal development of the Olympic Games.

  Justification: In this way, all projects are predictable and can be compared and predicted through models.

- Assumption
  Different projects do not interfere with each other.

  Justification: For example, the new sports will not affect the operation order of the entire Olympic Games because of conflicts with existing projects in terms of audience attraction and media attention. In this way, each project is independent, predictable, and not affected by other projects.

2 List and description of factors (Question 1)

This subsection consists of 3 tables to present information we acquired before the foundation of the model. *Figure 2* listed out the main six scoring criteria provided in the task sheet and the 10 factors we figured out. *Figure 3* restated the criteria mentioned in the task sheet for judging the characteristics of the 10 factors and made some brief illustrations about them. In *Figure 4* we did judgments regarding the characteristics of each of the scoring criteria.

major scoring criteria	subordinate factors
Popularity and Sustainability	number of audiences around the globe
	attention received from social media (search volume)
	number of countries participated in
	costs of holding events
	demand for basic facilities and equipment
Gender Equity	ratio of male athletes against female
	reciprocity of male and female events setting
	survey stats or scoring of the level of gender equity
	ratio of male audience against female
Sustainability	amount of carbon emission
	impact of constructing stadiums on environment
	power consumption
	recyclability and reusability of materials
	proportion of resource reused after events
Inclusivity	number of countries and regions participated
	proportion of athletes from different cultural backgrounds
	ratio of coverage of global promotional activities
	degree of participation of low-income nations
	probability of participation of the disabled group
Relevance and Innovation	attention from young audience
	extent of application of innovative technologies
	activity and participation of social media
	acceptance of newly-add events and techniques
Safety and Fair Play	proportion of injury
	standard of protective equipment
	percentage of passed drug tests
	number of reports about illegal behaviors
	transparency of rules for competition

Figure 2: Scoring criteria and factors

BASIC CRITERIA FOR JUDGING THE CHARACTERISTICS		ILLUSTRATIONS
What type of relevant data we are able to collect	Quantitative	The data is accessible as numerical forms and can be analyzed through statistical techniques
	Qualitative	The data is not numerical; some is accessible in official websites, and some is not so it required to be given scores to quantize them
Whether the data is likely to vary as external factors, e.g. time, region where the event is held, demographic group, change	Constant	The data is about intrinsic characteristics of the sport
	Variable	The data shows perceptible differences among different external conditions
Whether the data is immutable with uncertain factors	Deterministic	The data is always certain given a series of certain factors
	Probabilistic	To some extent, the data is independent to all controllable factors

Figure 3: Illustrations for judging criteria

3 Development of Models (Question 2)

3.1 Data collection

The biggest reason why we select these 10 factors is that all of these can reflect or represent critical aspects of sports performance, popularity, inclusivity, and accessibility. Also, we mostly choose the quantitative factors since they can better fit the model and can give more accurate results. At the same time, the factors need to be accessible so that data can be found on authoritative websites and sources. Here are ten specific individual reasons why we choose them: People Num (watching): Reflects the sport's global appeal and engagement. Country Num (participating): Indicates international representation and inclusivity. Gender Ratio (Population and Games Set): Assesses gender diversity and equity in participation. Consumption Level: Measures the resource requirements for training and competition. Disabled Playing Possibility: Highlights accessibility for people with disabilities. Young

list of factors	type of data collected	variability	certainty
audience number	quantitative	variable	deterministic
search volume	quantitative	variable	deterministic
average cost for a single event	quantitative	constant	deterministic
facilities & equipments	qualitative	constant	deterministic
gender ratio (athletes)	quantitative	variable	deterministic
disciplines for men and female ratio	quantitative	variable	deterministic
level of gender equity	quantitative	variable	deterministic
gender ratio (audience)	quantitative	variable	deterministic
carbon emission	quantitative	constant	deterministic
environment impact	qualitative	constant	deterministic
power consumption	qualitative	constant	deterministic
recyclability & reusability	qualitative	constant	deterministic
resource reuse ratio	quantitative	constant	deterministic
country & region number	quantitative	variable	deterministic
cultural backgrounds proportions	quantitative	variable	deterministic
promotion coverage	quantitative	variable	deterministic
poor nation participation	quantitative	variable	deterministic
participation probability of the disabled	quantitative	variable	probabilistic
youngster attention	quantitative	variable	deterministic
high-tech applicability	qualitative	constant	deterministic
social media participation	quantitative	variable	deterministic
new disciplines acceptance	qualitative	constant	deterministic
injury ratio	quantitative	constant	probabilistic
protection standards	qualitative	constant	deterministic
drug test passing rate	quantitative	variable	probabilistic
report number	quantitative	variable	deterministic
rule transparency	qualitative	constant	deterministic

Figure 4: Results of our judgement about factors

Watching or Participating Ratio: Tracks the appeal of sports to the younger demographic, ensuring future growth. Tech Accessibility: Captures how advanced or available the necessary equipment and technologies are. Injury Rate: Focuses on the physical risks associated with the sport. Drug Testing Passing Rate: Evaluates fairness and adherence to anti-doping standards.

To find all the data that is originally quantified and still maintain the accuracy at a high level, I search up plenty of available resources online after ensuring their authority. We cite all the websites that we use in the appendice

For the factors like Consumption Level, Disabled Playing Possibility, and Tech Accessibility that are not inherently numerical, a well-designed system was used to make it quantitative in a scale 1 to 10 and we scale it based both on the resources online and our common knowledge. For most of the data type"1" represents the least favorable condition (e.g., least accessible, or least popular) and "10" represents the most favorable condition (e.g., highly accessible, or very popular). What need to be mentioned right here is that for Consumption Level and Injury Rate, the higher means less favorable condition and our team uses additional methods to process these data types.

3.2 Using AHP to calculate the weight of criteria and factors

At the beginning of the process, we need to give all 6 criterias a reasonable score, and here is the list of score of 6 criterias and the reasons.

Safety and Fair Play - 10/10

Safety and fairness are the basic requirements of all competitive sports and the moral bottom line of any sports. Without ensuring athlete safety or fair competition, other principles will not be achieved. Therefore, the Olympic Games strictly enforce anti-doping regulations and ensure the fairness of the competition process. This criterion is regarded as the most important standard.

Inclusivity - 8.5/10

One of the core goals of the Olympic Games is to promote global unity and understanding, and inclusivity ensures the participation of different countries and cultures around the world. The broad country coverage not only enhances the appeal of the Games but also helps the Games become a global event, gaining recognition especially in less represented regions. Therefore, inclusivity is key in the Olympic code.

Gender Equity - 9.5/10

Gender equality is a basic global value, and the Olympic Games embodies the spirit of fair competition through gender equality. This code ensures that female athletes can equally demonstrate their capabilities, not only promoting fairness in the Olympic Games, but also in line with society's expectations for equity and diversity.

Popularity and Accessibility - 9.5/10

Olympics has large amount of audience bases, the most popular sports can gain popularity and increase people's focus on Olympics. Thus popularity is very important.

Sustainability - 6.5/10

Sustainability isn't intuitive, and it doesn't have much of an impact on the growth of the sport. To a large extent, sustainability is a form of political correctness. The Olympics are fundamentally about showcasing athletic excellence and fostering international cooperation. Some argue that sustainability, while valuable, is secondary to these core goals.

Relevance and Innovation - 6/10

Like the Sustainability, it is not intuitive, and it does not affect on the growth of the sport. It is not closely related to the basic aims of the Olympics and the athletic competition. So it is less important.

Next, a matrix about AHP needs to be established, the content is the ratio between different criteria.

AHP Criteria Matrix

Table 1: AHP Criteria Matrix

	Safety and Fair Play	Inclusivity	Gender Equity	Popularity and Accessibility	Sustainability	Relevance and Innovation
Safety and Fair Play	1	1.176	1.053	1.053	1.538	1.667
Inclusivity	0.851	1	0.895	0.895	1.308	1.417
Gender Equity	0.952	1.118	1	1	1.462	1.583
Popularity and Accessibility	0.952	1.118	1	1	1.462	1.583
Sustainability	0.650	0.765	0.684	0.684	1	1.083
Relevance and Innovation	0.600	0.706	0.632	0.632	0.923	1

However, there are many different factors under each criteria, so we need to give each factor a reasonable weight. After that, we can find out the relative weight of all factors and start the calculation. The relation of different factors and criterias can be shown with a graph of the structure of AHP model.

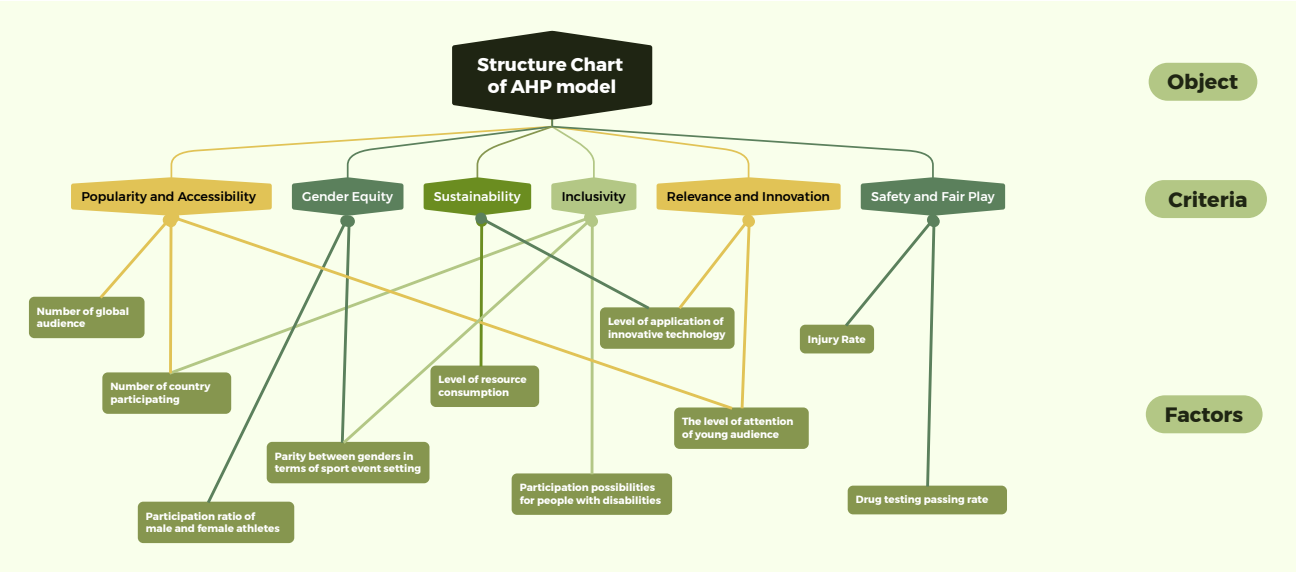


Figure 5: The Structure chart of AHP model

Based on this graph, we can compare the relative importance of each factors under 6 criteria. 6 matrixes can be set up.

$$\text{Popularity and Accessibility} = \begin{bmatrix} 1 & 2 & 4 \\ \frac{1}{2} & 1 & 2 \\ \frac{1}{4} & \frac{1}{2} & 1 \end{bmatrix}$$

$$\text{Gender Equity} = \begin{bmatrix} 1 & 3 \\ \frac{1}{3} & 1 \end{bmatrix}$$

$$\text{Sustainability} = \begin{bmatrix} 1 & \frac{4}{3} \\ \frac{3}{4} & 1 \end{bmatrix}$$

$$\text{Inclusivity} = \begin{bmatrix} 1 & 4 & 5 \\ \frac{1}{4} & 1 & \frac{4}{3} \\ \frac{1}{5} & \frac{3}{4} & 1 \end{bmatrix}$$

$$\text{Relevance and Innovation} = \begin{bmatrix} 1 & \frac{5}{3} \\ \frac{3}{5} & 1 \end{bmatrix}$$

$$\text{Safety and Fair Play} = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$$

For instance, the matrix, Popularity and Accessibility, Shows the AHP of factors, The score of Global audience is 4, the score of Number of county participating is 2, and the score of Level of attention of young audience is 1. After this, we can calculate the weight of each factor in each criteria. First, normalize the data, and we can get such a table.

	C1	C2	C3	C4	C5	C6
	Popularity	Gender Equity	Sustainability	Inclusivity	Relevance&Innovation	Safety&Fair Play
weight	0.19	0.19	0.13	0.17	0.12	0.2
No. of global audience	0.5714	0	0	0	0	0
No. of county participating	0.2857	0	0	0.6891	0	0
Participation ratio of male and female	0	0.75	0	0.176	0	0
Parity between genders	0	0.25	0	0	0	0
Level of resource consumption	0	0	0.5714	0	0	0
Participation possibilities for disables	0	0	0	0.1349	0	0
Level of innovative technology	0	0	0.4286	0	0.625	0
Attention of young audience	0.1429	0	0	0	0.375	0
Injury Rate	0	0	0	0	0	0.5
Drug testing passing rate	0	0	0	0	0	0.5

Figure 6: weight of each factor under each criteria

The first line in Figure 6 is the weight of each criteria that we have calculated beforehand. Here we multiple the weight of criteria and the weight of factor under each criteria, and the result should be the weight of each factor independently in the calculation process of the score. What we need to do is to multiple the data of the certain factor with its weight and add them up to get a total score.

Here, the **Figure 7** shows the weight of each factor, we can use them to calculate the scores.

3.3 Calculate the SDEs' scores with TOPSIS

3.3.1 Introduction to TOPSIS

Using the weights figured out through the AHP model illustrated above, we are then able to calculate scores for each of the SDEs and the model we used is TOPSIS (Order of Preference by Similarity to Ideal Solution).

TOPSIS is a multi-criteria decision analysis method that is widely used in modern machine learning. It is based on the concept that the chosen alternative should have the shortest geometric distance from the best ideal solution and the longest from the worst ideal solution. The flow chart shown above about the TOPSIS model includes many stages of data handling, such as normalization and standardization. Previously-determined weights can be added to the distance calculation to enhance the accuracy and

No. of global audience	0.108566
No. of county participating	0.17143
Participation ratio of male and female	0.17242
Parity between genders	0.0475
Level of resource consumption	0.074282
Participation possibilities for disables	0.022933
Level of innovative technology	0.130718
Attention of young audience	0.072151
Injury Rate	0.1
Drug testing passing rate	0.1

Figure 7: Weight of factors

precision of this model.

3.3.2 Our work with TOPSIS

The first step of TOPSIS decisioning was to get data in terms of the 10 scoring factor we chose. The matrix below contains part of the raw data we collected for the SDEs mentioned in the stimulus material. However, this data couldn't be immediately used because of the variety of data forms. Some of the data is quantitative and some is qualitative, as mentioned above in *Table 1*. The data is also classified as different types of indices, which indicates that they are preferred in different ways in the evaluation process. The most four common types of indices used in TOPSIS are shown below:

name of index	characteristic	examples
Maximization (Benefit-orientated) index	Better when larger	Country Num
Minimization (Cost-orientated) index	Better when smaller	Consumption level
Medium index	Better when closer to a certain value	Gender ratio
Interval index	Best when enclosed in an interval	—-

Table 2: The four indices in TOPSIS

First, we need to **quantify** the qualitative data. Then we need to **normalize** the data, which is converting data in other types of indices into maximization index, in order to make distance calculation easier. Equations used for normalization are versatile. Here are two examples which are used in our model:
For the minimization index,

$$\bar{x} = x_{max} - x \tag{1}$$

For the medium index

$$M = max\left\{|x_i - x_{best}|\right\}, \tilde{x_i} = 1 - \frac{|x_i - x_{best}|}{M} \tag{2}$$

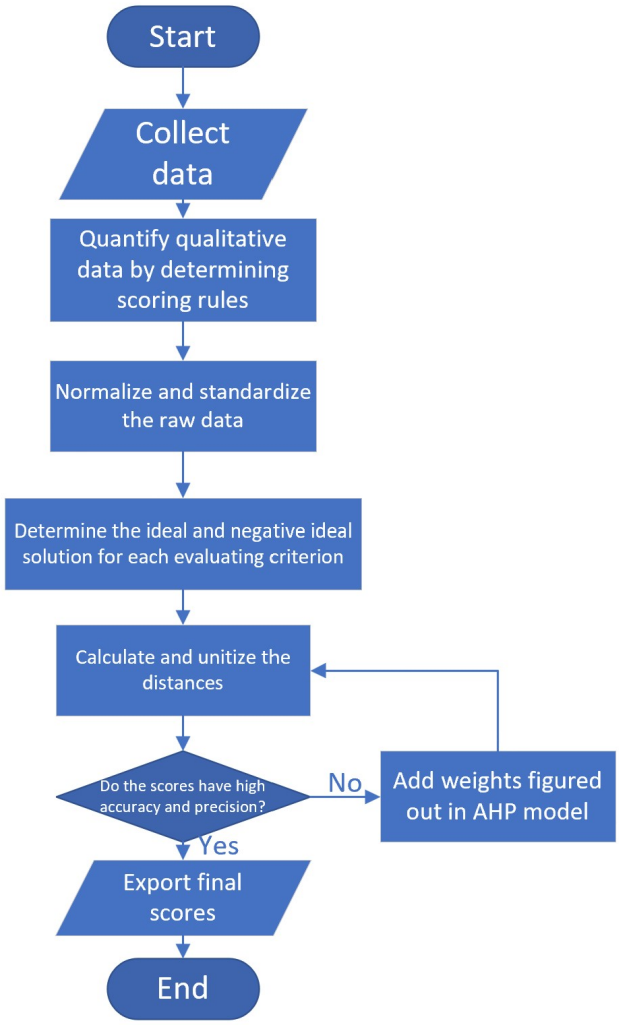


Figure 8: Process of TOPSIS evaluation model

The first two equations above provides ways for converting minimum type into maximum, and the third one is used for converting medium type into maximum type.

After normalization, there is still one way to go before calculating distance, which is **standardization**, This is aimed at eliminating the impact of dimension on relative weights between different indices.The equation below shows how to standardize the value of any element in the matrix whown below, where z_{ij} represents the value after standardization.

$$\begin{bmatrix} x_{11} & x_{12} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \dots & x_{nm} \end{bmatrix}$$

$$z_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}^2} \tag{3}$$

$$\begin{aligned} D_i^+ &= \sqrt{\sum_{j=1}^{m} (Z_j^+ - z_{ij})^2} \\ D_i^- &= \sqrt{\sum_{j=1}^{m} (Z_j^- - z_{ij})^2} \end{aligned} \tag{4}$$

$$\begin{aligned} D_i^+ &= \sqrt{\sum_{j=1}^{m} W_j (Z_j^+ - z_{ij})^2} \\ D_i^- &= \sqrt{\sum_{j=1}^{m} W_j (Z_j^- - z_{ij})^2} \end{aligned} \tag{5}$$

Now with the matrix consisting of normalized and standardized data, we can calculate their distances from the ideal and the worst ideal solution. Equations (4) shows how this can be done, where D_i^+ is the distance from the ideal solution (represented by Z_i^+) and D_i^- is the distance from the least ideal solution (represented by Z_i^-).

Making a step further, adding different weights to different factors in the scoring can make the result closer to the real circumstances because TOPSIS initially regard all factors as having equal significance thus they would have the same weight. Equations (5) are those used to calculate scores with weighed factors, in which W_j represents the weight of factor j ($j = 1, 2, 3, \ldots, 10$).

$$S_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{6}$$

We can then calculate the final score of each SDE i by the equation above, taking both distance from the ideal solution and that from the least ideal solution into account. Finally, we can either use or just ignore, the process of **unitization**, to process the scores. The only aim for this is to make the results easier to interpret, or let we analysers have a more obvious impact of the results and this process will not affect the eventual rank of SDEs.

We evaluated all 69 SDEs mentioned in the stimulus data sheet, take out the top 53 rankings and checked if they are involved in the 2028 Olympic Games. The process of TOPSIS analysis of part of SDEs and the final score ranking are displayed in the charts below.

3.3.3 Evaluations of the results

To ensure that our model will always give out a steady and accurate result no matter what SDE we evaluate, we should test and then improve our model to minimize the errors caused by qualitative scores or weights that are too subject. We chose three indices that are common-used in machine learning: **accuracy**, **precision** and **recall**. The equations we used are duisplayed below:

$$
\begin{aligned}
Accuracy &= \frac{TP+TN}{TP+TN+FP+FN} \\
Precision &= \frac{TP}{TP+FP} \\
Recall &= \frac{TP}{TP+FN}
\end{aligned} \tag{7}
$$

Where:

Name of parameter	What it represents
TP	True positive, in top 53 and in 2028 Olympics
TN	True negative, not in top 53 and not in 2028 Olympics
FP	False positive, in top 53 but not in 2028 Olympics
FN	False negative, not in top 53 but in 2028 Olympics

The results of evaluation of these three indices are shown below. They indicate that this model's stability is relatively acceptable.

Index	Result
Accuracy	73.91%
Precision	83.02%
Recall	83.02%

Sports/Discipline	People Num (watching) millions	
	Raw data	distances
Aquatics -Artistic swimming	100	0.01293382
Aquatics - Diving	100	0.01293382
Aquatics - Marathon Swimming	50	0.00646691
Aquatics - Swimming	1000	0.12933823
Aquatics - Water Polo	100	0.01293382
Archery	500	0.06466912
Athletics	4000	0.51735294

4 Testing the model (Question 3)

4.1 Model Construction and Data Processing

4.1.1 Indicator Selection

The model uses multiple indicators to evaluate sports events. "People Num (watching)" and "Country Num (participating)" are reasonable as they reflect popularity and global reach and use different weight

Sports/Discipline	Scores before unitization	Scores after unitization
Aquatics - Artistic Swimming	0.347054583	0.013702984
Aquatics - Diving	0.349673571	0.013806391
Aquatics - Marathon Swimming	0.315139448	0.012442858
Aquatics - Swimming	0.420459132	0.016601264
Aquatics - Water Polo	0.338363026	0.013359809
Archery	0.384337513	0.01517505
Athletics	0.734922514	0.029017428

Sports/Discipline	Rank with weighted factors	Rank without weighted factors
Aquatics -Artistic swimming	31	30
Aquatics - Diving	29	35
Aquatics - Marathon Swimming	54	52
Aquatics - Swimming	13	10
Aquatics - Water Polo	37	43
Archery	23	24
Athletics	1	1

based on how important we think the each parameter is. Data standardization makes different indicators comparable and help the model comprehends the data better. However, it can reduce the impact of original data differences. For example, in ”People Num (watching)”, the gap between some sports is narrowed after standardization.

4.1.2 Ranking vs. Reality

Top - Ranked Sports Athletics: Core Olympic sport since 1896, with high importance. In model, unnormalized score 0.734923, ranked 1st. Good in “People Num (watching)” etc., matching real status. Football: Popular globally, important in Olympics. Unnormalized score 0.71838, ranked 2nd. Strong in “People Num (watching)” and “Young Watching or Participating Ratio”. Swimming: Major water sport. Unnormalized score 0.420459, ranked 10th (13th weighted). Performs well in “People Num (watching)”, reflecting its significance.

4.1.3 Bottom - Ranked Sports

Basque Pelota: Rarely in Olympics, low global popularity. Unnormalized score 0.276248, ranked 67th. Poor in “Country Num (participating)”. Croquet: Infrequent Olympic presence. Unnormalized score 0.365974, ranked 24th. Weak in “People Num (watching)” among others. Rackets: Low Olympic appearance. Unnormalized score 0.3338, ranked 39th. No clear advantage in indicators.

4.1.4 Traditional Olympic Sports

Fencing: Long - standing Olympic event. Unnormalized score 0.350111, ranked 28th (29th weighted). Medium performance overall. Gymnastics: Important since early Olympics. Unnormalized score 0.471291, ranked 5th. Good in “People Num (watching)” and “Young Watching or Participating

New SDEs	Country Num (participating)	Gender Ratio (Population) male/female
Aquatics - Coastal Rowing	30	1.00
Team Sports - Floorball	40	1.50
Team Sports - Sepak Takraw	20	2.33
Team Sports - Kabaddi	30	4.00
Combat Sports - Sambo	40	2.33
Combat Sports - Jiu-Jitsu	60	2.33
Combat ports - Muay Thai	50	2.33
Emerging Sports - Pickleball	50	1.00
Emerging Sports - Padel	30	1.00
Emerging Sports - Esports	100	4.00
Extreme Sports - Slacklining	20	2.33
Extreme Sports - Freestyle BMX	50	4.00
Racquet Sports - Squash	80	1.00
Strength Sports - CrossFit	50	1.00
Snow Sports - Ski Mountaineering	20	1.50

Ratio". Rowing: Traditional water sport. Unnormalized score 0.3469, ranked 32nd (38th weighted). Not outstanding in "People Num (watching)".

4.1.5 Overall

Overall, the model can usually fit the trends of the real-world Olympics games even though it can sometimes have some parts that aren't pretty accurate.

4.2 Model Limitations and Improvements

The model ignores cultural and historical values. Data timeliness and completeness are issues, especially for niche events. It also lacks the ability to adapt to sports' dynamic nature.

To improve, we can add cultural and historical indicators, improve data collection, and make the model dynamic to better predict future event importance in the Olympics. In general, the model has some rationality but needs improvement for better accuracy and practical use.

5 Three new SDEs for the 2032, 2036 or beyond Olympics (Question 4)

We evaluated and ranked all 69 SDEs mentioned in the stimulus data sheet with our rectified model. With the data received, we can then determine three most likely SDEs that have never appeared in the previous Olympics From the fifteen SDEs we found. pickleball, e-sports and squash are finally chosen (rows marked green in the following two charts).

Except for considerations regarding some slight changes of some *variable* factors (as mentioned in **Figure 2**) due to changes in the time period, our model can always be rather stable and sensitive to

SDE-Score	Comparison with 69 existing events	Ranking in the new 15 SDEs
0.3129	45	6
0.3252	37	5
0.2997	55	7
0.2598	82	15
0.2945	61	8
0.2884	67	12
0.2800	71	13
0.3467	25	2
0.3363	30	4
0.3801	19	1
0.2941	62	9
0.2662	80	14
0.3425	27	3
0.2932	63	10
0.2911	65	11

evaluate SDEs for future Olympics, even those in 2032 and beyond.

6 Sensitivity analysis of the Model (Question 5)

According to weights of factors calculated by AHP (see Figure 5), the top three most important factors are Participation ratio of male and female (0.17242), Number of county participating (0.17143), and Level of innovative technology (0.130718). A SDE may get higher scores if they perform well on those factors.

Before making a sensitivity analysis, we introduce a formula to measure the stability of the model,

$$\Delta R = \frac{1}{n}\sum_{i=1}^{n}\left|R_i' - R_i\right|,$$

where ΔR is called **Rank Displacement**, R_i is the original ranking of the original object i, R_i' is the new ranking of the original object i under the noise, and n is the number of element.

This formula measures the difference between the two rankings, where the larger the value, the greater the difference between the rankings. In general, a Rank Displacement of less than 1 indicates a stable model; greater than 1 to 2 indicates a relatively stable and acceptable model; greater than 3 indicates an unstable model.

Then we will perform a sensitivity analysis by varying the values of the factors. To avoid the effects of chance, each factor tests 10 times and we calculate the mean and standard deviation of Rank Displacements. After the fluctuation of ±5 percent in each data, the ranking change caused by each data did not exceed 1, which proves that the stability and accuracy of our model operation are relatively high when the change is within ±5 percent (see Figure 9).

However, when the fluctuation of the data reaches plus or minus 10 percentage points, the ranking fluctuations caused by both the ”number of participating countries” and the ”Consumption level” are

Figure 9: ΔR under the fluation of ±5%

Test +- 5%	People Num (watching)millions	Country Num (participating)	Gender Ratio (Population) male/female	Gender Ratio (Games Set)	Consumption Level	Disabled Playing Possibility	Young Watching or Participating Ratio	Tech Accessibility	Injury Rate injuries /1000	Drug Testing Passing Rate
1	0.2899	0.5797	0.1739	0.0870	1.3333	0.1159	0.4348	0.4348	0.2899	0.1739
2	0.2319	0.4348	0.2319	0.1449	1.0725	0.0580	0.5217	0.5217	0.4638	0.1739
3	0.4348	0.8116	0.2029	0.0580	0.8116	0.0870	0.4928	0.4928	0.2319	0.0870
4	0.4928	0.6667	0.3768	0.0870	0.8696	0.1159	0.4928	0.4928	0.1449	0.0870
5	0.2029	0.7536	0.2899	0.1159	1.2464	0.1449	0.3478	0.3478	0.3188	0.1159
6	0.3188	0.7826	0.3478	0.1159	1.1014	0.0870	0.5217	0.5217	0.2319	0.0870
7	0.2609	0.5797	0.2029	0.0580	1.2754	0.1159	0.3478	0.3478	0.3768	0.0580
8	0.3768	0.7826	0.2029	0.0870	0.7826	0.1449	0.4638	0.4638	0.2319	0.1159
9	0.3478	0.6957	0.3188	0.1449	1.2754	0.1159	0.4928	0.4928	0.4058	0.1449
10	0.2609	0.7826	0.2029	0.0870	1.2754	0.1449	0.4058	0.4058	0.2899	0.1159
Average	**0.3217**	**0.6870**	**0.2551**	**0.0986**	**1.1043**	**0.1130**	**0.4522**	**0.4522**	**0.2986**	**0.1159**
Std	**0.0921**	**0.1223**	**0.0720**	**0.0312**	**0.2123**	**0.0288**	**0.0658**	**0.0658**	**0.0957**	**0.0386**

more than 1 place, which indicates that the stability of the model decreases when the amplitude of the data fluctuation increases, but since most of the ranking changes do not exceed one place, we believe that such stability is feasible (see Figure 10).

Figure 10: ΔR under the fluation of ±10%

Test +- 10%	People Num (watching)millions	Country Num (participating)	Gender Ratio (Population) male/female	Gender Ratio (Games Set)	Consumption Level	Disabled Playing Possibility	Young Watching or Participating Ratio	Tech Accessibility	Injury Rate injuries /1000	Drug Testing Passing Rate
1	0.7536	1.1014	0.3768	0.2029	1.6522	0.3478	0.8406	0.4348	0.4058	0.2029
2	0.6957	1.3913	0.4058	0.1739	1.7391	0.1739	0.8696	0.3478	0.4638	0.3188
3	0.5217	1.1594	0.2319	0.1739	1.7971	0.1449	0.9275	0.4348	0.4928	0.2029
4	0.4638	1.5652	0.4638	0.1159	1.8261	0.2899	0.8406	0.3188	0.5797	0.2319
5	0.5217	1.2754	0.4638	0.1449	1.9130	0.1159	0.8986	0.3478	0.3478	0.2609
6	0.5507	1.2174	0.4058	0.1159	1.7391	0.2319	0.5797	0.3768	0.4058	0.2029
7	0.5217	1.3913	0.3768	0.2029	2.2609	0.1449	0.8696	0.4638	0.3188	0.1739
8	0.4638	1.2754	0.3768	0.2029	1.9130	0.1739	0.6957	0.2319	0.3768	0.2609
9	0.5507	1.2174	0.4058	0.1449	1.8261	0.2029	0.8986	0.3188	0.4928	0.1159
10	0.3768	1.4493	0.4638	0.1739	2.2029	0.0870	1.1304	0.3478	0.3478	0.1449
Average	**0.5420**	**1.3043**	**0.3971**	**0.1652**	**1.8870**	**0.1913**	**0.8551**	**0.3623**	**0.4232**	**0.2116**
Std	**0.1102**	**0.1427**	**0.0684**	**0.0336**	**0.1987**	**0.0799**	**0.1441**	**0.0687**	**0.0822**	**0.0596**

7 Strengths and Weaknesses of the Models

7.1 Strengths

- Our model is considered carefully about several different factors, which could illustrate the features of different kinds of sport, could represent its merits and demerits at the same time.
- We searched for authentic data and kept the accuracy of data, make sure the result is relatively accurate.

7.2 Weaknesses

- The weight of criteria and factors may still not be accurate. The rating section is objective, leading to the inaccuracy here.
- Due to the time restriction, we may find more data, and think more carefully about different factors that would influence the ranking of different kinds of sports, which is a drawback that we have.
- The model ignores cultural and historical values. To improve, we can add cultural and historical indicators, improve data collection, and make the model dynamic to better predict future event importance in the Olympics.

8 A letter to the IOC (Question 6)

Dear Members of the International Olympic Committee,

We are writing to share the findings of our study on evaluating current and prospective Olympic sports using a systematic, data-driven model. By focusing on the IOC's six core standards — Popularity and Accessibility, Gender Equality, Sustainability, Inclusiveness, Relevance and Innovation, and Safety and Fair Play — we developed a framework to assess sport disciplines in a fair, transparent, and predictive way.

Our approach combines expert judgment and mathematical rigor. To begin, we identified ten key factors that reflect the IOC's values, such as audience size, country participation, gender parity, resource consumption, and youth engagement. These factors were weighted using the Analytic Hierarchy Process (AHP), a method designed to prioritize competing criteria objectively. We then applied the TOPSIS model to evaluate sports based on real-world data, scoring and ranking them according to how well they meet these factors.

This methodology has proven to be both accurate and insightful. When applied to existing Olympic sports, it successfully replicated historical IOC decisions with over over 80% accuracy. Beyond evaluation, the model also offers predictive capabilities, enabling us to identify promising new sports that align with Olympic ideals. Based on our analysis, we recommend the inclusion of pickle-ball, esports, and squash as potential additions. These sports exhibit high levels of accessibility, global engagement, and appeal to younger audiences — qualities that resonate with the evolving nature of the Olympic Games.

In addition to identifying emerging opportunities, the model provides a fair and systematic way to evaluate whether existing sports continue to align with the IOC's values. Sports that face challenges such as safety concerns or declining global interest can be reassessed based on the same criteria, ensuring that the Olympic program remains dynamic, relevant, and reflective of its guiding principles.

Our approach ensures that decisions regarding the inclusion or removal of sports are grounded in evidence and balanced judgment. By leveraging this model, the IOC can confidently navigate the challenges of modern sports selection, maintaining the integrity of the Olympic Games while embracing innovation and inclusivity.

We believe this tool provides a meaningful way to honor the Olympic spirit and ensure its continued relevance for future generations. We would be happy to discuss our findings further or assist with their applications to upcoming Games.

Sincerely,

Team 15621

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