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Original Paper

Modeling the Future Olympic Games by Entropy Evaluation

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Abstract

The goal of the IOC is to increase the number of sports, disciplines and events (SDEs), that resonate with modern values and appeal to a global audience (SDEs) to keep the Games relevant and influential. To evaluate which SDEs should be added to or removed from the 2032 Summer Olympics. We will create several mathematical models to evaluate SDEs against these criteria to provide sound recommendations. The model will be used for quantitative decisions to determine which SDEs are best suited to the evolving vision of the Olympic Games.

In problem 1, there are five factors which are comprehensive global participation, gender ratio, environmental factors (carbon emissions, water use, ecological impact, energy use, waste use), cultural impact and attractiveness. Each factor is considered as a variable in these models. And the properties of these variables are supposed to be determined. Some are quantitative and some are qualitative. And some are constant, some are variable. In the five factors: comprehensive global participation is constant and quantitative. Gender ratio and environmental factors are variable and quantitative. Cultural impact and attractiveness are constant and qualitative.

In problem 2, according to the factors, we build up a model or several models to evaluate the effects of these factors to the SDEs. And through the models, we get scores that can be used to help IOC to find whether the SDEs can meet the needs of the IOC or not and whether they can be added in the future Olympics Games or not.

In problem 3, the models will be tested on at least three SDEs added or removed from the most recent Olympic Games (i.e., the 2020, 2024, and 2028 Games), as well as at least three SDEs that have appeared in consecutive Olympic programs since the 1988 Olympics or earlier. The data in HiMCM_Olympic_Data.xlsx provides information on the sports and disciplines that have appeared in each Olympic Games since the formation of the modern Olympic Games, as well as the number of events. The general applicability of the model is highlighted by selecting different sets of SDEs for evaluation. These models confirm the current Olympic status of these SDEs. The Fuzzy Comprehensive Evaluation Model can be used to calculate the entropy of each influencing factor of a sport, then calculate their *respective weights, and finally calculate the total score of the sport and compare it with the standard score to see weather the sport can be added.*

In problem 4, identify three SDEs that could be added to as part of the 2032 Brisbane Games and list them first, second and third. In addition, there are other SDEs that should be determined whether they can be added to Olympics Games in 2036 and beyond. As result, there are two SDEs added to Olympics in 2036.

In problem 5, by using the method model TOPSIS, the models are able to calculate the respective weights of each factor, and the models will be performed a sensitivity analysis to address the robustness of the model and determine that the weight of what aspects of the model is high, and discus that doesn't the high weight of the aspect affect the model a lot. Then, through the discussion, it can response the strengths or weaknesses of our model. Especially, when the aspect is seen as a decision-making tool to the SDEs.

In problem 6, writing a letter to conclude the results of all the models about SDEs and summarize the findings in a non-technical way. In addition, it should include our recommendations for which SDEs to add or remove and give an explanation why these models can support these conclusions. As a result, the models can well support these results.

One of the contributions of this paper is the creation of a mathematical models to evaluate SDEs to determine whether they fit the requirements of IOC and be added to the future Olympics Games.

Keywords

SDEs, IOC's Standard, Fuzzy Comprehensive Evaluation Model, TOPSIS

1. Introduction

The International Olympic Committee (IOC) is planning to hold the 2032 Summer Olympics in Brisbane, Australia. As the Olympic Games grow, the IOC aims to maintain the relevance and impact of the Games by adding sports, events or competitions (SDEs) that resonate with modern values and appeal to a global audience. Throughout the history of the Olympics, SDEs has been introduced, removed, and even reintroduced to reflect the times. In 2020, for example, karate, sport climbing, surfing and skateboarding make their Olympic debuts. However, karate is no longer an event at the 2024 Paris Olympics, and break dancing (also known as break dance) has been introduced. Looking ahead to the 2028 Games in Los Angeles, flag football, lacrosse and coastal rowing will be added, while baseball and softball will return to the 2028 Games after a 20-year absence. To guide these decisions, the IOC's Olympic Project Commission has developed a set of criteria to help ensure that each sport is in line with Olympic values.

1.1 Question Restatement

- **Question 1**

Find several appropriate factors that probably affect evaluating the SDEs, and describe whether they are quantitative or qualitative, constant or variable, deterministic or probabilistic.

- **Question 2**

Build a model to determine how the factors affect evaluating the SDEs, and find which of them can fit the requirements of IOC.

- **Question 3**

Bring some of the SDEs into our model to rest our model, and then bring other SDEs into our model to evaluate whether they can be added to the future Olympics Games. In addition, explain how our model affirms these SDEs' current Olympic status

- **Question 4**

Predict which of the SDEs can be added or introduced in the Olympics Games in 2032 and 2036.

- **Question 5**

Build up a new model to perform sensitivity analysis to address the robustness of your model, and determine which of the factor has the most effect, explain why.

- **Question 6**

Write a letter addressed to the IOC summarizing your findings in a non-technical way, including the results of our model, our suggestions and why our model can support the conclusions.

1.2 Our Work

The problem requires us to study the evaluation factors and evaluate SDEs against these criteria to provide sound recommendations. These will be used for quantitative decisions to determine which SDEs are best suited to the evolving vision of the Olympic Games.

- **Question 1**

By referring to several previous Olympics Games, we conclude five main factors that will impact the SDEs to meet the requirements of IOC.

- **Question 2**

We make two models, but we eventually decide to use the second model which is gray prediction model. And we can bring data of SDEs into the model in order to help IOC to evaluate which SDEs can meet their requirements.

- **Question 3**

We choose three SDEs (swimming, cycling, athletic) which are continuously exist in the Olympics Games from 1988 to 2024 to figure out the standard point line, which is used to determine which SEDs can be added or removed. Also, we choose another three SDEs (baseball, karate, BMX freestyle) which are currently reintroduced in the Olympics Games, and with the previous three SDEs, then we bring their data into the model to test the model. In the end, we evaluate its general adaptation through the results.

- **Question 4**

Through the gray prediction model calculation, we get three SDEs (surfing, skateboard, e-sport) that can be reintroduced or added in the Olympics Games in 2032, and we rank them, which can be considered first (e-sport), second (skateboard) and third (surfing). In addition, we build a new gray prediction model to predict other SDEs that can be reintroduced or added in the Olympics Games in 2036. And the result is that we find that climbing and break dance can be added in the Olympics Games in 2036. This is because their predicted values are always increasing.

- **Question 5**

In this question we use the method of distance of good-gad solution (TOPSIS)[3][4]. This method can figure out the different weights of each factor in our model. The factor that has the biggest weight means that the factor takes more points than others. Given this factor, we can conclude the benefits and disadvantages of the model.

- **Question 6**

Given the conclusions in the previous five questions, we evaluate the general result, and give some suggestions. In the end, based on the features and the principles of our models, we should explain why they are able to support the result.

2. Assumptions and Justifications

To simplify the problem, we make the following basic assumptions, each of which is properly justified.

- **Assumption 1:** the SDEs are only affected by the five factors that we give, other factors don't make any difference.
- **Justification:** we only consider the five factors in our models.
- **Assumption 2:** in the gray prediction model, the total scores of the SDEs coefficient is 100.
- **Justification:** the sum of the weight of each factor is 1.
- **Assumption 3:** the Olympics Games will always operate successfully. They will never be canceled or postponed by emergency, such as extreme weather or epidemic situation etc.
- **Justification:** Tokyo Olympics Games in 2022 was remitted to 2023.

3. The Development of Models

3.1 Notations

Table 1. Notations

Symbols	Description	Unit
TS	Total score	None
GPS	Global participation score	None
GS	Gender score	None
ES	Environmental score	None
CS	Cultural score	None
AS	Attractiveness score	100 million US dollars
NOC	Number of countries	None
NOP	Number of players	None
NOE	Number of events	None
NOIFM	Number of international federation members	None
W_x	Data of x part	None

PG	Proportion gap	None
M	The amount of male exercise	None
F	The amount of female exercise	None
PMR	The number of positive information reports published by the media	None
PAC	The number of positive audience comments	None
V	The value of that economic growth of the Olympic Games minus the input cost of Olympic Games	None
np	Number of players	None
SPL	Standard point line	None

3.2 Model Overview

To evaluate which SDEs should be added (or possibly removed) to the 2032 Summer Olympics. We will create a mathematical model to evaluate SDEs against these criteria to provide sound recommendations. The model will be used for quantitative decisions to determine which SDEs are best suited to the evolving vision of the Olympic Games and to consider which SDEs should be chosen by their total scores.

In summary, the whole modeling process is shown in Figure 1.

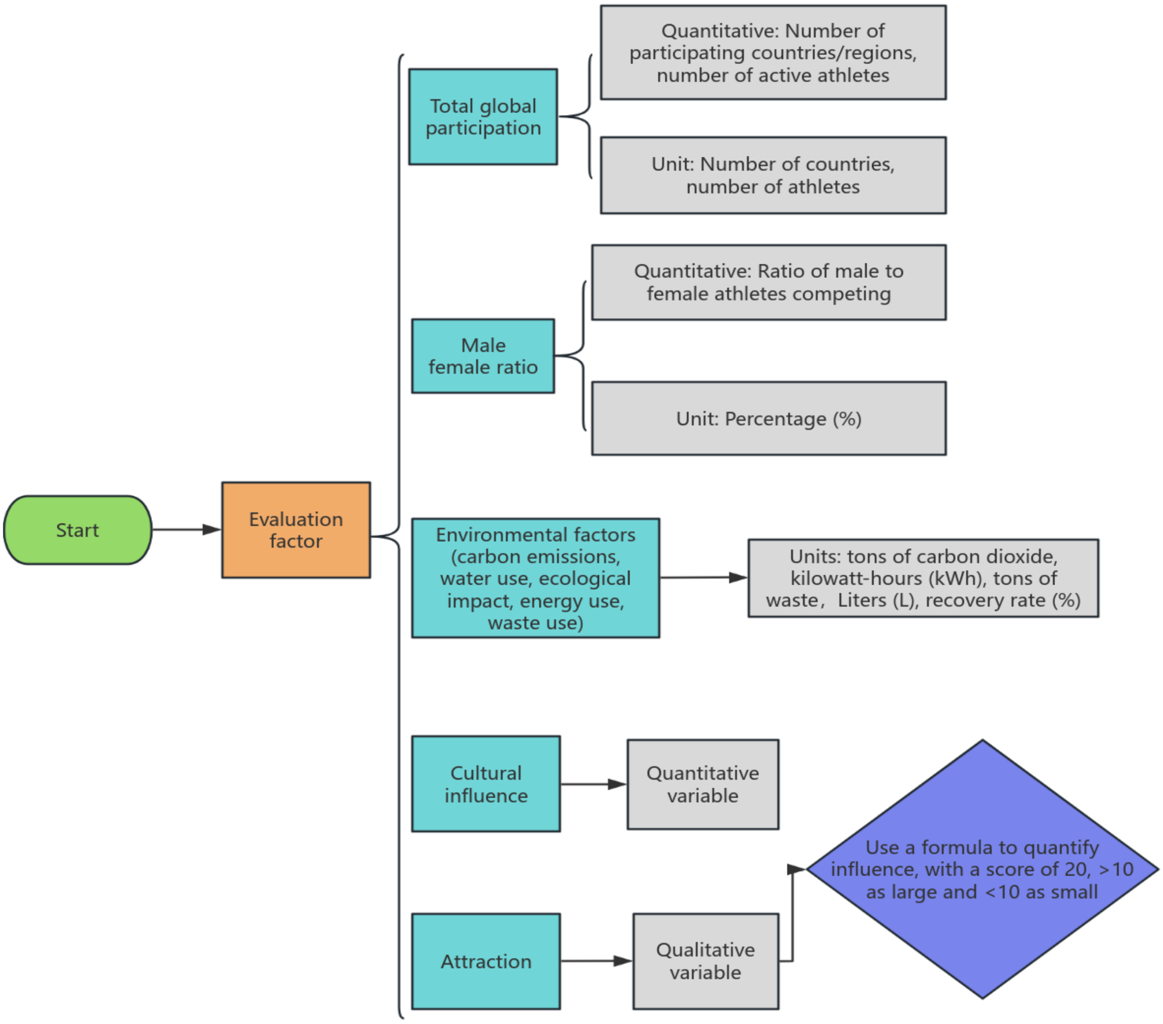

Figure 1. Model Overview

Step 1: We evaluated the influencing factors of the evaluation score from five aspects, namely the number of athletes participating in the competition, the ratio of male and female athletes, the impact on the environment (water use, carbon emissions, ecological impact, energy utilization), cultural impact, and attractiveness.

Step 2: For each aspect, we considered one or two aspects for evaluation. Regarding the number of athletes participating in the competition, we searched for how many countries participated in the six events and how many athletes participated in total; For the ratio of male and female athletes, we searched for the proportion of male and female athletes participating in each event, and then calculated their ratio. For the environmental impact factors, we evaluated them from four aspects, namely water use, carbon emissions, ecological impact, and energy utilization. For these four aspects, we scored them based on their degree of environmental damage. If the impact is relatively low, the evaluation score can be given 4 points. If the impact is significant, the evaluation score can only be 1 point. For the last two aspects of cultural influence and attractiveness, their influence is diverse.

Step 3: For each project with different data, we will calculate an evaluation score based on the above standards, and then use this evaluation score to see how inclusive the project is internationally.

Step 4: Finally, we will add up all sides of the evaluation sport's score to obtain a total score, and then compare it with a standard point score to determine whether the sport could be chosen.

4. Problem 1: Factors for Addressing the IOC Criteria

4.1 Overview

We consider the scoring factors to be **comprehensive global participation, gender ratio, environmental factors (carbon emissions, water use, ecological impact, energy use, waste use), cultural impact, attractiveness.**

Global participation directly reflects the global popularity of a movement. When a sport is widely played in multiple regions and countries around the world (especially 75 countries on four continents), it can increase the global appeal of the Olympic Games. Increasing global participation means that more viewers can watch the game on TV or online without incurring too much additional cost and logistical burden. Wider global participation also indicates that the popularity of the campaign has been achieved without adding unnecessary logistical requirements.

The **sustainability** and **environmental impact** of sports can affect the overall accessibility of the Games. If a sport has a low environmental impact (e.g. low carbon emissions, low resource consumption, etc.), it can reduce the cost and logistical requirements of event operations. Therefore, environmental factors are directly related to not adding too much logistics costs.

The implementation of **gender equality** has increased the popularity of sports. In gender-equal sports, both male and female athletes have the same opportunity to participate, which broadens the audience of the sport and increases overall audience interest and participation, thus contributing to the appeal of the Olympic Games.

Trends in modern society have fueled the popularity of new sports (such as e-sports, break dance, etc.) that appeal to a younger audience. The participation of young people not only makes the audience of the event more diverse, but also makes the event more innovative and attractive.

Cultural influence is crucial in this process, as it can reflect a society's interest and enthusiasm for an emerging movement.

The **global comprehensive** participation is a constant quantity, and the ratio of men to women is a quantitative variable and is variable. Environmental factors are variable and will vary from year to year with the Olympics. Cultural influences are also quantitative variables. Attractiveness is a qualitative variable, which is large or small influence, but we use the formula to quantify the influence, with a full score of 20, greater than 10 is large, and less than 10 is small.

4.2 Factor Analysis

To ensure that each sport is in line with the Olympic values, the mind map below shows a summary of the IOC standards for the entire sport and what factors to consider when dealing with the IOC standards.

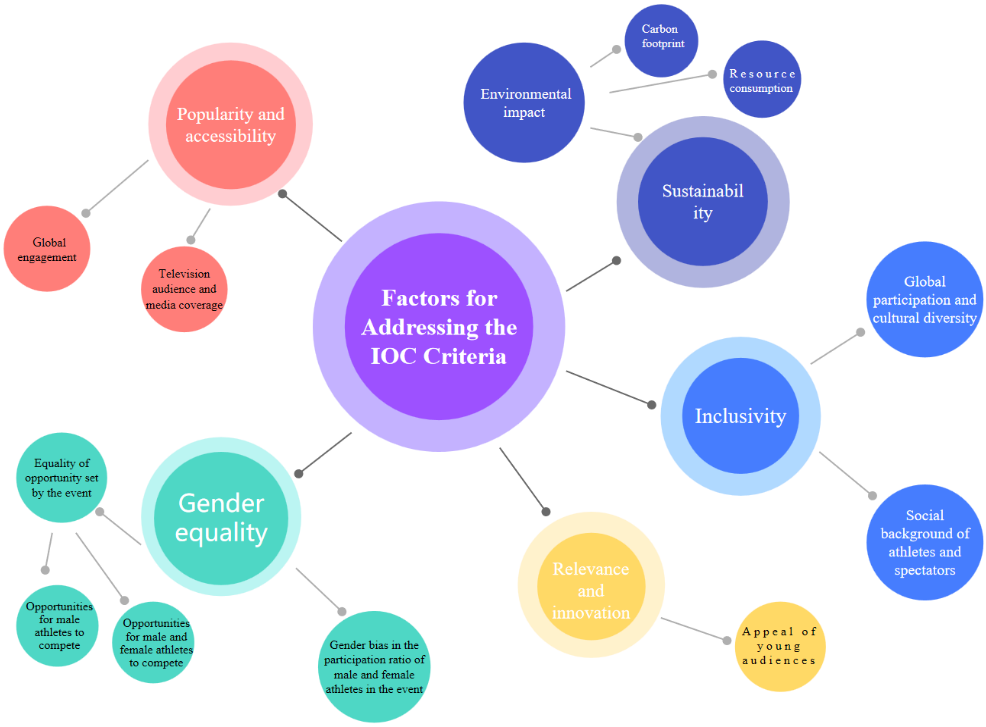

Figure 2. Factors for Addressing the IOC Criteria

1. **Popularity and Accessibility**

One of its factors is global engagement - a measure of the movement's global reach, specifically the participation of different regions and countries. The quantification is the number of participating countries/regions and the number of active athletes. The units are the number of countries and the number of athletes. Reliability is relatively certain, as it is usually measured by data from international sports organizations. Another factor is television audience and media coverage - the number of television viewers for the sport and whether there is enough international media attention. Quantitative: Global TV audience, social media following, number of sponsors. The unit is the number of viewers, social media interactions. This is a probabilistic factor, and reliability can be affected by a variety of external factors (such as game time, media market, etc.).

2. **Gender Equality**

The factor is whether there is a gender bias in the participation ratio of male and female athletes in the event. The quantification is the ratio of male to female competing athletes. The unit is percentage (%). With certainty, the data is relatively easy to obtain and is fixed, another factor is the equality of opportunity set by the event - whether it provides equal opportunities for male and female athletes to compete. Qualitative: Whether the event has equal events and MEDALS for men and women. Reliable and deterministic because it depends on the structural design of the event.

3. **Sustainability**

The factor is the environmental impact - the impact on the environment during the organization of the event, such as carbon footprint, resource consumption, etc. Quantification is carbon emissions, energy consumption, waste generation. Units are tons of carbon dioxide, kilowatt-hours (kWh), and tons of waste. It is probabilistic and needs to be estimated according to the scale and infrastructure of the event, with certain uncertainty. Resource consumption and recycling - the efficiency of the use of resources and the recycling and reuse of waste during the event. Quantified is water and energy consumption, waste recovery rate. Units are liters (L), kilowatt-hours (kWh), recovery rate (%). With probability, the specific consumption depends on the actual operation of the event.

4. **Inclusiveness**

Global participation and cultural diversity - whether the sport is able to reach across cultural and regional differences to attract athletes and spectators from different backgrounds. Quantitative is the number of participating countries, Cultural diversity index unit is the number of countries, cultural diversity index (e.g. Helfen formula). It is reliable and relatively certain, as it can usually be assessed through international data and survey reports. The social background of athletes and spectators - whether the economic and social background of athletes and spectators reflects social inclusion. Be identified as the athlete's financial source, whether there are athletes from low-income countries. It is probabilistic and may depend on the local social-economic situation.

5. **Relevance and Innovation**

The factor is the appeal of young audiences - whether the sport can attract the interest of young people, especially Generation Z. Quantified is the proportion of young viewers and social media interaction data. The unit is audience age distribution and number of social media interactions. It is probabilistic and depends on cultural trends and social changes, and there may be some uncertainty.

5. Problem 2: Entropy Evaluation Model for Scoring SDEs

In order to evaluate the best conformity to the Olympic criteria, we use five aspects:

$$TS = GPS + GS + ES + CS + AS. \tag{1}$$

1. The Global Participation Evaluation Score (*GPS*)

$$GPS = w_1 \times NOC + w_2 \times NOP + w_3 \times NOE + w_4 \times NOIFM. \tag{2}$$

Because this *TS* is going to be a big number, to make it easier to calculate the total value of the final equation, let's divide the result of *TS* by 100.

2. Evaluation of men and women (*GS*)

When analyzing this problem, we use the method of proportion gap:

$$GS = \frac{M}{M+F} - \frac{F}{M+F}, \tag{3}$$

where *M* represents the amount of male exercise, *F* represents the amount of female exercise. Through this formula into the data for calculation, we can calculate its percentage. To make it easier to calculate the value of the final formula, we multiply the value of this ratio difference by 100.

3. Environmental Score (*ES*)

The environmental score includes carbon emissions, energy consumption, water use, waste management and the final ecological impact. Each of these five aspects gets 10 points. The evaluation of carbon emissions is greater than 1 million tons CO_2 gets 2 points, and 5* 100,000 to 300,000 gets 3-6 points. 300,000 to 100,000 accounts for 6-8 points, less than 100,000 will account for 8-10 points, for each different stage of his evaluation score will be different, and then the energy consumption, if his consumption is high, it will account for 2 points, if the consumption is moderate, it will account for 3-6 points, if he is more efficient use. If his consumption is very low, he can get a full score of 8-10 points, about water use, if there is too much waste, he can only score 2 points, if it is moderate, he can get 3-6 points, if it is effective management, it is 6-8 points, high use is 8-10 points, if there is waste management, Based on their recovery rate, we calculated that <30% corresponds to 2 points, 30-50 corresponds to 3-6 points, 50-80 corresponds to 6-8 points, and 80 corresponds to 8-10 points. The last aspect is that the ecological impact corresponds to 1-10 points from severe damage to minor damage, the more minor the impact, the higher the score, and vice versa, so an environmental impact score is a sum of these scores. Since there are five parts, and we assume they all have the same weight for environmental impact, we just divide the total by five.

4. Culture Score (*CS*)

In this one, we will use the methodology for calculating the Cultural Diversity Index.

Common cultural diversity indices are usually based on the following steps:

Identify different cultural groups: First, define the cultural groups of the participants (or participating countries), often by country, language, or ethnic group. If more nuanced cultural classifications are taken into account in some analyses, multidimensional indicators such as language, religion, or tradition may be used. Calculating the distribution of cultural groups: The relative proportion of each cultural group is calculated. For example, consider how many different national, cultural, or linguistic backgrounds the participants come from, and what percentage of each group. The calculations are made using a mathematical model similar to Shannon Entropy: Shannon entropy is commonly used to measure the diversity and uncertainty of information, and in the Cultural Diversity Index, a higher entropy indicates greater cultural diversity. To facilitate the calculation of the final total value, we multiply its resulting value by 10.

Shannon entropy can be expressed as:

$$CS = -\sum_{i=1}^{n} p_i \log(p_i) \tag{4}$$

where *n* is the number of cultural groups (e.g. the number of participating countries or languages), p_i is the proportion of the i cultural group (such as the proportion of entries from a certain language, ethnic group or country).

Interpretation Entropy: The higher the entropy, the greater the diversity of cultures, and an entropy of 0 means that there is only one cultural group. The resulting entropy can be converted to a diversity index as needed for easy comparison.

Here's an example:

Suppose there are four countries participating in A sporting event (A, B, C, and D). If we know the number of participants from these countries is as follows:

a) Country A: 50% of the athletes

b) Country B: 30% of athletes

c) Country C: 15% of athletes

d) Country D: 5% of athletes

We can calculate the cultural diversity index using the Shannon entropy formula:

$$CS = -(0.5 \log 0.5 + 0.3 \log 0.3 + 0.15 \log 0.15 + 0.05 \log 0.05). \tag{5}$$

The entropy derived from this calculation gives a quantitative indicator of cultural diversity. If more countries and cultures participate, the entropy will be higher, indicating that the competition performs better in terms of cultural diversity.

5. Attractiveness Rating Score (AS)

$$AS = w_1 \times PMR + w_2 \times PAC + w_3 \times V. \tag{6}$$

The weight of these three parts is 33.3%, 33.3%, 33.3%. To facilitate the calculation of the final total value, we divide its resulting value by 100.

Nevertheless, the foregoing model we made is too ideal and impractical to account for which of the SDEs can be chose or removed. Thus, we use the gray prediction model with entropy evaluation method to find the weighting of each of the factors' effects.

$$TS = w_1 \times GPS + w_2 \times GS + w_3 \times ES + w_4 \times CS + w_5 \times AS. \tag{7}$$

We use the previous data we calculated to figure out the weighting. And because the sum of the weighting is 1. So, we assume that the total scores of the SDEs coefficient is 100. Then, we use one of the SDEs (swimming) of three Olympics Games (2024, 2020, 2016) to find the standard point line by multiplication of matrices.

$$score = [w_1\ w_2\ w_3\ w_4\ w_5] \begin{bmatrix} GPS_{2024} & GPS_{2020} & GPS_{2016} \\ GS_{2024} & GS_{2020} & GS_{2016} \\ ES_{2024} & ES_{2020} & ES_{2016} \\ CS_{2024} & CS_{2020} & CS_{2016} \\ AS_{2024} & AS_{2020} & AS_{2016} \end{bmatrix}. \tag{8}$$

After calculating, we get three values 18.851, 18.853 and 17.965, we chose the minimum one and it's divided by the sum of the three. Because: since even the smallest numbers are up to par, which means it already has representation. As the result, the rate is about 32.27%. Because the total score is 100, the standard point line is 32.27.

6. Problem 3: Test of Gray Prediction-based Model for Scoring SDEs

To solve this problem, we first take three SDEs that have consistently appeared from 1988 to 2024, and then find that swimming, cycling, and athletics have always existed according to the data. For the most recent Olympic Games 2020 and 2024, the TS (Total Score) of these three sports in these two Olympic Games are shown in the table below:

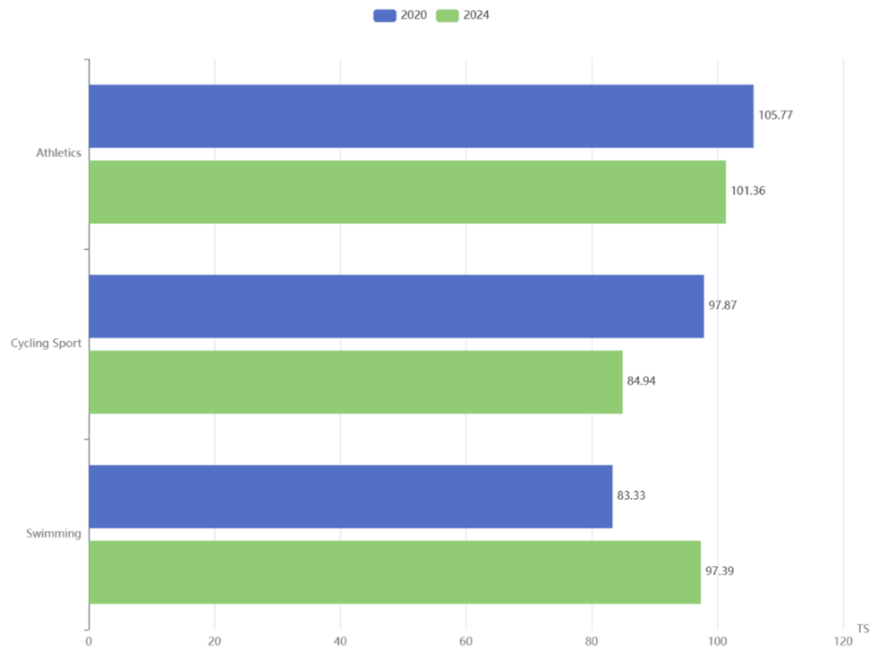

Figure 3. *TS* of Swimming, Cycling, and Athletics in These Two Olympic Games

Since the two sports with the lowest TS meet the requirements in 2020 and 2024, take the lowest TS sports in 2020, add the lowest TS sports in 2024, and divide their sum by two to find their average to get the standard point line score. Indicates that less than it is unqualified, and greater than it is qualified. The formula is as follows:

$$SPL = \frac{\min(score_{2020})+\min(score_{2024})}{2}. \tag{9}$$

Since swimming in 2020 has the lowest score and cycling in 2024 has the lowest score, we plug the data into the above formula and get 84.16.

In the following projects to be added in 2024 and 2028, we can calculate their TS as shown in the following table:

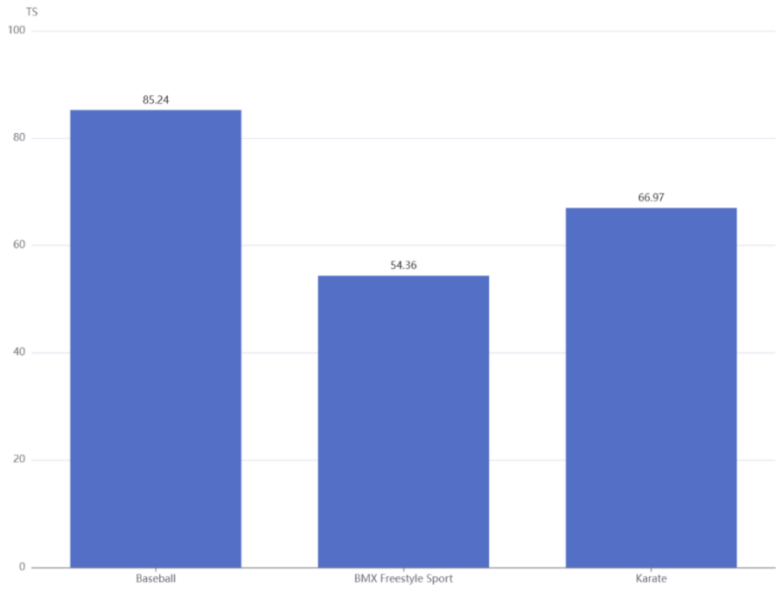

Figure 4. *TS* of Three New Sports

We can see that only the baseball fits the bill, not the other two.

To highlight the general applicability of the model, we must discuss the following three points:

1. Clarify the purpose and application scenarios of the model

First, you need to clarify the purpose and application scenarios of the model. Different variables have different weights on the model. For example, in this model, the impact of combined participation and influence is relatively large in the evaluation of SDEs. Moreover, variable reference objects also have an impact on model evaluation. Just like different countries have different cultural influences or whether the unit of money is dollars or yuan. So, let's assume that the number of participants and economic growth are in reference to the country hosting the Games, and that economic growth is in dollar terms. Then, we must clearly understand what problems we hope to solve with the model - assessing which SDEs are acceptable for inclusion in the Olympics and which are not. And the context in which the model will be used.

2. Data quality assessment

Integrity: Check that the data is complete with no missing values (the data is not clear in the number of media reports).

Accuracy: Ensure that the data is accurate, with no errors or outliers (none).

Consistency: Whether data is consistent across time or sources (consistency).

Representation: Whether the data represents the actual scenario to which the model will be applied (yes).

Therefore, in general, the overall difference has little impact and meets the applicability.

3. Suitability test

The model is tested in real-world scenarios to verify its performance in real-world applications. By comparing the SDEs scores for cycling, swimming and athletics at the 2020 and 2024 Olympic Games, we calculated our SDEs standard scores. Then the standard score is compared with the coefficients obtained from the other three SDEs, and the actual test is carried out.

In order to discuss how our model confirms the current Olympic status of these SDEs, we must revisit questions 1 and 2. In question 1, we confirmed that the total score is equal to the Global participation score plus the gender score plus the environmental score plus the cultural score and finally the attractiveness score.

The calculation methods of the above five parts have been shown in question 2. Because the total data have basis and certain certainty and exclude certain probability, our model can confirm the current Olympic status of these SDEs in this way.

For the gray prediction-based model, we evaluate it by the same SDEs of the first model. And the result is as same as the result of the first model that the scores of swimming, cycling and athletics are above the standard point line. Also, for baseball, BMX freestyle and karate, only baseball can meet the requirement. Its score is 34.67, which is higher than the standard point line 32.27.

Because we use the gray prediction model with entropy evaluation method and calculating of the weighting of each factor, the results we calculate by the model are more accurate. Therefore, in fact that the gray prediction-based model is more adaptive than the simple model.

7. Problem 4: The Reintroduction of SDEs for 2032 and 2036

In discussions about the addition or reintroduction of the 2032 Brisbane Games. We will ensure that the following SDEs will likely be introduced as shown in the table below:

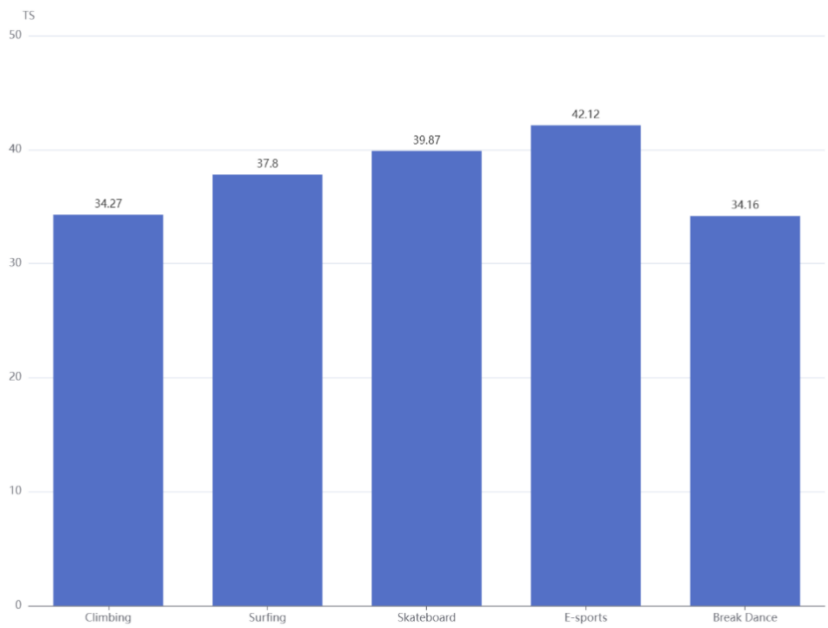

Figure 5. The *TS* (Total Score) of SDEs Coefficient in 2024

The higher scores mean higher ranking. Thus, as the diagram shows, **e-sport** has the highest scores, so it is the NO.1. And **skateboard** is NO.2, **surfing** is NO.3.

These three SDEs can be added in the 2032 Olympics. Except the three top SDEs, we also evaluate another two SDEs, which are climbing and break.

Next, we need to use a gray prediction model to predict which special sports are likely to be included in the Olympics in 2036 and beyond. This means that we need to predict the change in its SDEs value.

The graphs of the predicted values of climbing and break dance are shown below:

Figure 6. Predicted Value of Climb

8. Problem 5: Sensitivity Analysis and Resolution of Model Stability

In this question we use the method of technique for order preference by similarity to an ideal solution (TOPSIS) to solve it. TOPSIS is used to evaluate and rank each sample. There are five steps to analyze the question:

1. Prepare the data, and do the same trend processing and dimension problems.
2. To confirm the weight of each indicator, entropy weight method can be used, and custom weights can be defined (need to process by yourself, can use quantization -AHP).
3. Find the optimal and the worst matrix vectors (the system automatically handles them).
4. The distance between the evaluation object and the positive ideal solution D+ or the negative ideal solution D- is calculated respectively.
5. Combined with the distance value, the C value of the comprehensive degree score is calculated, and the ranking is carried out to draw a conclusion.

The table below shows the results:

Table 2. Weight Calculation Result of Entropy Weight Method

factor	Information entropy	Information effectiveness	Weight (%)
Global comprehensive participation	0.613	0.387	19.472
environmental influence	0.579	0.421	21.141
male-female ratio	0.613	0.387	19.472
cultural influence	0.613	0.387	19.472
attraction	0.593	0.407	20.444

The chart description: The above table shows the weight calculation results of entropy weight method, and analyzes the weight of each index according to the results.

Intelligent analysis: The weight calculation results of entropy weight method show that:

the weight of **global comprehensive participation** is 19.472%,

the weight of **environmental impact** is 21.141%,

the weight of **gender ratio** is 19.472%,

the weight of **cultural impact** is 19.472%,

and the weight of **attraction** is 20.444%, among which the maximum index weight is **environmental impact** (21.141%). The minimum value is **global comprehensive participation** (19.472%).

Obviously, environment influence has the biggest weight, which means it take up more points than other factors. And this feature of our model will cause both benefits and negative effects. On the one hand, the advantage of the model is that the SDEs that we choose are relative more environmentally friendly. On the other hand, the disadvantages are that people probably ignore the essence and the purpose of the sports and it may limit people to choose viable kinds of sports. Oppositely, people put more attention on the environmental conservation.

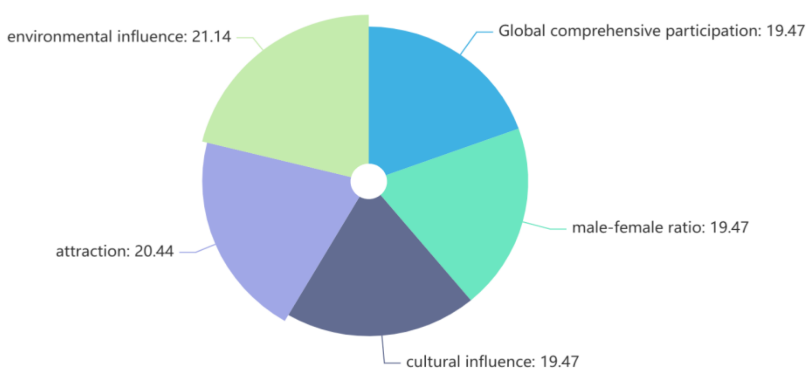

Figure 7. The Weight of the Five Factors in the Pie Chart

9. Problem 6: Non-technical Summary for the Solution to Evaluate SDEs

The model we made is mainly used to figure out which SDEs confirm to the requirements that the IOC gives and whether they can be reintroduced and added or removed from the future Olympics Games. At the beginning of our work, we made two models, the first is simple that we calculate different scores of factors and add them up. The second model uses the gray prediction model with entropy evaluation method to find the weighting of each of the factors. But eventually, we decide to use the second one. Because the first model is too ideal and impractical to accurately calculate the values of SDEs coefficient.

Firstly, we need find the factors. We find five factors that are global comprehensive participation, male-and-female-rate, environmental factors, cultural factors and appeal of the SDEs. The reason why we choose them is because that they are easy to evaluate and they are the main factors that will impact we evaluate which SDEs can be reintroduced or removed. And for the five variables, each of them has different arithmetic, like weighting operation and calculating their average values. In the end, we figure out the values of the single parts and add them up.

Secondly, we use the gray prediction model with entropy evaluation method to find the weighting of each of the factors.

Thirdly, we use the previous data of swimming, cycling and athletics from the Olympics Games in 2016 and 2024 to figure out the weighting. And because the sum of the weight is 1. So, we assume that the total scores of the SDEs coefficient is 100. Then, we use one of the SDEs swimming of three Olympics Games in 2024, 2020 and 2016 to find the standard point line by multiplication of matrices. After calculating, we get three values 18.851, 18.853 and 17.965. We choose the minimum one and it's divided by the sum of the three. Because: since even the smallest numbers are up to par, which means it just reaches the minimum standard. As the result, the rate is about 32.27%. Because the total score is 100, the standard point line is 32.27.

Last step, we find the SDE coefficient of karate, baseball and BMX freestyle. As a result, only baseball can be reintroduced in the future Olympics. Because its score is higher than the standard point line is 32.27.

In addition, we have some suggestion: except the six SDEs above, we also calculate the value of other five SDEs: climbing, surfing, skateboarding, e-sports and break dancing. And we suggest that they can be reintroduced in the future Olympics as well. Because their SDE coefficients of them are bigger than the standard point line 32.27, which means based on the five factors, they confirm to the IOC's requirements.

Finally, we explain why our model support the conclusion. Our model utilizes entropy weight method and gray prediction, they can deal with uncertainty and multi-objective decision-making problems, and provide scientific and objective basis for decision makers. And by the method, we are able to find the weight of the five main factors (global comprehensive participation, male-and-female-rate, environmental factors, cultural factors and appeal of the SDEs). So, the model can find a data series of regularity, and by using the determined weights and the standardized data, the model can evaluate the comprehensive index of the objects. This value can be used to support decisions or research conclusions. Therefore, our model can support the conclusions.

10. Strength and Weakness

10.1 Strength

For gray prediction model:

1. Low data requirements: the gray prediction method is especially suitable for the data prediction of small samples and poor information, and it has no special requirements for data distribution, and can handle various types of data. This is very important in practical applications, because the data in many fields are often difficult to meet the large sample conditions required by traditional forecasting methods.
2. High prediction accuracy: the gray prediction method can reduce the interference of random factors and improve the regularity of data by summing up the original data (1-AGO). This method makes the prediction result have high precision, especially suitable for short-term forecast.
3. Simple calculation: the calculation process of gray prediction method is relatively simple and easy to understand and master. It does not require complex mathematical models and a lot of computational resources, and is easy to be applied in practical problems.

For entropy evaluation method:

1. Sensitivity: the entropy method is sensitive to small changes in the data. When the data of an indicator changes significantly, its weight will be adjusted accordingly, so as to more accurately reflect the impact of data changes on the evaluation results.
2. Objectivity: the entropy method determines the weight of the index completely based on the discrete degree of the data itself, avoiding the subjectivity and arbitrariness of artificial weights. This makes the evaluation results more objectively and fairly, and can better reflect the characteristics of the data itself.
3. Wide applicability: the entropy method can be applied to various data types and different evaluation fields, such as economy, society, environment, etc. As long as the data are measurable and comparable, the entropy method can be used for comprehensive evaluation[1][2].

For TOPSIS:

1. The TOPSIS method[3]4] does not require complex calculations and models, but only requires standardized data processing and simple mathematical operations to obtain results. The calculation process is relatively simple, and the results can be displayed through visual charts and other ways, so that decision makers can understand the decision results more intuitively.
2. Low data requirements: TOPSIS method has no strict restrictions on data distribution, sample size, and the number of indicators, which is suitable for both small sample data and large systems with multiple evaluation units and indicators. At the same time, the method does not need any hypothesis or statistical analysis of the data, only the weight of each attribute and the data of each decision scheme can be analyzed.

3. Wide applicability: TOPSIS method is applicable to various data types and various decision-making problems, including evaluation, ranking, selection, etc. It can be applied to various decision-making fields, such as market research, product evaluation and enterprise management, and has a wide range of application prospects.

4. Strong comprehensiveness: TOPSIS method synthesizes a number of evaluation indicators and considers the weights and relationships among indicators, which can evaluate the decision-making scheme more comprehensively. By detecting the distance between the evaluation object and the best solution and the worst solution, the influence of multiple factors can be comprehensively considered to get the final decision result.

10.2 Weakness

For gray prediction model:

1. Rely on small amounts of data: the gray prediction method is mainly based on a small amount of historical data, which may lead to a relatively low accuracy of the forecast results. Especially in the face of complex and changeable situations, due to the limitation of the amount of data, it may not be able to fully reveal the internal laws and changing trends of the system, thus affecting the accuracy and reliability of the prediction.

2. Sensitive to outliers: if there are outliers or abrupt points in the data, the prediction results of the gray prediction method may be greatly affected. Outliers may be caused by data measurement errors, data recording errors or system mutations, which will interfere with the establishment and prediction process of the gray prediction model, resulting in the predicted results deviating from the actual values.

3. Lack of mechanism: gray prediction method is mainly based on the law of the data surface, and lacks the in-depth analysis and explanation of the internal mechanism of things. This can make the prediction results difficult to interpret and verify, and also limits the application of gray prediction methods in some fields that require a deep understanding of the system mechanism.

4. Prediction accuracy is limited: the prediction accuracy of gray prediction model may not be high when dealing with complex and highly nonlinear data. In addition, since the gray prediction method mainly relies on cumulative generated sequences and differential equations to describe the dynamic behavior of the system, it may lead to filtering out some important information or details in the prediction process, thus affecting the accuracy of the prediction results.

For entropy evaluation method:

1. Does not reflect the correlation between indicators: the entropy method mainly focuses on the degree of dispersion of a single index, but can’t directly reflect the correlation between indicators. In practical application, there is often a certain correlation between indicators, which may affect the result of comprehensive evaluation. Therefore, when using the entropy method, it may be necessary to combine other methods (such as principal component analysis) to eliminate redundant information between indicators.

2. Sensitive to extreme values: the entropy method is more sensitive to extreme values. If there is an

extreme value in the data of an indicator, it may cause the entropy of the indicator to be small, thus giving a greater weight. This can skew the results of the comprehensive evaluation from reality, as the extreme values may not represent the true distribution of the overall data.

3. Unable to consider the practical significance of indicators: the entropy method is a weighting method based entirely on the characteristics of the data, which can’t consider the actual significance of the index. In practical applications, some indicators may have more practical significance, but because the data distribution is more uniform, the entropy method may give a lower weight. This may cause the results of comprehensive evaluation to be inconsistent with the actual demand.

For TOPSIS:

1. Strong dependence on attribute weights: when TOPSIS method is used, each attribute needs to be weighted, and different weighting schemes will affect the final decision result. However, the determination of attribute weights often depends on the decision maker's subjective judgment, so it is easy to appear uncertainty and inconsistency. This subjectivity may lead to the deviation of decision results and affect the accuracy and reliability of decision making.

2. Strong sensitivity to data: in TOPSIS method, the quality of data has a great impact on the decision result. If there are outliers or missing values in the data, it will have a significant impact on the decision outcome. Therefore, before the TOPSIS method is used, the data needs to be carefully processed and cleaned to ensure the accuracy and integrity of the data. In some cases, accurate results cannot be obtained: when the index values of two evaluation objects are symmetrical about the line between the best and the worst scheme, TOPSIS method cannot obtain accurate results. In addition, TOPSIS method can only sort the advantages and disadvantages of each evaluation object, but can’t carry out file management, which limits the flexibility of its application to a certain extent.

11. Conclusion

As the Olympics evolving, the purpose of IOC is to keep the Games both relevant and influential by adding SDEs. In order to help ensure that sport aligns with Olympic values, we conclude five main factors that will affect our evaluation, and make several models to figure out the coefficient that are used to evaluate the SDEs.

The first model is gray prediction model with entropy evaluation method. We use it to find the weight of the five factors. And then, we bring some data of previous SDEs into the model to find the standard point line.

Lastly, we bring the data of the test SDEs into the model. If the results are bigger than the standard point line, these SDEs can be added. If they are less than the standard point line, they will be removed from the Olympics Games or not be added. In addition, we utilize the gray prediction model to predict which SDEs are able to be added in the further future Olympics Games, and TOPSIS to perform sensitivity analysis and address the problem of model stability.

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Appendices

Appendix A: Tools and Software

MATLAB R2018b

ECharts

Appendix B: The MATLAB Code

B.1 The Code for Problem 2

```
factor_scores = [
    49, 251, 51, 200, 0;
    0.5, 0, 0, 0, 0;
    2, 2, 2, 2, 2;
    8, 0, 0, 0, 0;
    2000, 5000, 20, 0, 0
];
weights = [0.25, 1, 0.2, 1, 0.33 ];
every_scores = SDE_scores * weights';
total_scores = sum(every_scores);
disp('total score of SDEs£º');
```

```
disp(total_scores);

data = [
    80, 70, 90, 85, 75;
    92, 78, 80, 86, 90;
    85, 95, 88, 78, 91;
     ];
normalized_data = data./ sum(data);
num_samples = size(normalized_data, 1);
num_indices = size(normalized_data, 2);
entropy = zeros(1, num_indices);
for j = 1:num_indices
    p = normalized_data(:, j);
    p(p == 0) = [];
    entropy(j) = -sum(p.* log(p));
end
weight = (1 - entropy)./ sum(1 - entropy);
disp('Entropy of each index:');
disp(entropy);
disp('Weight of each indicator:');
disp(weight);
```

B.2 The Code for Problem 3 and 4

```
function prediction = gray_predict(factor_value)
    n = length(factor_value);
    x0 = factor_value(:);
    x1 = cumsum(x0);
    B = [-0.5 * (x1(1:n-1) + x1(2:n)), ones(n-1, 1)];
    Y = x0(2:n);
    coeff = B \ Y;
    a = coeff(1);
    b = coeff(2);
    prediction = x0(1);
    for k = 2:n
        prediction = prediction + (x0(1) - b/a) * exp(-a * (k - 1));
```

```
    end
end

future_years = 5;
factor_value = [23, 20, 8, 5, 43
                24, 22, 5, 4, 47
                22, 0, 7, 8, 46
                30, 16, 8, 7, 47
                30, 23, 6, 7, 47
];
preds = zeros(future_years, 1);
for i = 1:5
    preds(i) = gray_predict(factor_value(:, i));
end
disp('Predicted rating:');
disp(preds);
```

Report on use of AI

ChatGPT

Query: <the principle of the entropy method>

Output: <If the information entropy of an index is smaller, it indicates that the degree of variation of its index value is greater, the more information it provides, and the greater the role it plays in the comprehensive evaluation, the greater its weight should be. Conversely, the greater the information entropy of an index, the smaller the variation degree of its index value, the smaller the information provided, and the smaller the role it plays in the comprehensive evaluation, the smaller its weight should also be.>

Query: <TOPSIS>

Output: <TOPSIS method is a commonly used comprehensive evaluation method, which was first proposed by C.L. wang and K. Yeon in 1981. The core idea of this method is to sort the schemes by calculating the distance between them and the ideal solution and the negative ideal solution, so as to determine the optimal scheme. The so-called positive ideal solution (optimal solution) is the best value of an assumption, and its each attribute value reaches the best value of each candidate solution. The negative ideal solution (the worst solution) is the worst value of the alternative scenario, and its property values all reach the worst value of each candidate. If a scheme is closer to the positive ideal solution and further away from the negative ideal solution, it is considered to be better.>

Query: <How gray prediction model works>

Output: <

Core Concept:

A gray system refers to a system in which some information is known while some is unknown. The gray prediction model is designed to handle time series data with limited samples, irregularity, and uncertainty. Its basic idea is to reveal the regularity of the data sequence and predict future trends by establishing a gray differential equation based on the original data.

Working Principle:

Data Preprocessing: The original data is first processed to generate a new sequence with stronger regularity, typically through cumulative generation or other methods. Cumulative generation involves summing the data points in the same sequence to generate a new data point, creating a cumulative generation sequence.

Model Establishment: Based on the processed data, a gray model, such as GM(1,1), is established. GM(1,1) is a commonly used gray prediction model that employs a first-order linear differential equation.

Parameter Estimation: The parameters of the model are estimated using methods such as the least squares method. These parameters are crucial for the accuracy of the predictions.

Model Validation and Optimization: The model is validated by examining the residual sequence to assess its fitting effect. Adjustments are made to optimize the model as needed.

Prediction: Using the established gray model, future data points are predicted and solved.>