

Selection of Olympic Events - A Quantitative Evaluation Based on the TOPSIS Model

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Abstract. The Olympic Games program is an extremely challenging task for the International Olympic Committee (IOC). This paper has designed a mathematical model to assist staff in evaluating the scores of Olympic events based on Olympic values. Firstly, based on the IOC's six criteria, this paper constructs an evaluation system using 12 variables. Secondly, the weights calculated by the AHP method and optimized weights are respectively used in the TOPSIS model for assessment, where the optimized weights are derived through the integration of reverse learning and sinusoidal strategy whale optimization algorithms. Thirdly, this paper filters out some events that have been continuously held but with many competitions, those that have been held continuously but few competitions, those that have not been held continuously, and newly added events and calculates the scores of these events using both sets of weights and ranks them. It was found that Equestrian Driving and Lacrosse Sixes have scores lower than others, suggesting a lower likelihood of continuous hosting. Finally, three events, Baseball, Flag football, and Jeu de Paume, were selected for TOPSIS model calculation. After calculation, Baseball and Flag football scores were found to be close to those of Volleyball Indoor, an ongoing event. It is believed that they will be introduced in the 2032 and 2036 Olympic Games, but Jeu de Paume has a lower score and is less likely to be included in the Olympics. Lastly, this paper compares the weights obtained by the two methods and finds that while most indicators have similar weights, the AHP method focuses more on sustainability, while the optimization method focuses more on popularity and accessibility.

Keywords: AHP; Whale Optimization Algorithm; TOPSIS; sinusoidal strategy.

1. Introduction

As an international multi-sport event, the Olympic Games include summer and winter sports competitions, attracting tens of thousands of athletes to participate. At the 2024 Paris Olympics, approximately 10,500 athletes from 206 countries gathered in Paris, making the city the global focus of attention. The Olympics allow athletes to share experiences and promote cultural integration between countries. The Olympic Games encompass various sports events, disciplines, and events (SDEs). For instance, at the 2024 Paris Summer Olympics, there were 48 disciplines across 32 sports and 329 medal events. However, the International Olympic Committee (IOC) regularly adjusts the number of SDEs for each Olympic Games based on a set of criteria reflecting Olympic values, such as the impact of sports on the environment, economy, and society, the balance between male and female athletes, and multiple factors including relevance, innovation, safety, and fairness. This paper will consider the factors above and establish a mathematical model to quantify which SDEs should be added or removed in future Olympic Games to offer reasonable recommendations.

The framework of this paper is shown in the figure below.

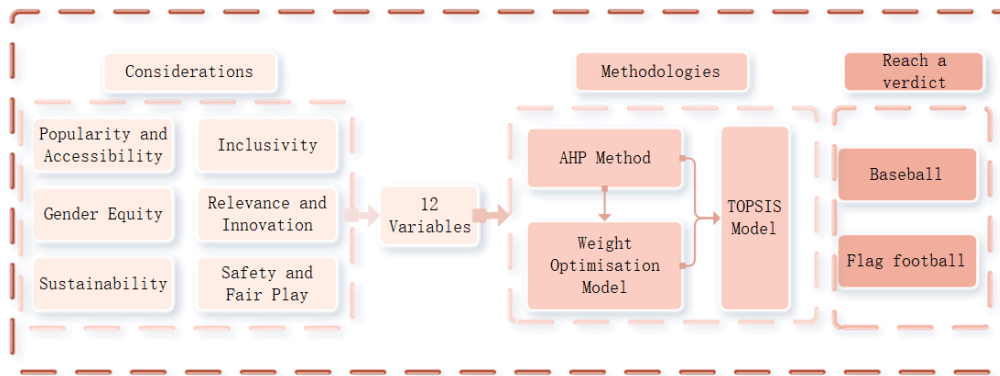


Fig. 1 Flow of Our Work

2. Assumptions and Variables

Assumption 1	Assuming no major changes in SDEs' popularity over 8 years
	Justification 1: Popularity is the most important factor influencing SDE programming. We are programming the 2032 Olympics based on current SDEs data. From a practical point of view, people's opinions about various types of sports will not obviously change in a relatively short period of time.
Assumption 2	The impact of external factors and unforeseen circumstances on the Olympic program is not taken into account.
	Justification 2: External factors mainly refer to weather conditions and venue conditions. For example, outdoor sports such as sailing and jet skiing may be canceled due to extreme weather conditions such as hurricanes and tsunamis. In addition, athletes' performance can be affected by venue conditions such as injuries, illnesses, and, more seriously similar to the 2020 Tokyo Olympic Summer Games being affected by COVID-19. For the above-mentioned unforeseen circumstances, they are not under our consideration.

Besides, the variables we used in our model are as listed in Table 1.

Table 1 Definition of Variables

Variables	Meaning
CI	the consistency index
CR	the consistency ratio
$b_{k,i}$	number of competition types in the event held in the previous i Olympic Games
$d_{k,i}$	the frequency of the event held in the previous i Olympic Games
v_j	the j -th variable weight
v_j^{down}	lower bounds
v_j^{up}	upper bounds
K_{max}	the maximum number of iterations
S_i^-	negative ideal solution distance
S_i^+	positive ideal solution distance
T_i	the score of the i -th SDE

3. Variables of Evaluation Model

3.1 Variable construction

3.1.1 Popularity and Accessibility

People's enjoyment of SDEs is the first thing to consider. In this paper, we use search engine keyword heat (C_{11}), the number of relevant topics on the YouTube platform (C_{12}), and the number of comments on relevant topics on social media YouTube platforms (C_{13}) as indicators to evaluate popularity and accessibility, where and are chosen as the average data of the Top 10 YouTube plays. A_{i2} denotes the number of video plays of the i -th place of the relevant topic on the YouTube platform; A_{i3} denotes the number of likes of the i -th place of the relevant topic on the YouTube platform.

$$C_{12} = \frac{\sum_{i=1}^{10} A_{i2}}{10}, \quad C_{13} = \frac{\sum_{i=1}^{10} A_{i3}}{10} \quad (1)$$

3.1.2 Gender Equity

Gender equality is a value advocated by the Olympic Games, and by incorporating gender equality as an evaluation indicator, it is possible to ensure that the principle of gender equality is fully taken into account when organizing specific SDEs. This paper selects the male-to-female ratio of competing team members (C_{21}) and the ratio of medals set up (C_{22}) as criteria for evaluating gender equality.

$$C_{21} = \left| \frac{N_{male} - N_{female}}{N_{male} + N_{female}} \right|, \quad C_{22} = \left| \frac{M_{male} - M_{female}}{M_{male} + M_{female}} \right| \quad (2)$$

Where N_{male} denotes the number of male participating team members of SDEs; N_{female} denotes the number of female participating team members of SDEs; M_{male} denotes the number of medals for male athletes in SDEs; M_{female} denotes the number of medals for female athletes in SDEs.

3.1.3 Sustainability

Sustainability refers to the impact of SDEs on the environment, including energy consumption and carbon emissions, as well as the impact on local economy and tourism development. This paper uses the average construction cost of the venue pavilion (C_{31}) and its durability assessment (C_{32}) as evaluation indicators. The durability assessment (C_{33}) is derived from expert scoring, with higher scores indicating greater compliance with Olympic requirements.

3.1.4 Inclusivity

This paper chose the number of countries participating in the competition (C_{41}) and the number of continents participating in the competition (C_{42}) as the criteria for evaluating the Inclusivity indicators.

3.1.5 Relevance and Innovation

This paper introduces an SDE's relevance and innovation indicator (C_5), which is determined using expert scoring, with higher scores representing greater compliance with Olympic VALUES (range 0-10).

3.1.6 Safety and Fair Play

This paper selected the injury rate (C_{61}) and the doping number (C_{62}) as indicators to evaluate the Safety and Fair Play criteria. For the injury rate (C_{61}) and the doping number (C_{62}), this thesis selected the average data of the four Olympic Games of 2008, 2012, 2016, and 2020 as criteria. Then we have:

$$C_{61} = \frac{\sum_{i=1}^4 B_i}{4}, \quad C_{62} = \frac{\sum_{i=1}^4 D_i}{4} \quad (3)$$

where B_i denotes the injury rate at the i -th Olympic Games during the period 2008-2020, and D_i denotes the number of doping incidents at the i -th Olympic Games during the period 2008-2020.

Finally, a total of 12 evaluative criteria were selected for this thesis.



Fig. 2 Structure of the factors

3.2 Variable processing

Since the units of the 12 variables screened in this paper are different, and the orders of magnitude and dimensions are different, the data must first be maximized and normalized.

4. Evaluation Model based on TOPSIS + AHP Method

This paper employs the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method to evaluate the candidate SDEs, and utilizes the Analytic Hierarchy Process (AHP) method to assign different weights to each variable during the evaluation. Finally, the score of each SDE is calculated through weighted summation.

4.1 AHP Method Calculation Results

Here, we first construct a judgment matrix according to the above rules. By observing the historical data of the SDEs program and analyzing the classic, introduced, removed, and reintroduced SDEs reflected in the data, we obtain the score of each element in the judgment matrix. The judgment matrix is shown in Figure 3.

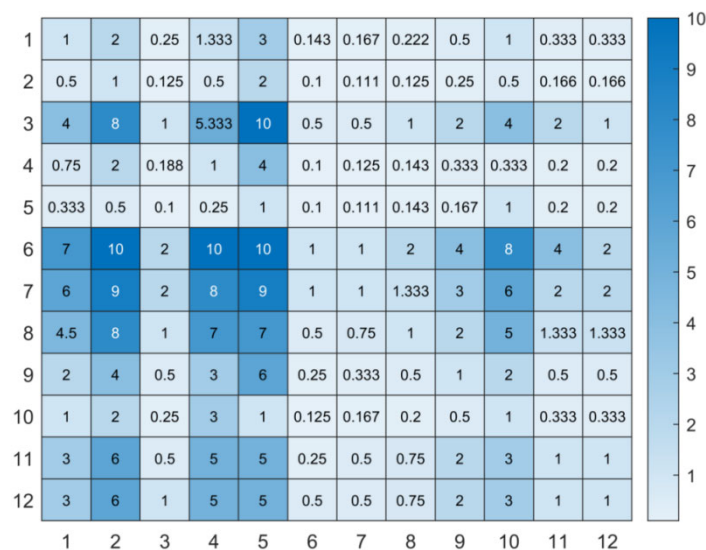


Fig. 3 Heatmap of judgment matrix C

Then, a consistency test is performed on the judgment matrix C to verify whether it can be used as a matrix for the AHP method.

Table 2 Consistency test results

Maximum eigenvalue	CI value	RI value	CR value	Consistency test results
12.391	0.036	1.536	0.023	Pass

As can be seen from the table, $CR=0.023 < 0.1$. The consistency test shows that the method of calculating weights by summarizing experience based on the information we have found and the characteristics of the analyzed data is very effective. Finally, the weight table obtained from the judgment matrix C is given:

Table 3 Weight value table

criteria	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{31}	C_{32}	C_{41}	C_{42}	C_{51}	C_{61}	C_{62}
Eigenvector	0.37	0.20	1.44	0.29	0.19	2.58	2.13	1.50	0.72	0.37	1.05	1.16
Weight value (%)	3.11	1.70	12.03	2.40	1.54	21.51	17.75	12.52	6.02	3.07	8.72	9.64

According to the weights vector $w = (3.106, 1.701, \dots, 9.641)^T$, different criteria have different weights in the data we found, which means that different criteria play different roles in the selection of SDEs. In order to more intuitively see the weight of each item, this paper visualize the weights of variables as in Figure 4.

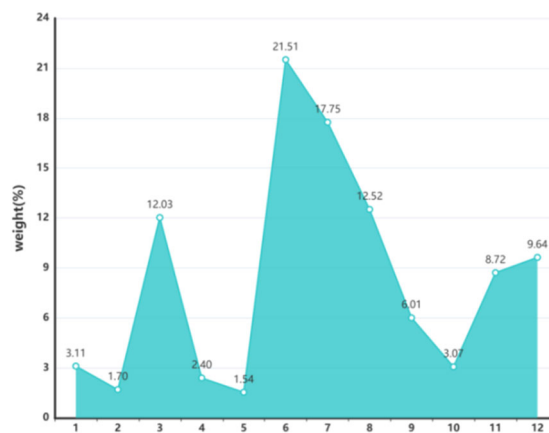


Fig. 4 Distribution of Weights

From Figure 4, we can see that the average construction cost (C_{31}) and durability assessment (C_{32}) of the arena have the largest weights, which also shows that the weights obtained by the AHP method pay more attention to the two criteria of the average construction cost (C_{31}) and durability assessment (C_{32}) of the arena.

4.2 Optimization of Weights

In order to reduce the influence of subjective factors, this paper established an optimization model and optimized the weights using the given SDE historical data. First, we collected information about the events of the last ten Olympic Games and established a methodology to assess the importance of SDEs in events based on their performance in the historical events of the SDEs. By looking at the given data, we found that the sports we considered more important appeared more often and had more events in the history of the Olympic Games, especially those that have existed since 1896.

4.2.1 Objective Variable

Here, the weight optimization method we use is a machine learning method. It optimizes the parameters by making the scoring results as close to our expected goals as possible. Therefore, we first need to define an indicator based on the importance of SDE performance in historical data. Let $score_k$ represent the score of the k-th SDE. Projects that have always existed in previous Olympic Games are often more likely to be included in the SDEs' program for the next Olympic Games. Hence, we define $score_k$ as in the equation:

$$score_k = \sum_{i=1}^J b_{k,i} d_{k,i} \tag{4}$$

Where $b_{k,i}$ represents the number of competition types in the event held in the previous i Olympic Games, and $d_{k,i}$ represents the frequency of the event held in the previous i Olympic Games. For example, if the number of times the event was held in the previous two Olympic Games was 2, then $d_{k,i}=1$. If the number of times the event was held in the previous three Olympic Games was 2, then $d_{k,i}=2/3=0.666$.

4.2.2 Optimization Model

Our goal is to calculate the optimal weight to fit the score so we can take the error function as the optimization target:

$$\min D = \sum_{k=1}^J (score_k - \sum_{j=1}^H v_j c_j)^2 \tag{5}$$

Where v_j is the j-th variable weight and c_j is the j-th variable score.

For the above objective function, when the weight v_j has no upper bound, multiple groups of solutions or weight overfitting may occur. That is, it is only applicable to the project data used and has weak generalization ability. Therefore, this article assumes that the sum of the weights is 1, that is:

$$\begin{aligned} \sum_{j=1}^H v_j &= 1 \\ 0 < v_j < 1 \end{aligned} \tag{6}$$

In summary, the optimization model established in this paper is

$$\begin{aligned} \min D &= \sum_{k=1}^J (score_k - \sum_{j=1}^H v_j c_j)^2 \\ s. t. &\begin{cases} \sum_{j=1}^H v_j = 1 \\ 0 < v_j < 1, j = 1.2 \dots J \end{cases} \end{aligned} \tag{7}$$

4.2.3 Improved whale optimization algorithm solution model

For the above optimization model, in order to ensure a high solution speed, we use WOA (Whale Optimization Algorithm) to solve this model. WOA is a heuristic optimization algorithm based on the behavior of whale groups in nature. The flowchart of the whale optimization algorithm is as follows:

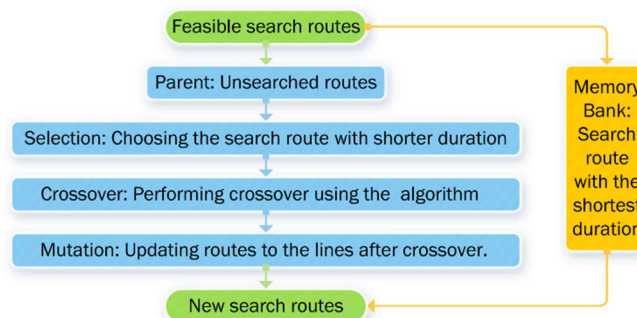


Fig. 5 Algorithm Flowchart

This paper improves the whale optimization algorithm by integrating reverse learning and sinusoidal strategy to obtain better robustness and search capability.

(1) Reverse learning initialization

In this paper, weight v_j is used as the independent variable, and each weight v_j has upper and lower bounds. Therefore, for each individual's j -th dimension encoding weight v_j , when initializing the population, equation (10) is used to obtain the reverse individual n -th dimension encoding v_j^1

$$v_j^1 = v_j^{down} + v_j^{up} - v_j \tag{8}$$

Where v_j^{up} and v_j^{down} represent the upper and lower bounds of v_j , respectively.

(2) Sinusoidal strategy

In order to ensure that the algorithm still has the ability to jump out of the local optimal solution in the later stage of iteration, this paper adopts the sinusoidal mutation strategy to improve the mutation probability $Pm(k)$. The specific formula is as follows:

$$Pm(k) = \sin\left(\frac{\pi}{3} + \frac{\pi}{6} \cdot \frac{K}{K_{max}}\right) \tag{9}$$

Where K represents the number of iterations, and K_{max} represents the maximum number of iterations.

4.2.4 Weight calculation results

Finally, the improved whale algorithm is used to solve the optimization problem and obtain the final weight:

Table 4 Optimized weight table

criteria	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{31}	C_{32}	C_{41}	C_{42}	C_{51}	C_{61}	C_{62}
Optimized weight value (%)	7.48	25.83	18.72	3.33	1.56	10.46	3.46	11.94	1.82	4.13	5.48	5.79
AHP method weight value (%)	3.11	1.70	12.03	2.40	1.54	21.51	17.75	12.52	6.02	3.07	8.72	9.64

It can be seen here that the optimized weights are slightly different from the weights obtained by the AHP method, but are generally similar.

5. Application and Analysis

5.1 Model Test

5.1.1 Selection of Test SDEs

Firstly, based on the requirements of the question, this thesis has filtered out five programs that contain more competitions: Swimming, Archery, Gymnastics Artistic, Rowing, Skateboarding, of which Swimming has contained more than 30 competitions per year since the 1988 Olympics, Archery Swimming has contained 40 or more competitions per year since the 1988 Olympics, and Artistic, Rowing, and Skateboarding have contained 10 or more competitions per year, consistent with the question's request for SDEs that have persisted since the 1988 Olympics.

Then, in order to increase the robustness and generalization ability of the model, this thesis filters out five sports containing a small number of competitions: Basketball, Equestrian Jumping, Modern Pentathlon, Table Tennis, and Volleyball Indoor, which have continuously existed since the 1988 Olympics but only have two competitions per Olympics. These programs have existed since the 1988 Olympics, but there are only two events per Olympics. Unlike the five SDEs of Swimming, Archery, Gymnastics Artistic, Rowing, and Skateboarding, Basketball, Equestrian Jumping, Modern Pentathlon, Table Tennis, and Volleyball Indoor have been in existence since the 1988 Olympics, only two competitions have been held at each Olympics, Volleyball Indoor, the five SDEs, host fewer events in each Olympics but persist.

There are also five programs that have been added or removed in the last three Olympics. The SDEs that have been added for the 2020, 2024, and 2028 Olympics are Cycling BMX Freestyle, Sport Climbing; Baseball, Lacrosse Sixes will only be held in some of the sessions of the 2020, 2024, and 2028 Olympics; and the SDE that has been removed for these three Olympics is Equestrian Driving. These SDEs can represent many other SDEs that were brought into the model for analysis.

5.1.2 Test Results and Analysis

We introduce the weights calculated by the AHP method and the optimized weights into the TOPSIS model, respectively, and the comparison of the comprehensive weights is shown in the figure below:

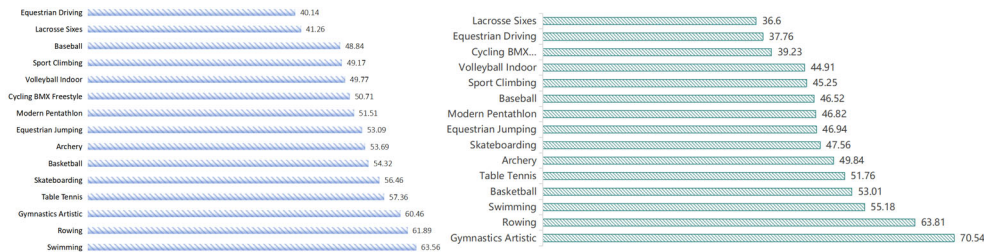


Fig. 6 AHP method weight diagram(left) and Optimized weight diagram(right)

As can be seen from the table above, three SDEs, Cycling BMX Freestyle, Equestrian Driving, and Lacrosse Sixes, have significantly lower scores than the others and are predicted to be eliminated at the 2032 Olympics. Besides, for the popular SDEs in the Olympics, the TOPSIS model given in this paper can also get high scores, which is basically consistent with the heat of the Olympic program.

Finally, the weights obtained with the AHP method are considered together with the optimized weights, and the scores are compared with the ranking to obtain the following picture:

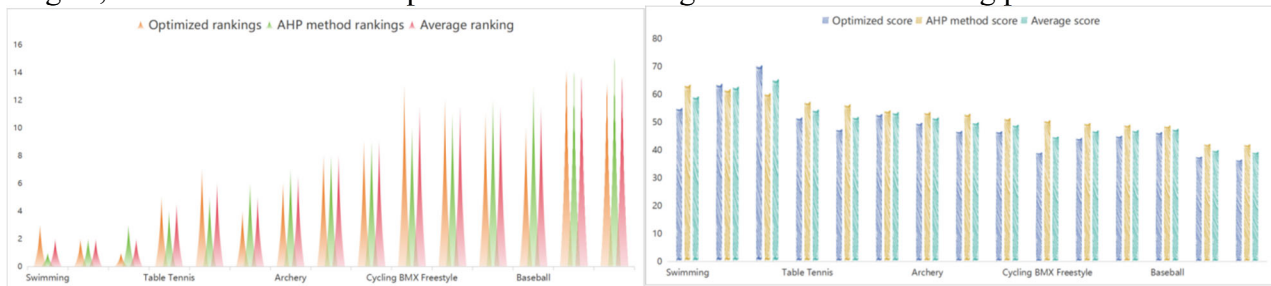


Fig. 7 Ranking Comparison Chart(left) and Score Comparison Chart(right)

As can be seen from the table above, for the average score, the two SDEs, Equestrian Driving and Lacrosse Sixes, scored significantly lower than the other SDEs, and their average rankings were also significantly lower than the other SDEs, and the combined TOPSIS model under the two weights suggests that these two sports will be eliminated in the 2032 Olympics. In addition, SDEs such as Baseball have different score rankings under the two weights, which also reflects the different focuses of the two weights versus the optimized weights that focus more on search engine keyword heat (C_{11}), the number of relevant topics on social media YouTube platforms (C_{12}), and the number of comments on relevant topics on social media YouTube platforms (C_{13}), and the AHP method. The weights obtained are more focused on the average construction cost of the arena pavilion (C_{31}) and durability assessment (C_{32}).

5.2 New SDEs Introduction to 2032 Olympics (Q4)

In the previous model test, we can see that Baseball's scores under both weights are significantly larger than those of Equestrian Driving and Lacrosse Sixes, which is an SDE that can be introduced for the 2032 Olympics. In addition to this, we selected two more SDEs: Flag football and Jeu de Paume. Scores were calculated for these two SDEs using the TOPSIS model, and the final calculations obtained were:

Table 5 Score of new SDEs that were introduced

	Optimized score	AHP method score	Average score
Baseball	46.52	48.84	47.68
Flag football	45.48	49.72	47.60

Jeu de Paume	39.76	43.26	41.51
Volleyball Indoor	44.91	49.77	47.34

From the above table, we can see that the highest to lowest scores are for baseball, flag football, and Jeu de Paume. We have already come to the conclusion that Baseball can be introduced earlier. By comparing the scores, we can see that Flag football scored more than Baseball in the AHP method, and the average score is close to that of Baseball. So, we can assume that Flag football will be introduced to the 2032 Olympics. However, Jeu de Paume's score has a big gap with baseball's score, so we think Jeu de Paume will not be introduced to the 2032 Olympics. Finally, the order of our recommendation is Baseball, Flag football, and Jeu de Paume.

Besides, we compared the scores of Volleyball-Indoor, Baseball, and Flag football, and found that the scores of these three SDEs are close to each other, and since Volleyball Indoor continues to be hosted in the Olympics, we can assume that Baseball and Flag football will continue to be organized in the 2036 Olympics.

5.3 Sensitivity Analysis

In the previous, we got the SDEs that will be held in the 2032 session, while the optimized weights in the model of this paper are from the data and then optimized to get the weights that minimize the error. As for the AHP method, the model is based on information and expert advice, which is more realistic. It can reflect the selection of SDEs for future Olympic Games well to a certain extent, and the scores obtained by combining the two kinds of weights can fully respond to the results of data and realistic significance. This can be considered as a good robustness of our model.

In order to visually compare the weight values before and after optimization, this paper draws a folded comparison chart between the weight values after optimization and the weights obtained by the AHP method:

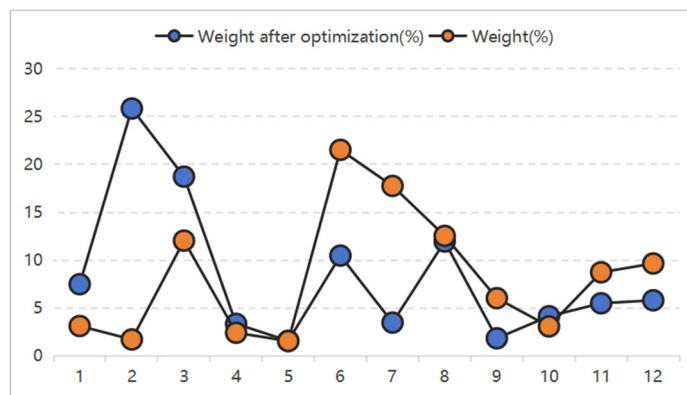


Fig. 8 weight comparison chart

As can be seen in the above figure, after optimization, the weights of the search engine keyword heat (C_{11}), the number of relevant topics on social media YouTube platforms (C_{12}), and the number of comments on relevant topics on social media YouTube platforms (C_{13}) have increased, and the average construction cost of the arena pavilion (C_{31}) and the durability assessment (C_{32}) have decreased.

6. Conclusion

This paper has designed a mathematical model to assist staff in evaluating the scores of Olympic events based on Olympic values. This paper has three strengths. First, two calculation methods were used to calculate the weights, which can enhance the validity of the conclusions. Second, when optimizing the weights, some additional variables were added, which effectively avoided overfitting the weights to the results. Third, by using sufficient data, we obtained more valid conclusions. However, there are also some weaknesses, such as the possible neglect of certain guidelines, leading to flaws in the results.

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