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Save the Future of the Olympics

Summary

Recently, due to COVID-19, there has been a decreasing number of regions applying to host the Olympic Games, which has drawn widespread attention. This article primarily focuses on how to quantify the impacts of hosting the Olympic Games and develop practical strategies and implementation timetables to alleviate its negative effects.

Firstly, based on the rich data collected, we conduct data preprocessing, including calculating cosine similarity to fill missing values, data normalization, and so on. Next, in order to measure the impact of hosting the Olympics, we select 18 secondary indicators, such as employment, from five aspects: **economy, society, politics, OFI,** and **environment**. Then, we combine **AHP** and **CRITIC** methods to calculate the weights of the relevant indices (see Figure 6) and the comprehensive scores. The results indicate that **Buenos Aires, Argentina** and **Vancouver, Canada** are the regions with the highest scores for the Summer and Winter Olympics, respectively, among the selected 35 regions.

Then, we evaluate the feasibility of the evaluation model from the perspectives of **discriminability** and **generalizability** by analyzing the impact of hosting the Olympic Games. To assess the discriminability, **K-means clustering** algorithm is applied to partition the 35 regions into three clusters, where the **threshold values** of economic indicators are 0.26 and 0.63 (see Table 7 for other indicators). Furthermore, we not only consider the direct impact, but also the potential long-term impact. Ultimately, we conclude that our model can effectively discriminate the impact of hosting the Olympic Games and can be used for the majority of regions around the world.

Next, we present the objectives of the strategy and propose **four feasible strategies** from the government's perspective: selecting permanent venues for sports with high environmental requirements; decentralizing the host region; arranging permanent locations for the Summer and Winter Olympics; hosting four small-scale Olympics. Subsequently, for each strategy specific recommendations related to economics, environmental protection, and other relevant aspects are proposed, and a plan for **the next 50 years** is formulated with a corresponding timetable (see Figures 10 to 13). In addition, we select four regions, including Beijing and Sydney for analyzing the impact. With strategy implementation, the secondary indicators are obtained based on the quantified impact of policies. Without strategy implementation, the secondary indicators are predicted by the **GM(1,1)** model. The results show that Strategy 3 is most effective when Beijing hosts the Olympics, while Strategy 2 is more applicable to Sydney. Overall, Strategy 2 has stronger universality.

Finally, we evaluate the strengths and weaknesses of the model and extend it. We also analyze the **sensitivity** of parameters: land use, event revenue, and reputation, which shows the validity of the model assumptions. Furthermore, a one-page memorandum for IOC is prepared.

Keywords: Olympic Games; AHP-CRITIC; K-means; GM(1,1)

Contents

1 Introduction

1.1 Problem Background

Since its commercial operation, the Olympic Games have had an increasingly wide-ranging impact on the host cities, as shown in Figure 1. The competition for hosting the world's top sporting events among cities is as fierce as that among athletes. However, in recent years, due to the impact of the COVID-19 pandemic, hosting the Olympics has gradually become an extremely expensive undertaking. As shown in Figure 2, cost overruns have been a persistent problem in recent editions of the Olympic Games. According to statistics, from 1960 to 2016, the average cost of the Olympic Games exceeded the budget by 156% [1].

Figure 1. Part of the impact of hosting the Olympic Games.

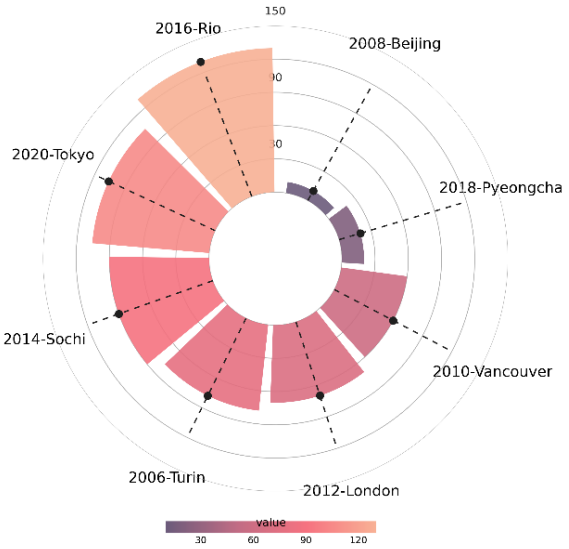


Figure 2. Percentage of Olympic overspending in recent years.

Therefore, it is of great significance to adjust and innovate the content and format of the Olympic Games, and to formulate feasible strategies and policies, for the smooth hosting of the Olympic Games and even for world unity.

1.2 Restatement of the Problem

In order to help the International Olympic Committee address the problem of decreasing number of regions bidding for the Olympic Games, and to propose potential choices, strategies, and policies to ensure the success of the Olympic Games, the following work needs to be done:

- Consider the economic, social, human, and long-term impacts, select appropriate indicators to measure the impact of hosting the Olympic Games, and consider the feasibility of the evaluation system.
- Propose potential strategies, analyze specific policy recommendations under each strategy, provide an implementation timetable, and explore the impact of potential strategies on indicators.
- Describe potential strategies and specific policy recommendations to the International Olympic Committee in the form of a memorandum.

1.3 Literature Review

Due to the rampant spread of the COVID-19 pandemic, the number of bidders for the Summer and Winter Olympic Games is gradually decreasing. Therefore, determining the comprehensive impact of hosting the Olympic Games and formulating feasible strategies have become important topics for research organizations related to the Olympic Games[1].

Regarding the impact of hosting the Olympic Games on aspects such as urban employment and government tax revenue, Jordan Rappaport and Chad Wilkerson (2001) [2] concluded through calculation and analysis that sports events can promote employment and increase tax revenue. Matos (2006) [3] studied the multidimensional and potential impact of major sports events and found that sports events also have an impact on the environment and political capital. Based on the above research, Huang Haiyan (2009) [4] proposed that the impact of sports events on urban development mainly lies in improving infrastructure construction, enhancing urban visibility, and driving the development of related industries. The Olympic Games Impact (OGI) study made suggestions to Olympic bid cities from seven aspects, including community economic development, environment, and democratic progress.

Some scholars have also conducted research on the response strategies of Olympic host cities under the COVID-19 pandemic. Zhang Wenmeng (2022) [5] proposed measures such as reasonable sharing of losses and appropriate adjustment of sports events by studying the impact of the delayed Tokyo Olympics. Yao Fanghong and Qian Junwei (2023) [6] proposed response measures to the Olympic public health crisis, such as improving the resilience of the event system and reducing the natural system risks. However, they did not propose feasible response measures from the plasticity of the event itself. We have integrated their work and considered the long-term impact of hosting the Olympic Games to propose creative strategies.

1.4 Our Work

The whole modeling process is shown in Figure 3.

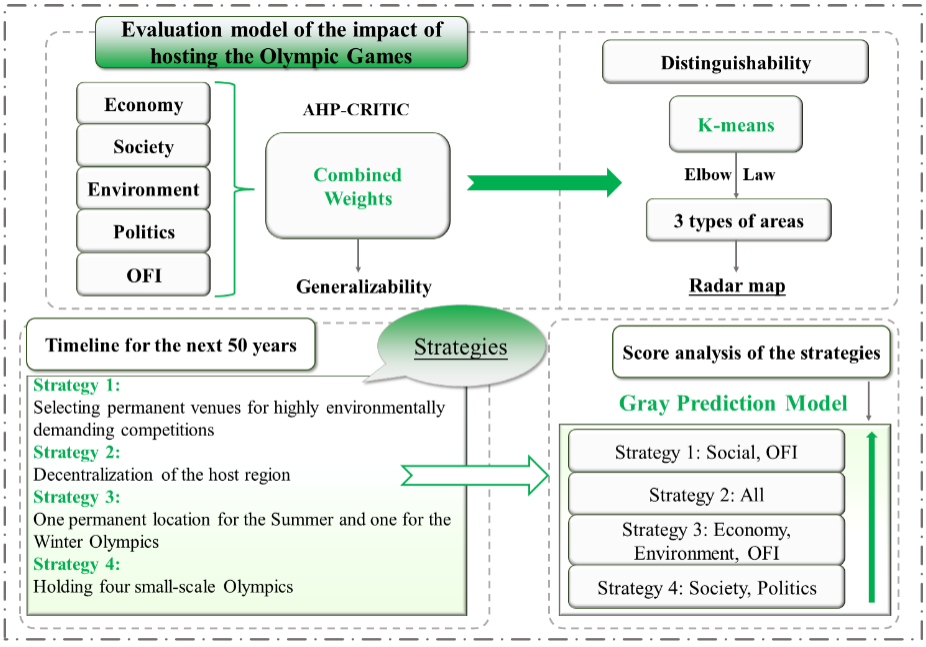


Figure 3. Flow Chart of Our Work.

2 Assumptions and Justifications

To simplify the considered problems, we make the following basic assumptions, which are properly justified. Other assumptions based on different models will be listed in the following model-related sections.

Assumption 1: Assuming that the environment in the Olympic host region is relatively stable.

Justification: The probability of a sudden global major event is small, and although regional emergencies occur from time to time, the overall international situation is basically stable. Therefore, we have reason to assume that accidental small-scale events will not fundamentally affect the environment of the studied region or country.

Assumption 2: The indicators we construct are assumed to behave regularly (e.g. stable or cyclical fluctuations) in the short term when the international environment is relatively stable and no strategies are implemented.

Justification: Based on the relative stability of the international environment and the lack of implementation of strategies, the indicators of a region will continue to follow their original trend in the short term, rather than experiencing abrupt changes due to external interference.

Assumption 3: Assuming that the impact of strategies on indicators remains constant during the same time period.

Justification: Due to various factors in reality, it is difficult to estimate the impact of strategies on each indicator as time changes. Therefore, we do not consider their changes. We will analyze the validity of this assumption in ***Section 7***.

Assumption 4: Assuming that the data obtained from the website is accurate.

Justification: Because our data come from the websites of international organizations (e.g. IOC and UNWTO), it is reasonable to assume that their data are of high quality.

3 Notations

The key mathematical notations used in this paper are listed in Table 1.

Table 1. Notations.

Symbol	Description	Unit
EB	event benefits	dollar
TC	Consumption of foreign personnel	dollar
LE	The financial support of the event organization to the region	dollar
CR	Olympic Games contribution to local GDP	%
λ	The threshold obtained by k-means clustering	/
WP	Per capita willingness to pay	dollar
ATS	athlete satisfaction	/
OFI	opportunity for future improvements	/
AUS	audience satisfaction	/

4 Evaluation model of the impact of hosting the Olympic Games

This chapter evaluates the impact of hosting the Olympic Games from five aspects: economic, social, political, environmental, and opportunities for future improvement. Based on extensive data collection, an AHP-CRITIC model was established to calculate the weights of indicators, achieving a comprehensive evaluation of the impact of hosting the Olympic Games.

4.1 Indicator Selection

In order to establish the most suitable evaluation system for assessing the impact of hosting the Olympic Games, indicators were identified from five aspects, including economic and social factors, among others. These indicators were chosen by referring to the Report of the IOC Evaluation Commission (2022) [7]. Some of the identified indicators are listed below:

4.1.1 Economy

The economic impact of the Olympic Games refers to the driving effect on the host's economy resulting from new investments and consumer spending brought about by the Games. This impact is mainly reflected in three aspects: the new investments and consumer spending brought about by the Games, the influence on macroeconomic indicators such as GDP and CPI, and the driving effect of the Games on related industries such as catering and transportation[8].

The revenue generated by the Olympic Games consists of two parts: the additional consumer spending brought to the host city by the relevant groups involved in the Games, and the financial flow generated by the operation of the Games. The calculation formula is as follows:

$$EB = TC + LE \tag{1}$$

Where EB represents the revenue, TC represents the amount of consumer spending by non-local visitors, and LE represents the local expenditures of the Games' organization.

The consumption by non-local residents attracted to the Olympic Games in local sports events and other areas promotes the growth of GDP, contributing to a virtuous cycle of economic development. The formula for the contribution rate of the Games to GDP is as follows:

$$CR = \frac{TC}{GDP_{region}} \tag{2}$$

Where CR represents the contribution rate, GDP_{region} represents the GDP of the region, and TC represents the total amount of consumer spending by non-local visitors.

4.1.2 Society

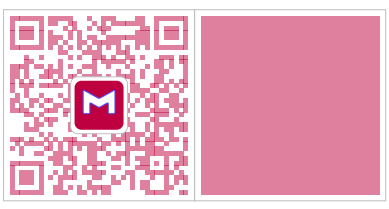
The social impact of the Games on the host includes its influence on social life, public satisfaction, as well as long-term effects on the local image and tourism destination, etc[4].

Regarding audience satisfaction, we use the willingness to pay for the pride brought by attending sports events as an indicator, and the calculation formula [4] is as follows:

$$AUS = \frac{WP^{*}q}{2} \tag{3}$$

Where AUS represents audience satisfaction, WP represents the average willingness to pay, and q represents the number of spectators.

For athlete satisfaction, we use the average number of gold medals per athlete as an indicator, and the calculation formula is as follows:



$$ATS = \frac{GM}{NA} \tag{4}$$

Where ATS represents athlete satisfaction, GM represents the total number of gold medals, and NA represents the number of athletes.

4.1.3 Politics

Successfully hosting the Olympic Games can establish a positive international image for the host region, showcase its unique culture and characteristics, and increase its international reputation. Furthermore, hosting the Olympics can promote communication and cooperation between the host country and other nations, and enhance international friendship index[9].

4.1.4 Opportunities for future improvement(OFI)

The opportunities for future improvement refer to the long-term potential benefits and opportunities gained from hosting the Olympic Games, as shown in Figure 4.

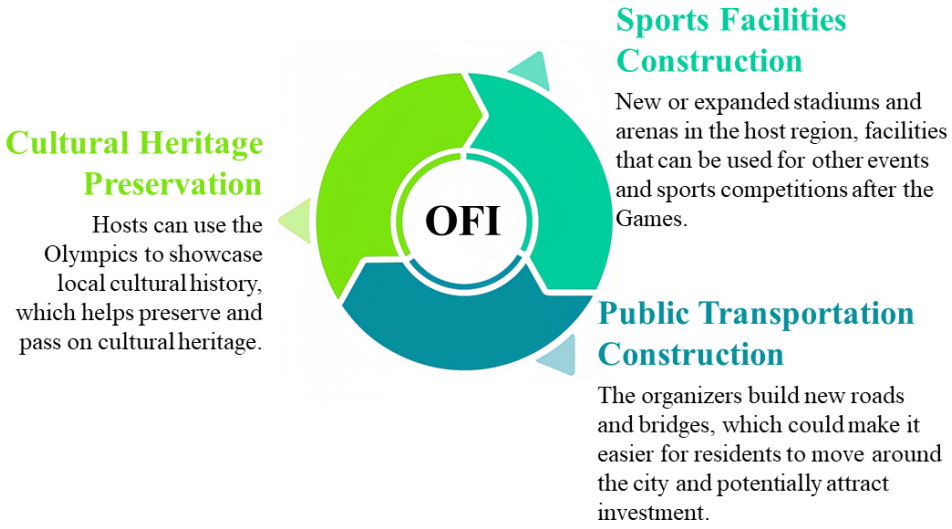


Figure 4. OFI composition diagram.

4.1.5 Environment

The impact of sports events on the natural environment has been widely recognized and reflected in the operation of the Olympic Games. After the United Nations Conference on Environment and Development in 1992, the International Olympic Committee (IOC), its individual sports federations, and national Olympic committees jointly signed the "Earth Charter" and incorporated environmental themes into the Olympic bid manual[7].

The construction of infrastructure can cause certain damages to the natural environment. Taking carbon dioxide emissions as an example, the calculation formula[4] is:

$$C = q^{*}c + t^{*}m \tag{5}$$

Where C represents the amount of carbon dioxide emissions, q represents the number of audience members, c represents the per capita normal carbon dioxide emissions, t represents the carbon dioxide emissions per kilometer of vehicles, and m represents the total distance traveled.

In summary, the indicator framework for measuring the impact is shown in Table 2.

Table 2. Indicator framework table.

Level Ⅰ	Level Ⅱ	Explain	Unit
economy	Contribution to GDP	Contribution to GDP	dollar
	Event income	The total income of holding event	dollar
	Industrial pull rate	The degree of promotion of related industries	dollar
	Number of travelers	The number of travelers	number
	Tourism growth rate	The growth degree of tourism industry	%
society	Athlete satisfaction	The average number of gold medals per athlete	number
	Audience satisfaction	Audience consumption intention	-
	Employment number	The number of jobs opened by the competition	number
politics	Land use	Utilization rate of stadium space	%
	host city prestige	The forwarding rate of the media	-
	International friendship index	Number of friendship treaties signed	-
OFI	Sports facilities construction	The number of stadiums expanded	number
	Public transport construction	Number of new roads and Bridges	number
	Cultural heritage protection	The protection of the Olympic legacy	-
environment	Amount of waste generated	The amount of waste produced	ton
	Carbon dioxide emissions	Regional carbon dioxide emissions	ton
	Water resource consumption	Regional water consumption	m^3
	Energy consumption	Total regional resource consumption	GWh

4.2 Data Collection and Pre-processing

4.2.1 Data Collection

Prior to establishing a comprehensive indicator system, data collection is crucial. To ensure the applicability of the model in different regions, we not only selected countries that have previously hosted the Games as data sources, but also considered countries with the potential to host the Games to formulate the best selection strategy. Rich data from different countries and regions from 1972 to present were obtained through consulting official statistics and websites such as the Olympic World Library. Some of the data sources are listed in Table 3.

Table 3. Data and Database Websites.

Database Names	Database Websites
Resource Consumption	https://library.olympics.com/
Tourism data	https://www.unwto.org/
Olympic Medals	https://www.statista.com/
National prestige	https://www.ipsos.com/en/nation-brands-index-2021

4.2.2 Data Filling

In order to ensure that the analysis is reliable and truthful, we usually need to ensure the

continuity and authenticity of the data. Since the data provided by the data website is not complete and some missing values exist, we use the following methods to fill in the data:

(1) If the data of an indicator in a region is missing, and the variance is relatively small. We used the mean completion method to fill in the missing data using the mean of other regions.

(2) If there is a lack of data for an index in a region, and the index fluctuates greatly, we will conduct unique thermal coding for the five features that quantify the impact of hosting the Olympic Games, and then find similar regions to fill in by calculating the cosine similarity between regions with and without missing values. The steps are as follows:

Step1：For regions without missing values, unique heat coding was used for five characteristics: economy, society, politics, natural environment and future improvement opportunities.

Step2：For regions with missing values, we respectively conduct unique thermal coding for the features without missing values, and calculate cosine similarity with samples without missing values. The formula is shown in Equation 6：

$$D(p,q) = \cos(\theta) = \frac{p \cdot q}{\| p \| \| q \|} \tag{6}$$

The variables p and q denote the encoding vectors of the samples without missing values and those with missing values, respectively.

Step3：The region with the highest cosine similarity ranking is selected as the region with the most similar volume to the region with missing values. The corresponding missing feature values are used as the feature values for the region with missing values and filled in accordingly.

4.2.3 Data Normalization

Now that we have a complete and accurate dataset, considering the different dimensions of the indicators, we cannot directly compare the data. In order to standardize the data and eliminate the adverse effects of singular samples, all data is transformed into numbers between 0 and 1. We use standardization processing, with the following formula:

$$\hat{x} = \frac{x - \overline{x}}{\sigma} \tag{7}$$

Where $\overline{x}$ represents the mean value of the original data, and σ represents the standard deviation of the original data.

4.3 Calculation of Indicator Weights

Weighting models is essential to evaluate the different contribution of the indicators. Consequently, two weighting models are adopted to calculated the weight vector in this section.

4.3.1 AHP

The analytic hierarchy process (AHP) dissects the problem into a series of methodological levels based on the affiliation between interrelated factors, and determines the importance weights by comparing the relative importance of indicators.

Step 1 Construct the judgement matrix. one must construct the judgment matrix by delineating the target layer, criterion layer, and scheme layer. Through a meticulous process of weighing the relative significance of each factor in the previous level, the indices of the same tier are then compared in pairs utilizing the corresponding 9-grade scales, and the judgment matrix A is obtained, where x_{ij} represents the result of the comparison between the *i*-th factor

and the *j*-th factor, and $x_{ij}>0, x_{ij}=\frac{1}{x_{ji}}$:

$$A=(x_{ij})_{n*n} \tag{8}$$

Step 2 Calculation of weights. The relative weights of the criteria were obtained by applying different methods, namely the arithmetic mean, geometric mean, and eigenvalue methods. The decision matrix was used as a basis for obtaining the weights of the criteria.

Step 3 Check the consistency. $\lambda_{\max}$ is the maximum eigenvalue of the judgment matrix.

When $CR=\frac{CI}{RI}<0.10$, the consistency of the judgment matrix is acceptable, and the matrix can be used as the weight vector of the evaluation factor. Otherwise, it should be amended.

$$CI=\frac{\lambda_{\max}-n}{n-1} \tag{9}$$

Through the above steps, we obtained the target weight vector ω_{AHP}.

4.3.2 CRITIC

The CRITIC method comprehensively assesses the objective weight of an indicator based on the evaluation indicator's comparative strength and the conflict between indicators.

After forward processing of the data, the following matrix is obtained, where X_{ij} represents the value of the *j*-th evaluation index in the *i*-th sample.

$$X=\begin{pmatrix} x_{11} & \cdots & x_{1p} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{np} \end{pmatrix} \tag{10}$$

Step 1 Calculate the contrast of the indicator: the variability of the indicator is expressed by the standard deviation of the data in each column. Let the contrast of the *j*-th indicator be S_j. The formula is as follows:

$$\begin{cases} \overline{x}_j=\frac{1}{n}\sum_{i=1}^{n}x_{ij} \\ S_j=\sqrt{\frac{\sum_{i=1}^{n}\left(x_{ij}-\overline{x}_j\right)^2}{n-1}} \end{cases} \tag{11}$$

Step 2 Calculate the conflict of indicators: the conflict of indicators is expressed by the correlation coefficient. Let the size of the contradiction between the *j*-th indicators and the rest of the indicators be R_j. The formula is as follows:

$$R_j=\sum_{i=1}^{p}\left(1-r_{ij}\right) \tag{12}$$

Where r_{ij} indicates the correlation coefficient between evaluation indicators i and j. When an indicator is strongly correlated with others, it reflects more of the same information and is less conflicting. Thus, the weight assigned to the indicator should be decreased.

Step 3 Define the information carrying capacity:

$$C_j = S_j \sum_{i=1}^{p} \left(1 - r_{ij}\right) = S_j \times R_j \tag{13}$$

Based on the amount of information, we can obtain the objective weight W_j of the j-th indicator with the following formula:

$$W_j = \frac{C_j}{\sum_{j=1}^{p} C_j} \tag{14}$$

The complete flow of CRITIC is shown in Figure 5.

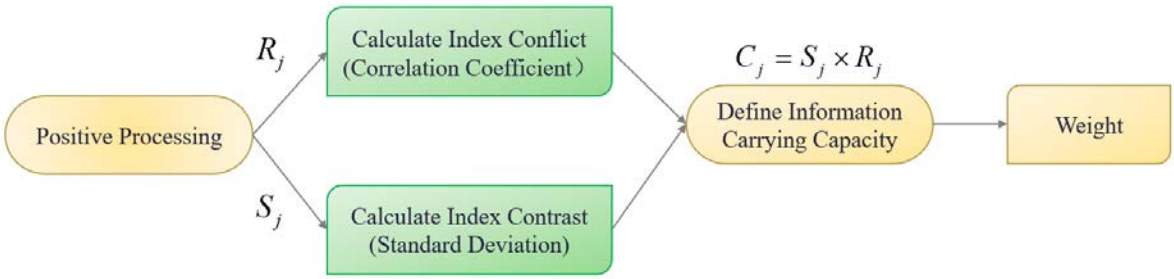


Figure 5. CRITIC flow chart.

4.3.3 Weighted Combination of AHP and CRITIC

The final weights of the indicators are computed using the Mon formula[10], which integrates the AHP and CRITIC methods of indicator weighting. The resulting weights take into account both subjective and objective perspectives, enabling the calculation of a comprehensive weight vector of indicators based on AHP-CRITIC.

$$\omega_{total} = \beta \cdot \omega_{AHP} + (1-\beta) \cdot \omega_{CRITIC} \quad (0 \le \beta \le 1) \tag{15}$$

Based on experience, $\beta = 0.6$, the final weights for each indicator are shown in Figure 6.

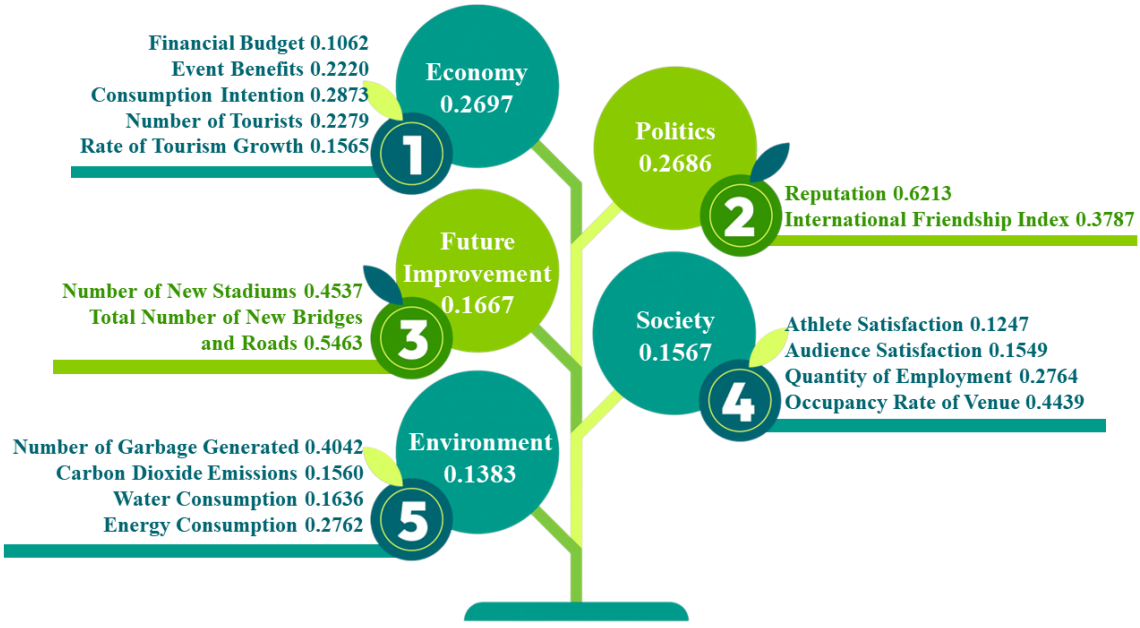


Figure 6. Comprehensive index weight.

4.4 Analysis of Results

Based on the evaluation model established above, this paper calculates the comprehensive scores of each region and ranks them, as shown in Tables 4 and 5.

Table 4. Summer Olympics rankings.

Rank	City	Nation	Score
1	Buenos Aires	Argentina	0.6401
2	Beijing	China	0.6245
3	London	UK	0.6189
...			
33	RIO	Brazil	0.4266
34	Munich	Germany	0.4251
35	Moscow	Russia	0.2045

Table 5. Winter Olympic rankings.

Rank	City	Nation	Score
1	Vancouver	Canada	0.5407
2	Helsinki	Finland	0.5396
3	Trondheim	Norway	0.5389
...			
33	Sochi	Russia	0.4270
34	Pyeongchang	Korea	0.4159
35	Sarajevo	Bosnia	0.0691

Based on the rankings presented in Tables 4 and 5 and other literature materials, we offer the following analysis:

1. Buenos Aires, Argentina, received the highest score for hosting the Summer Olympics. As the second largest economy in South America, hosting the Olympics has positive impacts on its economy and society. The city has a long history and rich cultural heritage. The Olympics can stimulate the development of its tourism industry. Furthermore, Buenos Aires has modern infrastructure and sports facilities, and has hosted many international events. Therefore, hosting the Olympics can increase venue utilization rates and employment opportunities.

2. Moscow received the lowest score for hosting the Summer Olympics due to the recent impact of the pandemic. Hosting the Olympics could lead to excessive cost overruns, which negatively impact the economy. Additionally, Moscow's history of hosting a controversial Olympics has had a negative impact on its politics.

3. Vancouver received the highest score for hosting the Winter Olympics. On the one hand, Vancouver providing a highly accessible transportation network. This makes hosting the Olympics easy to increase satisfaction for both audiences and athletes, as well as benefiting global business investment. On the other hand, Vancouver has long been recognized as the most outstanding city in Canada and even in North America for its performance in sustainable development. These have positive impacts on environmental protection and provide greater opportunities for future improvement.

4. Sarajevo received the lowest score for hosting the Winter Olympics due to its complex historical conditions, which negatively impacted its politics and economy.

5 Feasibility Analysis of K-means Based Clustering Algorithm

In order to analyze the feasibility of our constructed model for assessing the impact of hosting the Olympic Games, we explore both the differentiation and generalization aspects of the model.

5.1 Calculation of the Differentiation Degree

5.1.1 K-means Clustering Algorithm

To analyze the discriminative effect of the model, we utilized K-means to search for clustering centers, from which we obtained the threshold by calculating the mean value. This threshold was then used to evaluate the discriminability of the model results.

The K-means clustering algorithm is an iterative solution to the cluster analysis algo-rithm. The idea of the algorithm is to find a partitioning scheme of K clusters by iterating so that the loss function corresponding to the clustering result is minimized:

$$J = \sum_{i=1}^{n} \| x_i - \mu_{ci} \|^2 \tag{16}$$

Where x_i represents the i-th sample, ci is the cluster to which it belongs x_i , μ_{ci} represents the central point corresponding to the cluster, n is the total number of samples. The pseudo-code of the algorithm is as follows:

Table 6. K-means clustering algorithm pseudocode.

Algorithm：K-means clustering	
	Input: Dataset X, number of clusters k
	Output: Cluster allocation C, set of cluster centroids M
1.	Randomly select k points as initial centroids
2.	Repeat
3.	For each data point in the dataset X
4.	For each centroid in the set of cluster centroids M
5.	Calculate the distance between the centroid and the data point
6.	Assign the data point to the nearest cluster
7.	For each cluster, calculate the mean of points in the cluster as the new centroid.
8.	Until cluster allocation C and set of cluster centroids M no longer change,

To analyze whether the indicator system has a significant discriminative effect, we used the K-means clustering algorithm to cluster the data. Using the elbow method, we determined that these 35 regions can be divided into three categories. We calculated the midpoint coordinates of two of the three cluster centers, and used this value as the threshold. The specific formula is as follows:

$$\begin{aligned} \lambda_1 &= \frac{\mu_1 + \mu_2}{2} \\ \lambda_2 &= \frac{\mu_2 + \mu_3}{2} \end{aligned} \tag{17}$$

Where λ_1, λ_2 represents the threshold, μ_1, μ_2, μ_3 represents the three cluster centers.

5.1.2 Analysis of Results

The threshold values were calculated using the above method and are shown in Table 7. It can be observed that the classification criteria for the five indicators are different. Taking the economic indicator as an example, the threshold value divides the economy into three levels. When the Economy value is less than 0.26, it indicates that hosting the Olympics has a negative impact on the local economy, imposing a certain burden on the city's economy. When the Economy value is between 0.26 and 0.63, it indicates an average impact on the local economy. An Economy score greater than 0.63 is considered excellent.

Table 7. Threshold of each indicator.

Indicator	Level 1	Level 2	Level 3
Economy	[0,0.26)	[0.26,0.63)	[0.63,1]
Society	[0,0.35)	[0.35,0.58)	[0.58,1]
Environment	[0,0.33)	[0.33,0.66)	[0.66,1]
Politics	[0,0.41)	[0.41,0.70)	[0.70,1]
OFI	[0,0.38)	[0.38,0.69)	[0.69,1]

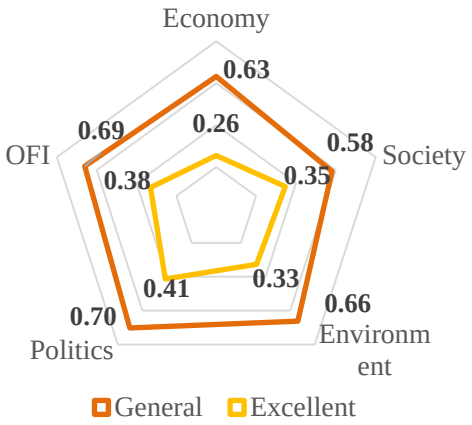


Figure 7. Differentiation effect map.

As shown in Figure 7, the threshold values can form an approximate regular pentagon. This divides the radar chart into three parts corresponding to Level 1, Level 2, and Level 3. This boundary effectively distinguishes the impacts of hosting the Olympics and demonstrates the feasibility of our evaluation system.

5.2 Analysis of Generalizability

Firstly, our indicator system not only covers countries that have hosted the Olympic Games, but also includes other countries and regions around the world. We have considered a series of indicators in various aspects such as the economy, society, and environment to comprehensively measure the impact of the Olympic Games on countries, making the model widely applicable to most countries and regions.

Secondly, our evaluation system not only considers the short-term direct impact of the Olympic Games on countries, but also takes into account its potential long-term impact. We have constructed the indicator OFI from three aspects: sports facilities construction, public transportation construction, and cultural heritage preservation, to study the long-term impact of the Olympic Games on the country's society and economy, to support decision-makers in making reasonable decisions and plans before and after the Olympic Games.

Finally, our evaluation system has fully considered the special circumstances of the regions during the construction process. We have divided it into the Summer Olympics and Winter Olympics, adjusted the indicators and classification standards of the evaluation system to ensure consistency with the actual situation, and has high applicability and practicality.

6 Possible Strategies and Specific Policy Recommendations

6.1 Objectives of the Strategy

The strategy is proposed to alleviate the negative impact on the host region caused by hosting the Olympics and ensure the success of the event. We believe that the closer the scores of each sub-index are to 1, the better the impact of hosting the Olympics.

Taking Beijing and Sydney as examples, we explain the objectives of the strategy. As shown in Figure 8, only the Society sub-index in Beijing has not reached the general level. The

goal of our strategy is to raise Beijing's Society score above 0.35 and achieve as close to excellent as possible on the other four indicators. Similarly, both OFI and Society sub-indexes in Sydney have not reached the general level. The goal of our strategy is to raise Sydney's Society score above 0.35, OFI score above 0.38, and achieve as close to excellent as possible on the other three indicators.

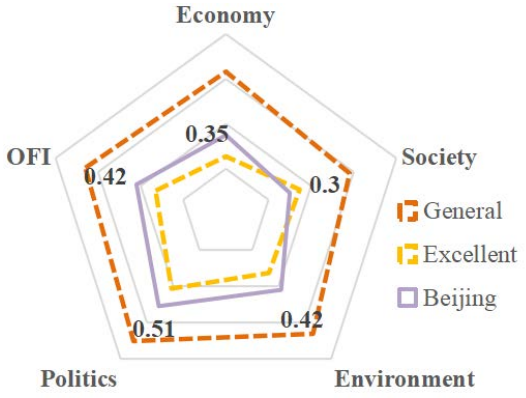


Figure 8. Beijing's strategic goals.

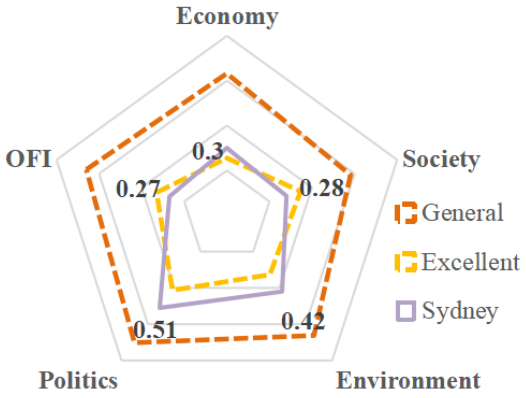


Figure 9. Sydney's strategic objectives.

6.2 Promising Strategies and Policy Recommendations

To address the negative impacts faced by host cities in hosting the Olympics and to alleviate the problem of decreasing numbers of Olympic bids, we have proposed four strategies.

6.2.1 Strategy 1: Selecting a permanent venue for high environmental demand competition events

In certain sports, such as skiing and skating, which require strict control of environmental factors such as temperature and humidity, which would otherwise have a greater impact on the performance of the competitors, choosing a fixed permanent venue for the competition would ensure fairness and stability. At the same time, this will also reduce the cost and maintenance of building demanding venues for specific sports at each Olympics.

Considering the real-world constraints, we propose a series of policy recommendations and a timeline for implementation for Strategy 1, as shown in Figure 10. We developed policy recommendations for the next 50 years and divided these 50 years into four phases.

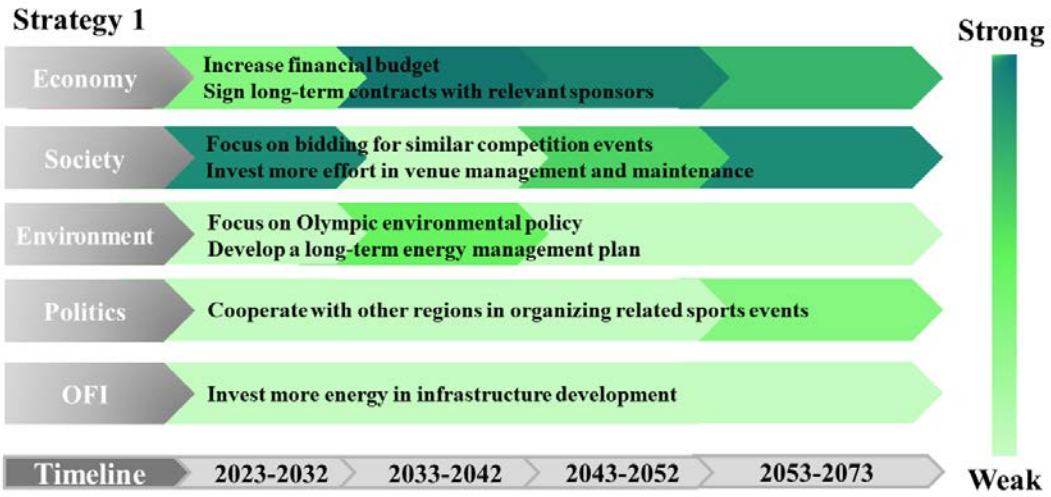


Figure 10. Implementation table of specific policy recommendations for Strategy 1.

2023-2032: To ensure the fairness and safety of competition programs with high environmental demands, the quality and reliability of equipment and facilities need to be guaranteed. Host regions should increase their financial budgets and sign long-term contracts with relevant sponsors. The indicators we implemented in the evaluation system are to increase the contribution to GDP by 4%, land use by 5% and athlete satisfaction by 3%.

2033-2042: Considering that some visitors and athletes may travel long distances, the economic burden and time costs increase. This phase focuses on the Olympic environmental policy, developing a long-term energy management plan and promoting green transportation. In response, we increase the number of travelers by 7%, reduce energy consumption by 5%, and increase the contribution to GDP by 6%.

2043-2052: After the permanent site is completed, the government should focus on bidding for similar competition events so that the site is fully utilized. In response, the land use rate increases by 6% and the contribution to GDP increases to 9%.

2053-2073: Invest more effort in infrastructure and venue maintenance and management. In response, increase land use by 8%, contribution to GDP by 7%, and prestige by 4%.

6.2.2 Strategy 2: Decentralize the host region, i.e. decentralize the Games

Having multiple host cities for each Olympic Games[11] can promote cooperation and development between different regions. Some of the more backward regions can use the opportunity of hosting the Olympics for infrastructure development and economic development, and also to make the culture and characteristics of these regions more accessible to more people. In addition, the economic burden can also be spread across multiple regions, reducing the pressure and risk on individual regions. We propose a series of policy recommendations for Strategy 2 with a timeline for implementation, as shown in Figure 11.

Figure 11. Implementation table of specific policy recommendations for Strategy 2.

2023-2032: Due to the decentralization of the Olympic Games, different host regions can promote diverse Olympic-themed peripheral goods. Urban planning can also be integrated with the hosting of the Olympic Games to improve infrastructure. The impact of our implementation in the evaluation system is to increase the event revenue by 4%, public transportation construction by 4%, and contribution to GDP by 3%.

2033-2042: This phase focuses on Olympic environmental policies, develops long-term

environmental plans, and promotes green transportation. Meanwhile, to enhance audience satisfaction, the government can build Olympic cultural plazas around the Olympic venues to provide people with cultural activities and entertainment venues. In response, we increase spectator satisfaction by 7%, increase the number of visitors by 5%, and reduce CO2 emissions by 6%.

2043-2052: The decentralization of the Olympic host regions may reduce the uniformity and coherence of the games. The government should establish strict rules and procedures to ensure fair and transparent competition. In response, prestige increases by 6% and athlete satisfaction increases to 9%.

2053-2073: Invest more effort in the coordination and organization of events in each host region to further support the development of the Games in a more diverse society. In response, increase the International Friendliness Index by 4%, land use by 5%, and prestige by 4%.

6.2.3 Strategy 3: One permanent location for the Summer and one for the Winter Olympics

This can reduce the burden on each Olympic Games host region while increasing the sustainability of the Games. By establishing a permanent location, the Olympic venues and infrastructure can be reserved for multiple future Games, reducing waste of resources and environmental impact. We propose a series of policy recommendations for Strategy 3, with a timeline for implementation, as shown in Figure 12.

Figure 12. Implementation table of specific policy recommendations for Strategy 3.

2023-2032: Due to the persistence of the effects of the global epidemic, the host city faces serious economic problems, including the construction and maintenance of extensive facilities, the provision of accommodation, security and other services. Therefore, the IOC should increase subsidies to meet the needs of various infrastructures as a permanent venue. At the same time, long-term environmental plans should be developed to reduce resource consumption. The targets we have implemented in our evaluation system are to increase the contribution to GDP by 8% and to reduce energy consumption by 2%.

2033-2042: After the gradual economic recovery, the permanent host site can establish an Olympic legacy program to provide long-term sports and cultural services to local residents and visitors. The area around the Olympic venues will be planned as an Olympic tourism area,

and tourism companies will be introduced to invest and build it to attract more tourists and consumers. As a result, it will increase the contribution to GDP by 9%, reduce energy consumption by 4%, increase event revenue by 3%, and increase cultural heritage preservation by 2%.

2043-2052: Start to cooperate with other regions in organizing relevant sports events and increase the policy on political aspects. The indicators implemented in the evaluation system are a 5% increase in prestige, a 6% reduction in the contribution to GDP, a 5% increase in land use, and a 4% increase in cultural heritage preservation.

2053-2073: Limit the implementation of policy recommendations to further support the development of permanent host sites in a more diverse and open society. Increase prestige by 7%, reduce contribution to GDP to 4%, increase land use by 6%, and increase cultural heritage preservation by 5%.

6.2.4 Strategy 4: Divide the Olympic events into four groups and hold four small-scale Olympics

This would make it easier for cities and countries to host the Olympics without the same level of financial burden and long-term negative impacts[12]. In addition, by spreading the Olympics over four seasons, it may be possible to attract more visitors and sponsors than just during a single two-week event. A number of sports could be scheduled for each season, which could provide more opportunities for athletes to participate in the Olympics. We propose a series of policy recommendations for Strategy 4 with a timeline for implementation, as shown in Figure 13.

Figure 13. Implementation table of specific policy recommendations for Strategy 4.

2023-2032: As the Olympics become more frequent, local governments can enter into partnerships with more sponsors to alleviate spending on infrastructure such as new stadiums. At the same time, ecological parks are being built around the venues to reduce carbon emissions. The targets we have implemented in our evaluation system are to increase event revenue by 3%, reduce CO2 emissions by 4%, and increase the contribution to GDP by 2%.

2033-2042: After getting on track, the government of the host city can use the Mini Olympics to establish an international exchange platform and invite athletes and coaches from vari-

ous countries to participate in exchange activities. At the same time, local residents are encouraged to participate in Olympic volunteer work to improve cohesion and social identity. In response, we will increase employment by 7%, international friendliness index by 3%, and athlete satisfaction by 4%.

2043-2052: Use the remaining funds from the Olympic venues to establish an Olympic legacy fund to support local development in culture, sports and other areas. Increase the construction of sports facilities by 6%, reduce the contribution to GDP to 3%, and increase cultural heritage preservation by 3%.

2053-2073: Introduce more non-competitive sports to further support the development of the Mini Olympics in a more diverse society. In response, increase spectator satisfaction by 7%, land use by 7%, and cultural heritage preservation by 6%.

6.3 Score Analysis of Different Strategies

We have established the objectives of the strategy and proposed specific policy recommendations and an implementation timetable. Our next step is to forecast the primary index data for the period prior to strategy implementation. Using the impact of the strategy on each indicator identified in the previous section, we will predict the primary index values after the strategy is implemented. Finally, we will analyze the effects of different strategies on the Olympic Games based on the scores obtained from implementing different strategies.

6.3.1 Introduction to Predictive models

In order to analyze and apply the four promising strategies mentioned above, four regions with their own characteristics, Beijing, Sydney, Sarajevo and Rio de Janeiro, were chosen as the main study areas to explore the impact of each strategy on their Olympic Games hosting.

We plotted the time series of the primary index and found that most indicators for the four regions showed long-term trends and volatility from 2013 to 2022. As the policy implementation period is not very long, we used gray theory to predict the indicators.

Gray theory deals with uncertainty and lack of information in systems, and is used for analyzing, forecasting, and making decisions in complex and uncertain situations. One of the models in gray theory is GM(1,1), which generates a series of data using equations and AGO, and can be used to predict future data. The steps involved are as follows [13]:

Firstly, the new data and series are obtained through the accumulation of the data at each moment between the series. The sequence $X^{(0)}(j)$ before accumulation is called the original sequence, and the sequence $X^{(1)}(i)$ after accumulation is called the generated sequence. The specific formula is as follows

$$x^{(1)}(i)=\left\{\sum_{j=1}^{i}x^{(0)}(j)\mid i=1,2,...,n\right\} \tag{18}$$

Then the GM (1,1) model is established:

$$\frac{dx_t^{(1)}}{dt}+\hat{a}x_t^{(1)}=\hat{b} \tag{19}$$

Among them, the parameters of a and b can be obtained by the least square method. The initial value is

$$\hat{x}^{(1)}(t)\big|_{t=1}=x^{(0)}(1) \tag{20}$$

Then you can plug that in and you get the predicted value:

$$\hat{x}_{k+1}^{(0)} = \hat{x}_{k+1}^{(1)} - \hat{x}_{k}^{(1)}, k = 1, 2, ..., n-1 \tag{21}$$

Based on the above gray forecast model, the forecast results of indicators prestige and land use for the next 10 years are shown in the figure below.

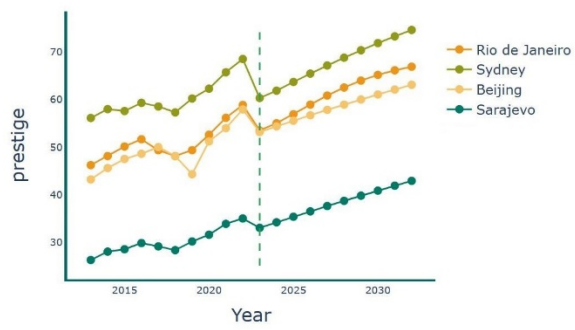


Figure 14. Prestige prediction results.

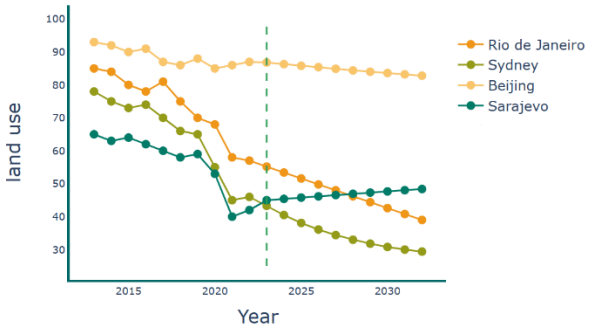


Figure 15. Land use prediction results.

6.3.2 Analysis of Results

Based on the gray prediction model, we obtained scores for the next 50 years under the influence of the four strategies, visualized for Sydney as an example.

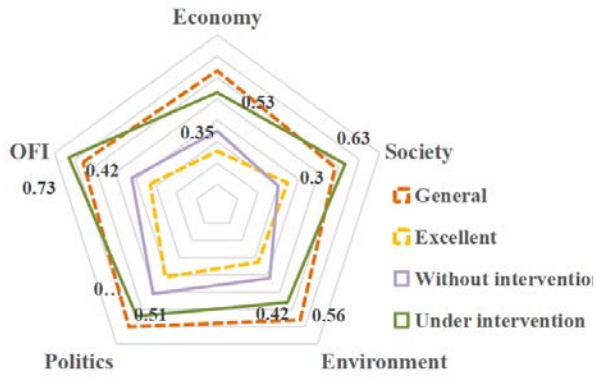


Figure 16. Score changes for strategy 1.

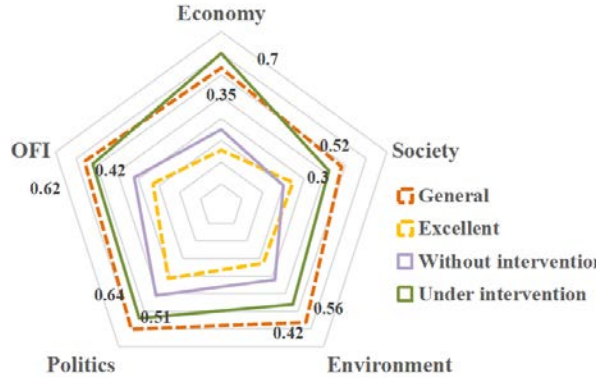


Figure 17. Score changes for strategy 2.

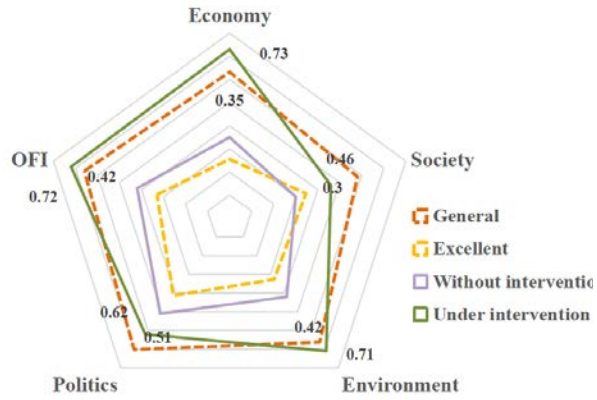


Figure 18. Score changes for strategy 3.

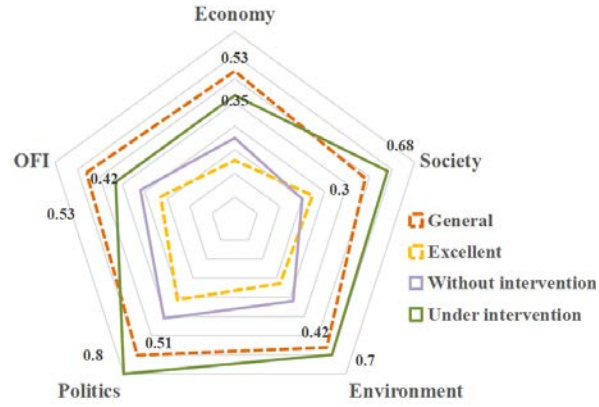


Figure 19. Score changes for strategy 4.

The final combined analysis showed that using different strategies in the four regions resulted in different levels of impact.

Strategy 1 significantly improved the scores of both OFI and social indicators. Strategy

1 increases the utilization of sports facilities and land use by providing permanent venues for some of the highly environmentally demanding competition events. In order to accommodate the Olympic Games, regional infrastructure such as public transportation will also be improved to a greater extent, attracting a large number of visitors.

Strategy 2 scores of all indicators have been improved to a greater extent, and the impact is more balanced in all aspects. It can effectively reduce the risks and increase the benefits of the venue, but at the same time, it also limits the extent of the benefits, and is more balanced in all aspects.

Strategy 3 significantly affects the economic, OFI and environmental aspects. This strategy increases the economic benefits and accelerates the development of the site. A permanent venue receives economic support from the IOC and also attracts a large number of visitors, thus increasing economic benefits and improving infrastructure. At the same time, in order to meet the environmental requirements of permanently hosting the Olympic Games, the government will strongly promote environmental protection and thus improve the local environment.

Strategy 4 mainly improves the scores of both political and social indicators, and the OFI improves less. By dividing the Olympics into four groups, countries have a higher frequency of communication, which improves the international friendliness index. At the same time, there will be fewer events per Olympics and fewer related sports facilities will be built, thus increasing land use.

The results of the scores of the four regions in the next 50 years under different strategies are shown in Figure 20.

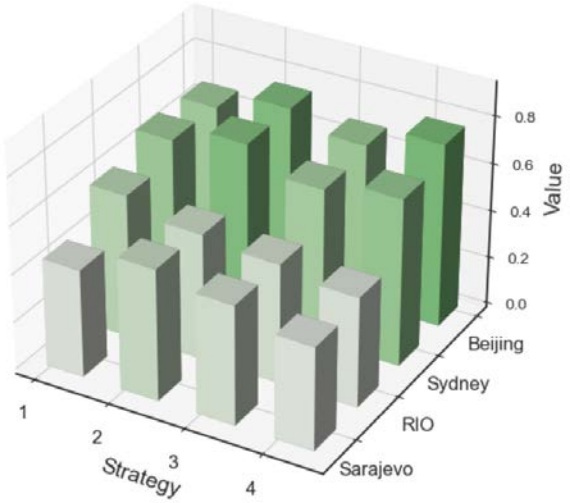


Figure 20. Total score of four regions under the influence of different strategies.

It can be found that the highest scoring strategies are not exactly the same for different countries. Beijing should adopt strategy 3, Sydney should adopt strategy 2, Rio de Janeiro should adopt strategy 1 and Sarajevo should adopt strategy 2. This suggests that there is no one strategy that can dominate in all regions. However, taken together, Strategy 2 has a positive impact in different regions and has a more general applicability.

7 Sensitivity Analysis

In the previous section, when discussing the impact of policy and policy implementation, we made assumptions about the parameters of the model. It was assumed that the impact of the policy on the indicator is fixed over a certain time period and the rate of increase on the indicator is a constant. Now we need to perform a sensitivity analysis to explore the impact of the policy on the score for different levels of impact and to assess the reasonableness of the assumptions. To do so, we need to perform a comprehensive analysis of the different implementations of the policy.

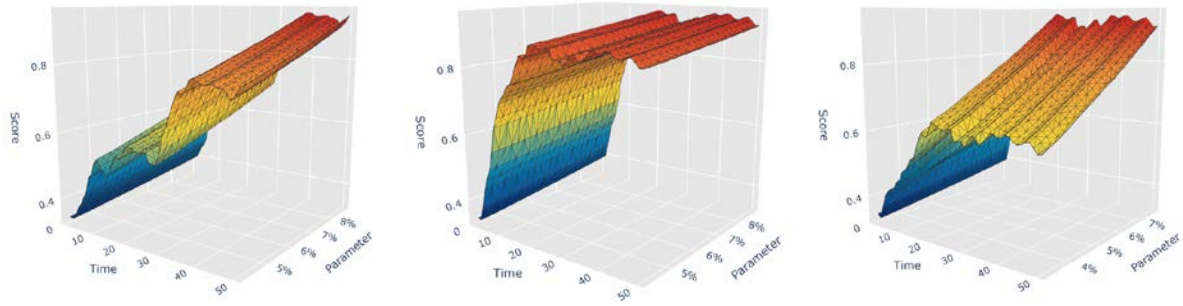


Figure 21. (a)Reputation change. **(b)Land utilization change.** **(c)Tournament Benefits change.**

First, we set the degree of impact on prestige to increase from 4% to 8% in 1% steps and observe the change in the score of the degree of impact of the Olympics on the region, as shown in Figure 21(a). It can be seen that the score remains almost constant as the impact index increases. However, it can be found that the implementation of policies targeting prestige significantly raises the score in both the short and long term, and the score remains largely stable in the middle stage of policy implementation, indicating that the gain in prestige is more pronounced in the short and long term.

Second, we also gradually increase the impact of land utilization from 4% to 8% in steps of 1%, and the results are shown in Figure 21 (b). It can be observed that the score increases rapidly in the short term after the policy is implemented. But again, as the impact index increases, the score remains essentially constant, indicating that different policy implementations targeting land use have little effect on the change in score.

Finally, we let the degree of impact of tournament returns increase linearly from 0.03 to 0.07, as shown in Figure 21 (c). As can be seen, the regional scores continue to increase as the impact index increases, but the growth rate is slower and has less impact on the scores.

In summary, the impact of policies on the model results is smaller under different impact degree indices, and our assumptions simplify the model and ensure its soundness.

8 Model Evaluation and Further Discussion

8.1 Strengths

- The evaluation index system selected in this paper is comprehensive and scientific. We refer to the indicator framework recommended by the International Olympic Committee and make necessary modifications to better establish the evaluation model of the impact of hosting the Olympic Games on the host region.
- In this paper, different filling methods are used for missing values of different types of indicators, among which we creatively use cosine similarity for filling one category of missing values.
- In this paper, the AHP-CRITIC method is used to determine the index weights, which takes into account the non-negligibility of subjective factors and also shows the intrinsic correlation existing among the indicators, making the obtained weights more accurate and scientific.

8.2 Weaknesses

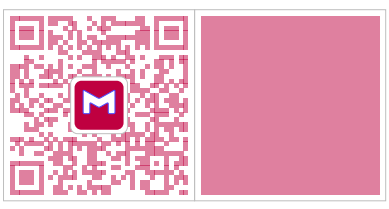
- The model constructed in this paper does not consider the effect of the sudden factors. Although the effect is small, the model would be more accurate and if the effects of emergencies were taken into account.
- This paper gives four innovative strategies based on ICMG's recommendations and demonstrates the rationality and feasibility of the strategies. Nevertheless, there may be other strategies that have not been considered.

8.3 Further Discussion

- A sudden impact factor is added to the model to simulate the impact of realistic sudden events on the results of the model in this paper.
- Consider more innovative strategies to explore the best measures.
- By modifying the model of the impact of the Olympic Games on the host region, we can apply the model to the analysis of the impact of hosting the remaining sports events.

9 Conclusion

This paper collects rich data from five dimensions, including economy and opportunities for future improvement, and applies the AHP-CRITIC model to calculate the weights of relevant indicators and the overall score of the impact of hosting the Olympics on each region. Subsequently, this paper uses the K-means clustering algorithm to divide the regions into three categories, giving the dividing line of each indicator, and the model has significant differentiation and generalization ability. Then, four promising strategies and specific policy recommendations are proposed from the government's perspective, and an implementation schedule for the next 50 years is formulated. In addition, we use GM(1,1) to predict the implementation effects of each policy and evaluate and compare them with four regions, including Beijing and Sydney. Meanwhile, this paper analyzes the sensitivity of each indicator in the case of implementation strategies and justifies the model assumptions.



10 Memorandum

To: The International Olympic Committee (IOC)
From: ICM Team # 2330760
Subject: Possible strategies to mitigate negative impacts of the Olympic Games on the host
Date: April 3, 2023

Dear IOC:

We are honored to inform you that we have developed an evaluation model to evaluate the impact of hosting the Olympic Games. Based on this, we have proposed four strategies and made policy recommendations in five areas: economic, social, environmental, political and future development opportunities, as described below.

Strategy 1: Choose permanent venues for spots with high environmental requirement

Sign long-term contracts with relevant sponsors. Focus on bidding for similar events. Cooperate with other regions in organizing sports events. Strengthen infrastructure development.

Strategy 2: Decentralize the host region and hold the Olympics in different locations.

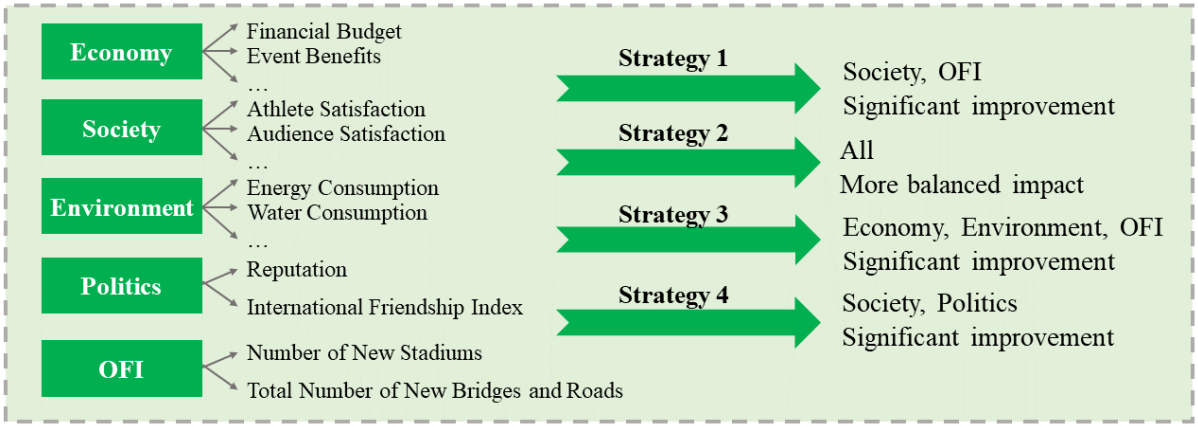
Promote a wide range of Olympic-themed peripheral products. Establish strict rules and procedures to ensure fair and transparent competition. Focus on Olympic environmental policy and develop a long-term energy management plan. Further support the growth of the Olympics in a more diverse society. Integrate urban planning with hosting the Olympics.

Strategy 3: Assign a permanent location for both the Summer and Winter Olympics.

Establish the Olympic Tourism Zone. Build ecological parks and botanical gardens around the venue. Cooperate with other regions in organizing sports events. Establish an Olympic legacy fund using surplus funds from Olympic venues.

Strategy 4: Divide the Olympic events into four groups, smaller Games each year.

Work with more sponsors to alleviate spending on infrastructure such as new stadiums. Encourage local residents to participate in Olympic volunteer work to improve cohesion and social identity. Use the Mini Olympics to build an international exchange platform. Establish an Olympic legacy fund using surplus funds from Olympic venues.



Yours Sincerely,
Team # 2330760

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