Research on Olympic Games Hosting Scheme Based on Comprehensive Evaluation and Grey Prediction Model

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Abstract. Owing to the confluence of financial, environmental, and societal pressures confronting both the host city and nation, the allure of bidding for the Olympic Games across diverse global regions is experiencing a discernible wane. In an effort to proffer a structured framework for Olympic Games bidding, this paper undertakes an initial phase of indicator selection and subsequent determination of their respective weights. We have meticulously curated a selection of the utmost fitting cities to serve as potential hosts for the grandeur of the Summer Olympic Games across the global stage. This intricate process is achieved through the confluence of methodologies including the Delphi Method, the Analytic Hierarchy Process (AHP), and the EWM-TOPSIS Method. Subsequently, guided by the Comprehensive Evaluation Model, the study identifies a pair of fitting global locales poised for the enduring stewardship of the summer and winter Olympic Games. This paper culminates in scrutinizing the feasibility of the proposed scheme. This scrutiny takes the form of an inquiry into both immediate and prolonged repercussions of the Olympic Games upon the host city or nation. Parameters of Real GDP per capita, the proportion of international trade taxes, and carbon emissions are dissected, employing the discerning capabilities of the GREY Model. The outcomes of this inquiry distinctly underscore the efficacy of the strategy involving a fixed hosting address, bolstering affirmative developmental trajectories for the host locale. This study bears substantial reference value for the Olympic Organizing Committee in its pursuit of identifying a fresh and distinctive Olympic venue.

Keywords: AHP Model, EWM-TOPSIS Method, Comprehensive Evaluation Model, GREY Prediction Model.

1. Introduction

A few years ago, hosting the Olympic Games was highly competitive and prestigious. Nowadays, hosting the Olympic Games has brought many negative effects to the host country or city. The International Olympic Committee (IOC) is facing an increasing challenge, that is, the decline in the number of Olympic bids.

In order to solve these problems, this paper constantly explores and puts forward new solutions and strategies to ensure the success of the Olympic Games and continue to connect the whole world through the Olympic spirit and sports competitions. However, there are many factors to be considered in choosing a suitable Olympic host city, such as economy, land use, people's satisfaction, tourism, its influence on the future, the prestige of the host country or city, ecology and so on. In Zhang Aiping's research, he used descriptive statistical analysis and robustness test to analyze the impact of large-scale stadium events on the urban environment [1].In the research of Timothy Koba and others, they measure the economic impact of hosting the Olympic Games by studying the sustainable development of the host city and the legacy venues in recent Olympic Games [2].Xue Desheng and others found that hosting the Olympic Games is conducive to promoting the development of the world city network(MCN) [3].Flyvbjerg and others studied the cost budget and cost overrun of the Olympic Games, and the results showed that the cost overrun of the Olympic Games was very serious [4].In a

word, most studies only evaluate a few cities or indicators, and there are few studies that evaluate many cities in many aspects.

In this case, it is necessary to use mathematical modeling methods and comprehensively consider various factors to provide scientific basis for choosing a reasonable bid for the Olympic Games. Different from other studies that only evaluate one or several aspects of a city or country's GDP or urban infrastructure construction for the Olympic Games. We selected the most suitable cities for hosting the Summer Olympic Games in the world, including Beijing, Vancouver, Nagano, Lillehammer and Lake Placid, and the most suitable cities for hosting the Winter Olympic Games, including Los Angeles, Sydney, London, Beijing and Tokyo. Using Analytic Hierarchy Process (AHP) and EWM-TOPSIS method, this paper evaluates and quantifies seven indicators, such as economy, land use, effect for future improvement, prestige of the city or country hosting the Olympic Games, human satisfaction and travel. Considering comprehensively in many aspects, a GREY Model is established to predict the per capita real GDP, net inflow of FDI and carbon emissions of the selected cities, and the most suitable cities for hosting the Summer Olympic Games and the Winter Olympic Games are selected under the consideration of the current situation and future prediction of each city. In order to establish a mathematical model to solve the problem, we divide the research process into the following three steps.

step 1: Establish metrics for the impacts of hosting the Olympic games. We applied the Delphi Method to identify 7 first-level indicators. We calculated the impacts of the Olympics using two methods: the Analytic Hierarchy Process (AHP) and the EWM-TOPSIS Method. Then integrated the two scores to perform a combined weighting analysis on the weight values of the relevant indicators, in order to obtain the final score of each city, and decide which countries are suitable for permanent hosting.

step 2: According to the Comprehensive Evaluation Model, we have identified two suitable cities around the world to host Summer and Winter Olympic Games permanently. Beijing is the most suitable country to host the Summer Olympics, while Vancouver and Whistler are the most suitable countries to host the Winter Olympics.

step 3: Ultimately, we would like to predict whether our strategy can solve the challenges. Set up the GREY Model taken into consideration, so as to analysis the influence of the host cities/nations in short-and long-term. We selected three significant model indicators, Real GDP per capita, Net FDI Inflows, and Carbon Emissions, to predict the situation of the two cities in two years and seven years from now respectively.

2. Model Establishment and Solutions

In order to solving the above problems, to evaluate the impacts of hosting the Olympic games, a comprehensive approach was taken. First, the Delphi Method [5] was used to determine the first-level index system, and second-level quantitative index data was collected through the official website. The first-level index system consists of seven indicators, such as Economic, Land Use , Effect for Future improvements, Ecology , Human Satisfaction, Travel, Host City or Nation Prestige. The second-level index system consists of fifteen indicators, such as real GDP per capita, the revenue and expenditure, the proportion of international trade taxes, proportion of venues in urban area/million square meters, number of patents, inflation by GDP deflator, inflation by consumer consumption, carbon emissions, average summer temperature, athlete satisfaction, employment rate, international tourism passenger revenue, international tourism arrivals, international tourism revenue, net FDI inflows. The above indicators were used to establish an model for impacts of Olympics, which is helpful to integrate with the following comprehensive evaluation model.

Then, the AHP Assessment Model and EWM-TOPSIS Assessment Model of Impacts of Olympic Hosting were established. Both models weighed and compared the subjective and objective factors of each index to determine the final weight summative ranking of each scheme's suitability for hosting the Olympic Games.

To complete the evaluation process, we establish and utilize the AHP-EWM-TOPSIS Comprehensive evaluation Method, which takes into account the above two evaluation models. Using this method, we are able to obtain the final weight and ranking for each scheme layer in terms of their suitability for hosting the Olympic Games.

2.1. AHP Assessment Model of Impacts of Olympic hosting

Based on the information provided, it seems that a hierarchical structure has been established for the impacts of hosting the Summer or Winter Olympics, with the target layer being the impacts themselves and the quasi layer being the Delphi expert evaluation method.

The primary indicators identified through the Delphi method are Economic, Land Use, Human Satisfaction [6], Travel, Effect for Future Improvements, Host City or Nation Prestige, and Ecology.

With each of these having secondary indicators. For example, Real GDP per capita, revenue and expenditure, proportion of international trade taxes, etc. are secondary indicators for Economic.

The scheme layer includes different host cities for the Olympics, such as Beijing, London, Sydney, Tokyo, Los Angeles, Vancouver & Whistler, Nagano, Lillehammer, and Lake Placid.

It appears that the AHP and EWM assessment models will be used to comprehensively evaluate the impacts of hosting the Olympics for these different cities. As shown in Figure 1 and Figure 2, the weight calculation results for the Olympic, effect for future improvements and Economic have a relatively large proportion, whether in summer or winter.

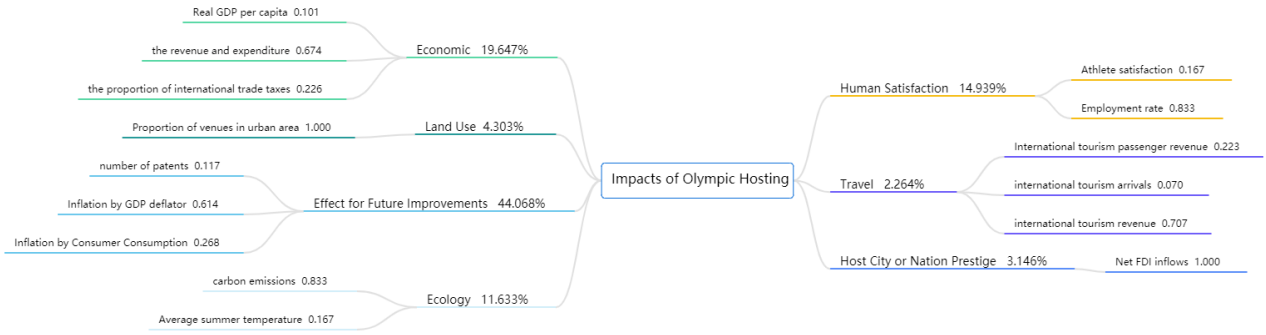


Figure 1: The weight calculation results for the Summer Olympic

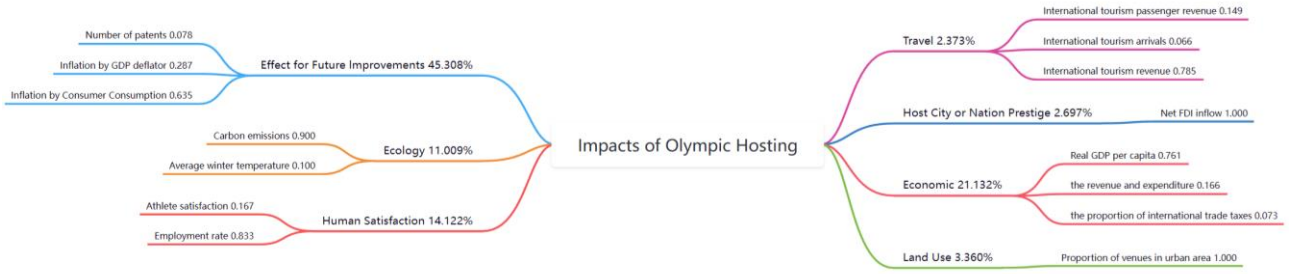


Figure 2: The weight calculation results for the Winter Olympic

2.1.1. Analysis and Evaluation of Results

According to Figure 3, the country that is best suited to host the Winter Olympics is Los Angeles.

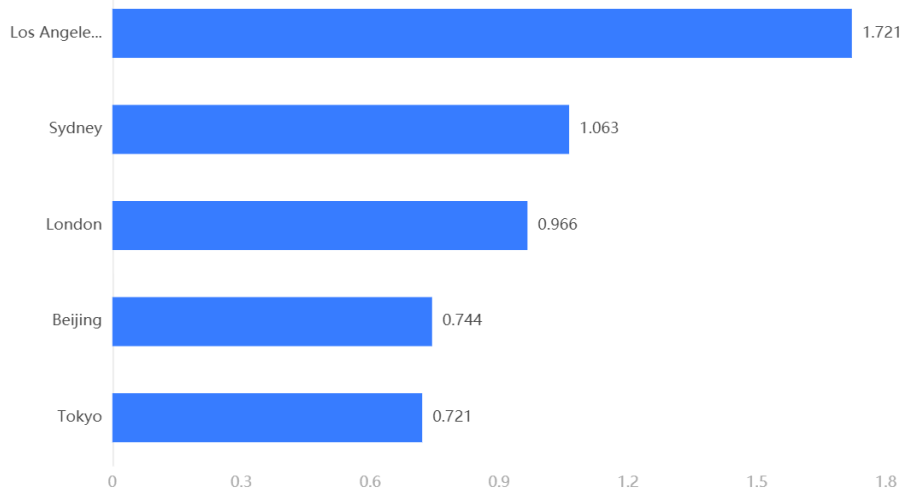


Figure 3: The weight calculation results for the Summer Olympic

According to Figure 4, the country that is best suited to host the Summer Olympics is Beijing.

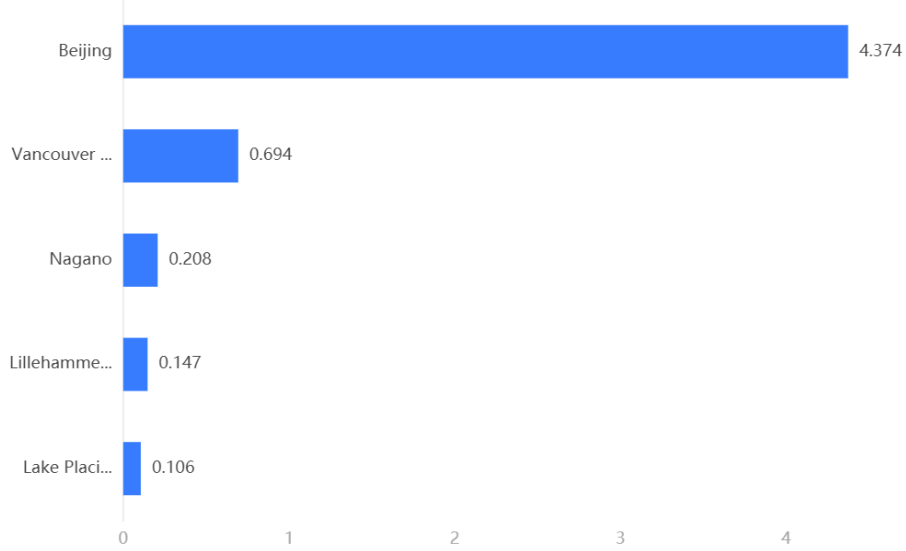


Figure 4: The weight calculation results for the Winter Olympic

2.2. EWM-TOPSIS Assessment Model of Impacts of Olympic Hosting

2.2.1. Model Establishment

The TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) model is a method used to rank evaluation objects based on their degree of proximity to idealized targets. It is a comprehensive distance evaluation method.

The basic idea of the TOPSIS model is to calculate the weight of each indicator using the Entropy Weight Method (EWM), The Entrophy Weight Method(EWM) is an objective weighting method, which based on the greater the degree of dispersion, The greater the degree of differentiation, the more information we can get. We used EWM to determine the weights of normalized indicators. By assuming positive and negative ideal solutions, the distance between each sample and the positive and negative ideal solutions is measured. This allows us to obtain the relative closeness degree between each sample and the ideal solution, which is used to rank the evaluation objects based on their proximity to the ideal solution.

step 1: Homogeneity and standardization of indicators.

EWM model was used to get the weights. The entropy weight method is used to confirm the weight of each index and avoid the influence of subjective factors. The weight vector W and the standardized matrix P are obtained.

Since all of dates are normalized and are of benefit-type, the normalization process for each indicator is:

Firstly, we calculate the weight of the jjth indicator in the iith cities or countries.

$$w_{ij} = \frac{r_{ij}}{\sum_{i=1}^{n} r_{ij}} \tag{1}$$

$$r_i' = \frac{r_{ij} - min\{r_j\}}{max\{r_j\} - min\{r_j\}}, \tag{2}$$

And then, According to the concept of self-information and entropy in information theory, the information entropy $EEjj$ of each evaluation indicator can be calculated,

$$E_j = -\frac{\sum_{i=1}^{m} p_{ij} \ln p_{ij}}{\ln m}, \tag{3}$$

$$p_{ij} = \frac{r_{ij}'}{\sum_{i=1}^{m} r_{ij}'}, \tag{4}$$

Lastly, Based on the information entropy, it will further calculate the weight of each indicator which we defined before.

$$\beta_j = \frac{1 - E_j}{n - \sum_{j=1}^{n} E_j} \tag{5}$$

step 2: The normalized matrix Z is weighted. Z is given by P times W

$$Z = (z_{ij})_{n \times m} = (p_{ij} * w_j) \tag{6}$$

step 3: Determine positive and negative ideal solutions.

Positive ideal solution means that each index reaches the best value in the sample, while negative ideal solution means that each index reaches the worst value in the sample.

step 4: Calculate the distance between each sample and the positive and negative ideal solutions. Calculate the degree of closeness between each evaluation object and the optimal scheme.

$$D_i^+ = \sqrt{\sum_{j=1}^{m} \left(z_{ij} - z_j^+\right)^2}, D_i^- = \sqrt{\sum_{j=1}^{m} \left(z_{ij} - z_j^-\right)^2}, (i = 1, \ldots, n) \tag{7}$$

step 5: The value range is [0,1]. The closer the value is to 1, the better the sample score is.

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{8}$$

2.2.2. Analysis and Evaluation of Results

The ideal distance, weight and ranking of Winter and Summer Olympic Games with EWM-TOPSIS Assessment Model. Table 1 show the rank first of Summer Olympic is Beijing. Table 2 show the rank first of Winter Olympic is Vancouver & Whistler.

Table 1: Results of Summer Olympic

Cities	Positive ideal distance(D+)	Negative ideal distance(D-)	Weight	Ranking Order
Beijing	0.46201983	0.8161257	0.6385233	1
London	0.73320286	0.5160979	0.41310941	2
Sydney	0.76653683	0.51735668	0.40295918	3
Tokyo	0.83481529	0.44701369	0.34873115	4
Los Angeles	0.85146687	0.25407109	0.22981671	5

Table 2: Results of Winter Olympic

Cities	Positive ideal distance(D+)	Negative ideal distance(D-)	Weight	Ranking Order
Vancouver & Whistler	0.55252876	0.7118575	0.56300636	1
Nagano	0.61466349	0.62235346	0.50310827	2
Beijing	0.67158181	0.65370106	0.49325399	3
Lillehammer	0.6931455	0.56141349	0.44749868	4
Lake Placid	0.77500823	0.49358286	0.38907956	5

2.3. Comprehensive evaluation model of Impacts of Olympic hosting

2.3.1. Model Establishment

We use AHP and EWM-TOPSIS respectively to calculate two sets of weight vectors. Now we take both into account and get the final weights.

$$\mathbf{W}_i = \omega \mathbf{W}_{\mathbf{A_i}} + (1-\omega)\mathbf{W}_{\mathbf{E_i}} \tag{9}$$

This where represents the coefficients of the two methods, the importance of each method. Since our data are all measurable, we value EWM-TOPSIS more because EWM is more objective than AHP. We set w= 0.3 and the final weight of each part.

2.3.2. Analysis and Evaluation of Results

As shown in Figures 5 and 6, for both the Summer Olympics and Winter Olympics, Travel, Effect for Future improvements, and Economic have the highest weights[7]. Travel in Summer Olympics accounts for about 30%, which is 50% higher than it in Winter Olympics, however, the Winter Olympics are more important for the Host City or Nation Prestige[8].

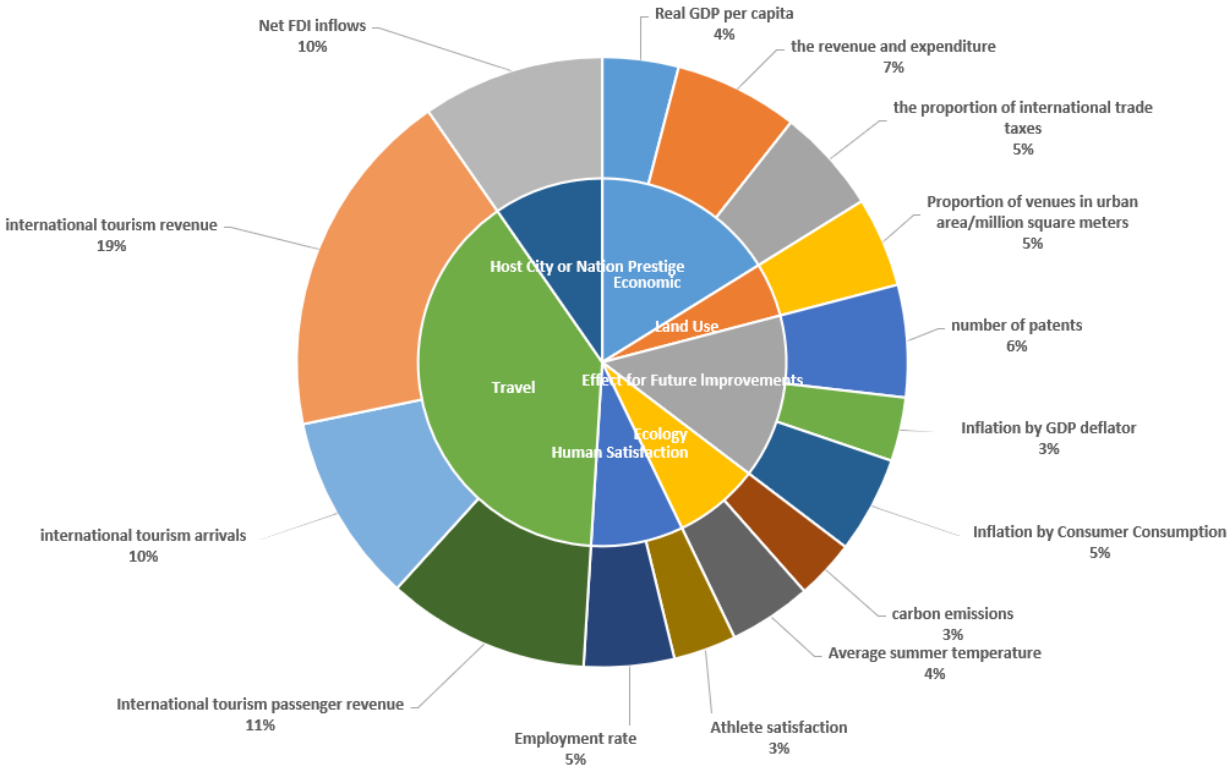


Figure 5: Comprehensive Weight of each Summer Olympics Indicator

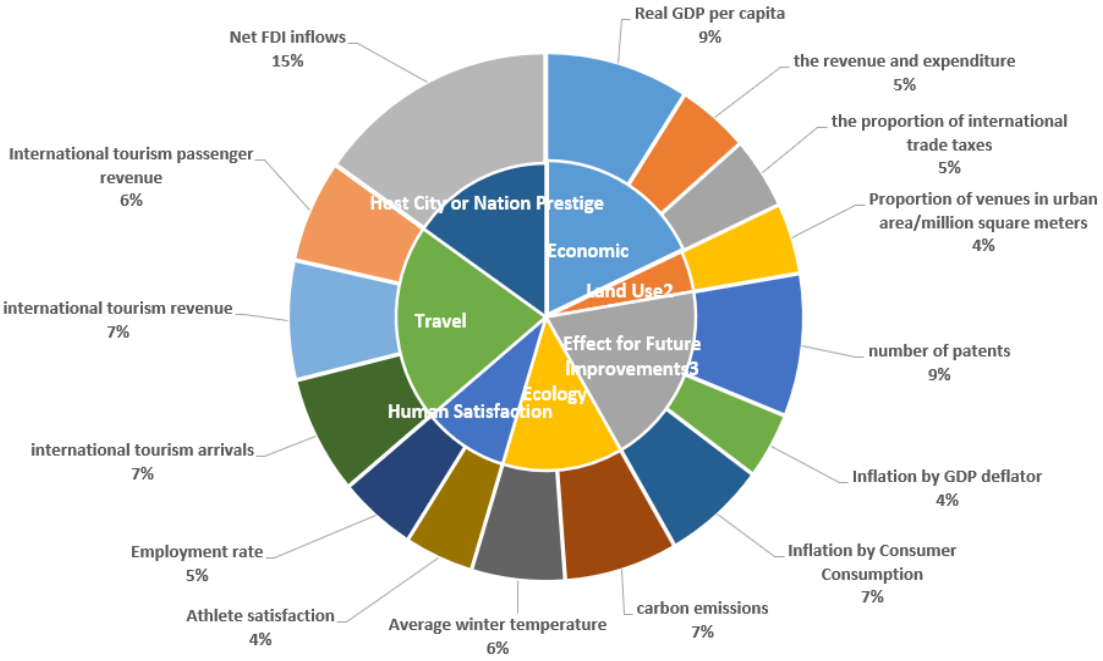


Figure 6: Comprehensive Weight of each Winter Olympics Indicator

Based on the established AHP-EWM-TOPSIS comprehensive evaluation method, the above-mentioned two evaluation models have been considered and the final weight and ranking have been obtained. This comprehensive evaluation approach provides a robust mathematical framework for further analysis and decision-making.

Based on the Comprehensive Evaluation Model, Beijing has ranked first in the comprehensive weight of each Summer Olympics indicator, making it the most suitable city to host the Games on a regular basis. Similarly, Vancouver & Whistler have been ranked first in the comprehensive weight of each Winter Olympics indicator, making it the most suitable city to host the Winter Olympics on a regular basis. These results provide a strong mathematical model that can guide further approaches and policy-making in hosting the Olympics.

3. Strategies and Prediction

3.1. Complete Solution

After analyzing the issue from various aspects, we figure out the method of holding the Summer Olympics and the Winter Olympics in two cities: Beijing and Vancouver & Whistler. Starting from 2032 and 2030, the Summer Olympics and the Winter Olympics will be held multiple times in the above-mentioned two cities in a 4-year cycle.

For analysis the influence of the host cities/nations in short-and long-term of this strategy[9], we set up the GREY Model. We selected three significant model indicators, Real GDP per capita[10], Net FDI Inflows, and Carbon Emissions, to predict the situation of the two cities in two years and seven years from now respectively.

3.1.1. GREY Model Establishment

We used historical data collected from the official website database to establish grey prediction fitting curves for the Real GDP per capital, Net FDI Inflows, and Carbon Emissions indicators in two cities, and corrected the results.

Prediction analysis for the Beijing is shown as Figure 7, prediction analysis for the Vancouver&Whistler is shown as Figure 8. Through the curve, we predicted the two and seven years after the implementation of the strategy.

3.1.2. Results of model

The results of the GREY Model, we found that both Real GDP per capital and Net FDI Inflows increased, while carbon emissions decreased. Therefore, the prediction results further confirmed the correctness of the conclusions drawn above. In conclusion is that the impact of the regular hosting of the Olympic Games is positive.

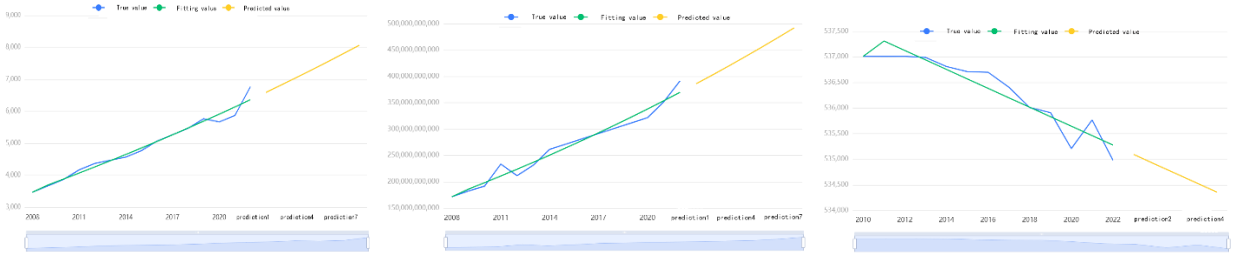


Figure 7: Prediction analysis for the Beijing

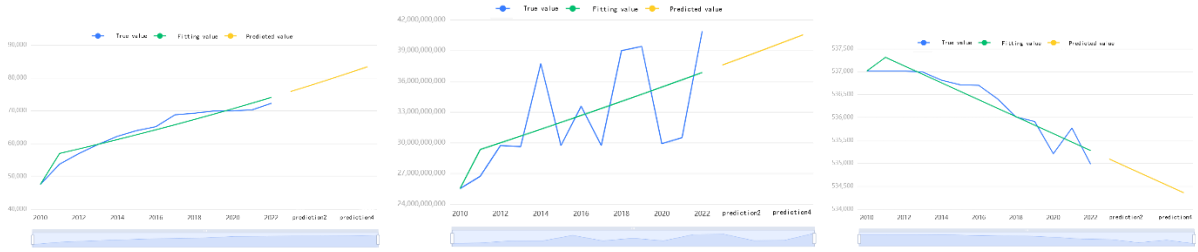


Figure 8: Prediction analysis for the Vancouver & Whistler

3.2. Impact of Potential Strategies

The following are some potential strategies for cities hosting the Olympic Games:
Building new sports venues and facilities: This will improve the city's ability to host the Olympic Games and increase its attractiveness to tourists and athletes.

Improving the public transportation system: This will provide better travel methods for tourists and residents, improve urban accessibility, and reduce private car use and traffic congestion.

Strengthen environmental protection measures: Improve the environmental quality and sustainability of cities by reducing pollution and waste emissions in order to better prepare for the Olympic Games.
Promote tourism development: Increase the number of tourists and create more employment opportunities by providing more tourist attractions, activities, and services.

These strategies may have a positive impact on the hosting of the Olympic Games in fixed cities, but when implementing strategies, it is necessary to consider the relationship between different factors, and adopt appropriate decision-making models and methods for analysis and evaluation to achieve the best results.

4. Conclusions

Guided by an integrated assessment model, our methodology aims to identify the two cities best suited to host the Summer and Winter Olympic Games on a permanent basis. The impact of hosting the Olympic Games was synthesized by creating an assessment framework. To this end, we identified seven main indicators (economy, land use, human satisfaction, tourism, impact on the future, reputation of the host city or country, and ecology) using the Delphi method and quantified the impact of the Olympic Games using two different methods. The first is the Hierarchical Analysis Method (AHP), followed by the EWM-TOPSIS method. The latter method combines the Entropy Weight Method (EWM) and the Technique of Ordering Preferences for Similarity to Ideal Solutions (TOPSIS). The achievement scores measured above are fused and a combined weighted analysis is performed to determine the weights of the relevant indicators to provide guidance on the selection of countries suitable for hosting the Olympic Games on a permanent basis.

The summer and winter Olympic Games have very different impacts on GDP per capita, and the negative effect of the winter Olympics is not robust under the various corrections in the sensitivity analysis compared to the summer Olympics [11]. Based on the results of the new methodology, Beijing was identified as the most suitable city to host the Summer Olympics, while Vancouver and Whistler proved to be the best choices to host the Winter Olympics. Criteria for selecting the cities included climate suitability, stress-resistant transportation networks, well-developed infrastructure and well-developed economies. At the same time, the host country needs to bear the designated hosting costs and provide the necessary support staff and other necessary expenses.

Based on the results of the study, we analyzed the expected impacts of the host city and host country in the short and long term using the Gray model. Real GDP per capita, net FDI inflows and carbon emissions are the three key variables. The forecasting analysis spans a period of seven years and aims to provide a reliable prediction of the future situation of the selected cities. According to the relevant literature, the feasibility of hosting the recent Olympic Games for the host city or government is mainly a budgetary issue, with tourist demand and infrastructure investment providing benefits over and above the costs, so within the limits of its capacity, the country should seize the opportunity to host mega-events and the benefits from the indirect effects of the mega-events are widely diffused throughout the economy [8].

The main conclusion based on the computational model is that the continuation of the Olympic Games will produce positive results. And that the Olympic legacy will benefit the host city in the long term under the expected long-term benefits policy of the Olympic Legacy Framework proposed by the International Olympic Committee (IOC).

According to the above research, the long-term effects of the Olympic legacy will be long-lasting in the host city and country, and the scale effect and economic investment will stimulate the whole country's new vitality in the global economy [5]. In addition, the Olympic Games is a milestone of human civilization, and the host city will leave its mark in the long history of human spiritual civilization.

References

[1] A. Zhang, “Research on the Surrounding Environment of Large-scale Sports Events,” IOP Conf. Ser.: Earth Environ. Sci., vol. 208, p. 012057, Dec. 2018.

[2] T. Koba, H. Gong, W. J. Ross, and J. Grady, “Sustainable Olympic Development: A Proposed Benchmark for Managing Economic Outcomes,” Journal of Global Sport Management, vol. 6, no. 1, pp. 49–69, Jan. 2021.

[3] D. Xue and Y. Ou, “Intercity connections and a world city network based on international sport events: Empirical studies on the Beijing, London, and Rio de Janeiro Olympic Games,” J. Geogr. Sci., vol. 31, no. 12, pp. 1791–1815, Dec. 2021.

[4] B. Flyvbjerg and A. Stewart, “The Oxford Olympics Study 2016: Cost and Cost Overrun at the Games,” SSRN Journal, 2016.

[5] S.-J. Han, W.-J. Lee, S.-H. Kim, S.-H. Yoon, and H. Pyun, “Assessing Expected Long-term Benefits for the Olympic Games: Delphi-AHP Approach from Korean Olympic Experts,” SAGE Open, vol. 12, no. 4, p. 215824402211444, Oct. 2022.

[6] M. J. Stinson and D. R. Stinson, “An Analysis and Critique of the Scoring Method Used for Sport Climbing at the 2020 Tokyo Olympics.” arXiv, Aug. 28, 2021.

[7] M. Khraiche and A. Alakshendra, “Hosting the Olympics: why are we always getting the cost wrong? ,” MF, vol. 47, no. 6, pp. 845–855, Jun. 2021.

[8] J. Wood and S. Meng, “The economic impacts of the 2018 Winter Olympics,” Tourism Economics, vol. 27, no. 7, pp. 1303–1322, Nov. 2021.

[9] M. Müller, S. D. Wolfe, C. Gaffney, D. Gogishvili, M. Hug, and A. Leick, “An evaluation of the sustainability of the Olympic Games,” Nat Sustain, vol. 4, no. 4, pp. 340–348, Apr. 2021.

[10] J. Li, X. Wang, and S. Sun, “The Impact of Successful Bid for 2022 Beijing Winter Olympic Games on Local Economic and Social Lives,” AEMPS, vol. 3, no. 1, pp. 154–164, Mar. 2023.

[11] M. Firgo, “The causal economic effects of Olympic Games on host regions,” Regional Science and Urban Economics, vol. 88, p. 103673, May 2021.