A Study on the Olympic Hosting Proposal Based on Comprehensive Evaluation and the ARIMA Model

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Abstract. As a significant event, the Olympic Games have attracted considerable attention since their inception. However, in recent times, enthusiasm for hosting the Olympics among countries worldwide has seen a decline. To propose a reasonable Olympic hosting plan, this article establishes an Olympic hosting capability assessment model. The study selected 11 countries that have hosted either the Summer or Winter Olympics in the past 20 years and investigated seven key aspects of evaluation indicators. Using the EWM-AHP method combined with the TOPSIS method, scores were assigned to these 11 countries. Based on the scores, nations that have previously hosted the Olympics were ranked. The top three countries for both Winter and Summer Olympics were identified, suggesting that the Olympic Games rotate among these nations. To predict the future impact of hosting the Olympics on the host country, this article employs the ARIMA model to forecast the future development of the host nations. The results indicate that hosting the Olympics will lead to a rise in the nation's score, thus validating the reasonability of the hosting proposal.

Keywords: Olympic Games, Olympic Hosting Capacity Assessment Model, Olympic Hosting Influence Forecasting Model, ARIMA method, EWM-AMP Method.

1. Introduction

In recent years, hosting the Olympics has become increasingly costly, leading to financial challenges for many cities. Coupled with the economic impact of events like COVID-19, the International Olympic Committee (IOC) is seeing fewer bids for both summer and winter Games[1]. Urgent solutions are needed to reduce this financial burden and reignite global enthusiasm for the Olympics, ensuring the Games can continue to unite the world through sports.

In order to propose a viable Olympic hosting plan, we conducted a series of studies and analyses.

Dolan et. al. (2019) show that hosting the Olympics increases subjective well-being of the host city's residents during the event, particularly around the times of the opening and closing ceremonies[2]. In contrast Hiller et. al. (2019) use microdata from Game-time public opinion surveys and post-Games surveys gathered 1 year and 4 years after the Games in both Vancouver and London using models that control for the demographic characteristics of respondents in order to understand how local residents perceive the economic value and economic outcomes of hosting the Games[3]. Zhang et. al. (2020) examine the changes in relationships among event impacts, satisfaction and behavioral intentions of host city residents before and after a major sporting event. Ritchie et. al. (2020) extend the temporal and spatial evaluation of mega-event impacts, by investigating residents' perceptions of the Olympic legacies from a non-host community perspective[4]. Yeerkenbieke et. al. (2021) aim to investigate the effects of the 2022 Winter Olympics on host city sustainability from public perspective[5]. In order to clearly sort out the impacts of the Winter Olympic Games on sport tourism of the host city Bai et. al. (2021) employ a systematic review[6]. Chen et. al. (2021) investigate the impact of the Nanjing Youth Olympic Games (NYOG) on environmental efficiency (EE) of the host city[7].

Almost all the studies highlight the importance of the influence of hosting Olympics, but little of them had thought of how to evaluate whether a city has the ability to host Olympics. These papers describe the Olympics impact in economy, public opinion, the Olympic legacies, host city sustainability, tourism, and the environment. They illustrates how the city will be after the games

perfectly. However, it's also significant to focus on before the games, which city is able to undertake the responsibility of Olympics. And that is where our study stands.

On the background that fewer and fewer countries are willing to bid for the Olympics, the analysis of the Olympic impact has emerged as a commonly explored subject in the broader field of sports sociology literature[8]. Thus, we will proceed as follows for the sake of tackling these problems. We first collect and identify past Summer and Winter Olympics host countries. For data precision, focus on 11 nations that hosted either event since 2000. Then, we choose impact indicators for hosting the Olympics and develop a weighted assessment model to evaluate the 11 candidate countries' suitability. Additionally, we score the 11 identified countries using our assessment model. Some countries' overall scores drop post-hosting, leading to their elimination. To meet stricter Winter Olympics requirements, we opt for a rotational system among the top three highest-scoring countries. A similar rotation applies to the Summer Olympics, hosted by the top three highest-scoring countries among the others. Having pinpointed suitable countries, we create a forecasting model. Among the top three high-scoring nations, rotating Winter Olympics is challenging. We select one from these to forecast future comprehensive score changes, confirming our policy's feasibility.

2. Notations

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

Table 1. Notations used in this paper

Symbol	Description	Unit
KCI	Key Capacity Indicator	-
W_{E_j}	The weight vector of the j-th indicator calculated by EWM	-
W_{A_j}	The weight vector of the j-th indicator calculated by AHP	-
W_j	Integrated weight of the j-th indicator	-
$f(t)$	Fourier series expression	-

3. Olympic Hosting Capacity Assessment Model

In the past two decades, 11 countries have hosted the Summer of Winter Olympic Games. In order to comprehensively assess which countries are suitable for hosting the Games, we analyse from the point of view of different sets of effects on the host country[9], and establish the Olympic Hosting Capacity Assessment Model. The KCIs considered by the model consists of seven aspects of indicators: economic, land use, human satisfaction, travel, opportunity for future improvements, host city/nation prestige[10] and safety.

We integrated two methods to determine the scores of countries that have hosted the Summer and Winter Olympics since 2000. In the first method, the combination of Entrophy Weight Method (EWM) and Analytic Hierarchy Process (AHP) is adopted to determine the weight of each KCIs. The resulting integrated weight achieves a unity of subjectivity and objectivity, making it more persuasive.

The weights calculated by EWM of seven aspects, economic (w_{E_1}), land use (w_{E_2}), satisfaction (w_{E_3}), travel (w_{E_4}), improvement opportunity (w_{E_5}), prestige (w_{E_6}), safety (w_{E_7}) are shown as followed respectively:

$$w_{E_j} = \{0.2715,\ 0.1562,\ 0.1024,\ 0.2063,\ 0.0543,\ 0.00735,\ 0.1359\} \quad j = 1, 2, \ldots, 7. \tag{1}$$

Also, by calculating the eigenvalues using AHP, we figure out the weights shown as followed:

$$w_{A_j} = \{0.0742,\ 0.2894,\ 0.1256,\ 0.1815,\ 0.1371,\ 0.0586,\ 0.1136\} \quad j = 1, 2, \ldots, 7. \tag{2}$$

After the weight of each KCI is determined, we use the second method Technique for order preference by similarity to ideal solution (TOPSIS) to score these countries. Finally, scores are

generated by two methods to identify the countries that are suitable for hosting the Games. Since our KCIs are all measurable, and the EWM is more objective than the AHP, we considered the EWM as more important. The results are listed below.

$$W_j = \{0.2123,\ 0.1962,\ 0.1094,\ 0.1989,\ 0.07914,\ 0.0227,\ 0.1292\} \quad j = 1, 2, \ldots, 7. \tag{3}$$

3.1. The Solution of Olympic Hosting Capacity Assessment Model

By using our model, we get the result of which countries being advised to host different seasons Olympic Games in turns. First, using the final weight and the data of KCIs we have collected, scores of different countries in the past 20 years and the influence index (the growth rate that brought by the Olympic Game in the special year) are calculated. The influence index changing by session is shown in Figure 1:

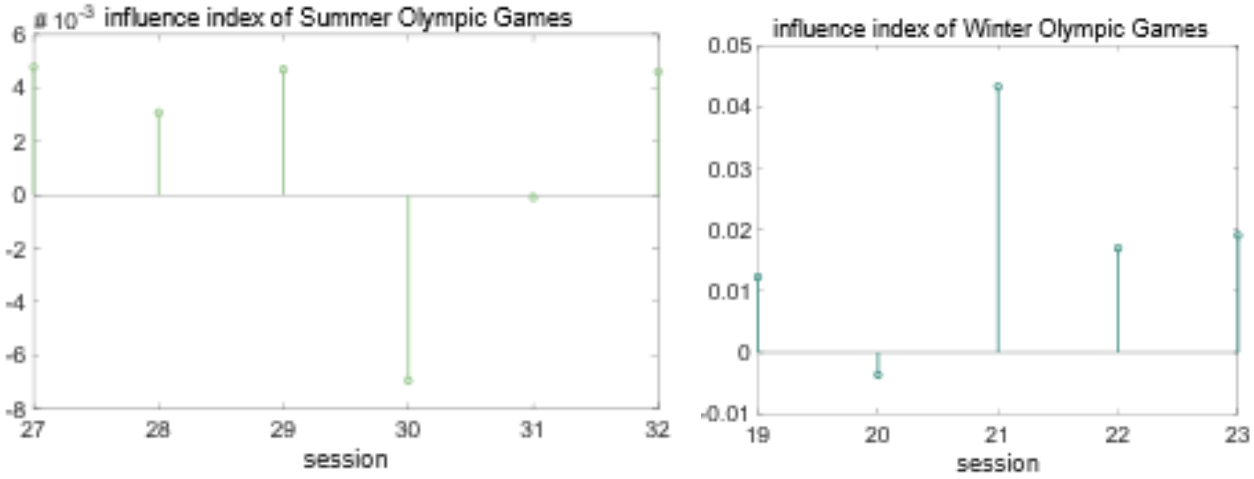

Figure 1. Influence Index of Summer and Winter Olympics Games

After excluding the countries whose influence index is smaller than 0, which means hosting the Olympics will result in a decrease in score for these countries, we rank the countries by seasons according to their scores based on the principle of priority for the Winter Olympic Games. Then we respectively take the top three as the countries we advise to hold on Olympic Games in turns. Through rank, we finally determine the Winter Olympic Games will be host in turns by China, the US, and the Russia, and the Summer Olympic Games will be host by Greece, Japan, Australia in rotation.

4. Olympic Hosting Influence Forecasting Model

In order to test whether the suggestion of Olympic Hosting Capacity Assessment Model is accessible, we establish Olympic Hosting Influence Forecasting Model to forecast the future of the countries we chose and take the US as an example to calculate (we assume that the next Winter Olympic Game will be hosted by the US). According to the time series of the score, the Autoregressive Integrated Moving Average Model (ARIMA) is introduced to forecast the score-changing trend without the interference of hosting Olympic Games. Given that the influence of hosting the game is affected by both the world situation and the country itself, the influence is shown by these two factors. When it comes to the world situation, the Fourier series is used to fit the influence index changing curve and forecast the future trend. And to reflect the country's effect, we average the influence index of this country in the past time and the influence index by forecasting to embody how hosting Olympic Game influences the score of this country.

4.1. The Forecasting by ARIMA

The Autoregressive Integrated Moving Average Model (ARIMA), is a kind of time series prediction analysis, which is generally suitable for non-stationary time series based on ARMA, and its different process can effectively transform non-stationary data into stationary data.

Taking the US as an example, we have the time series of scores X_t where t is an integer index and the X_t are real numbers:

$$X_t = \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + ... + \alpha_p X_{t-p} + \varepsilon_t + \beta_1 \varepsilon_{t-1} + ... + \beta_q \varepsilon_{t-q} \quad (4)$$

where the α_i are the parameters of the autoregressive part of the model, the β_i are the parameters of the moving average part and the ε_t are error terms. The error terms ε_t are generally assumed to be independent, identically distributed variables that are sampled from a normal distribution with zero mean value.

By calculation, we determine the $p = 1, q = 1$ to establish the ARIMA(p, d, q) model and the results are presented Figure 2. The red dot represents the 95% confidence interval, the gray line represents the original data, and the black line represents the trend. The specific illustration is shown below:

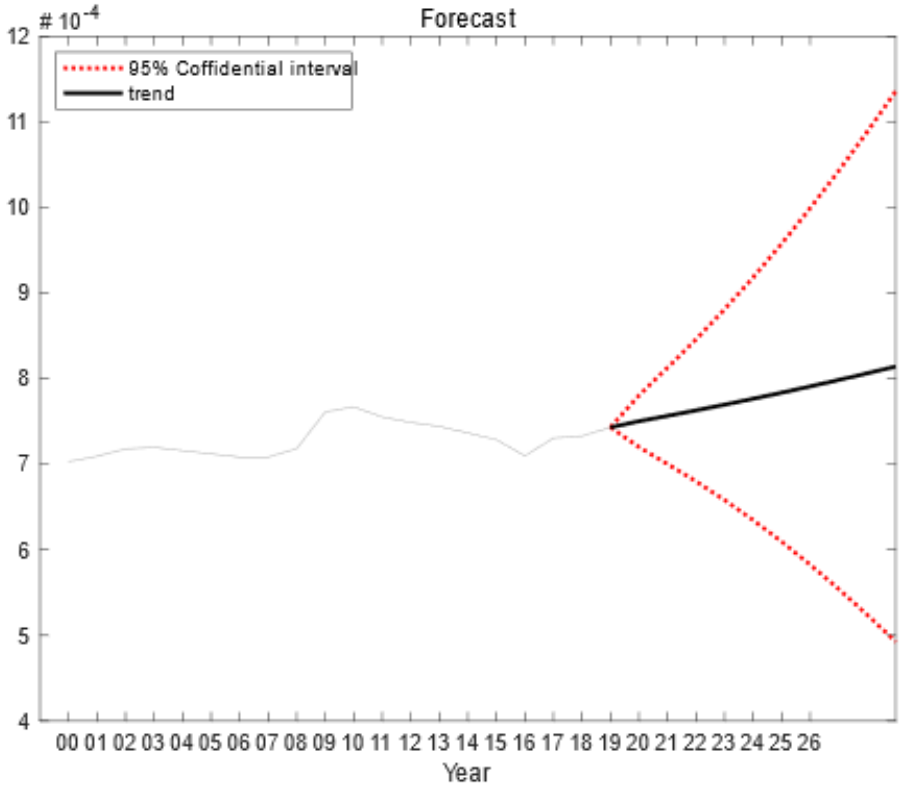

Figure 2. The Result of the ARIMA

The Autocorrelation function and the Partial Autocorrelation function are shown in Figure 3:

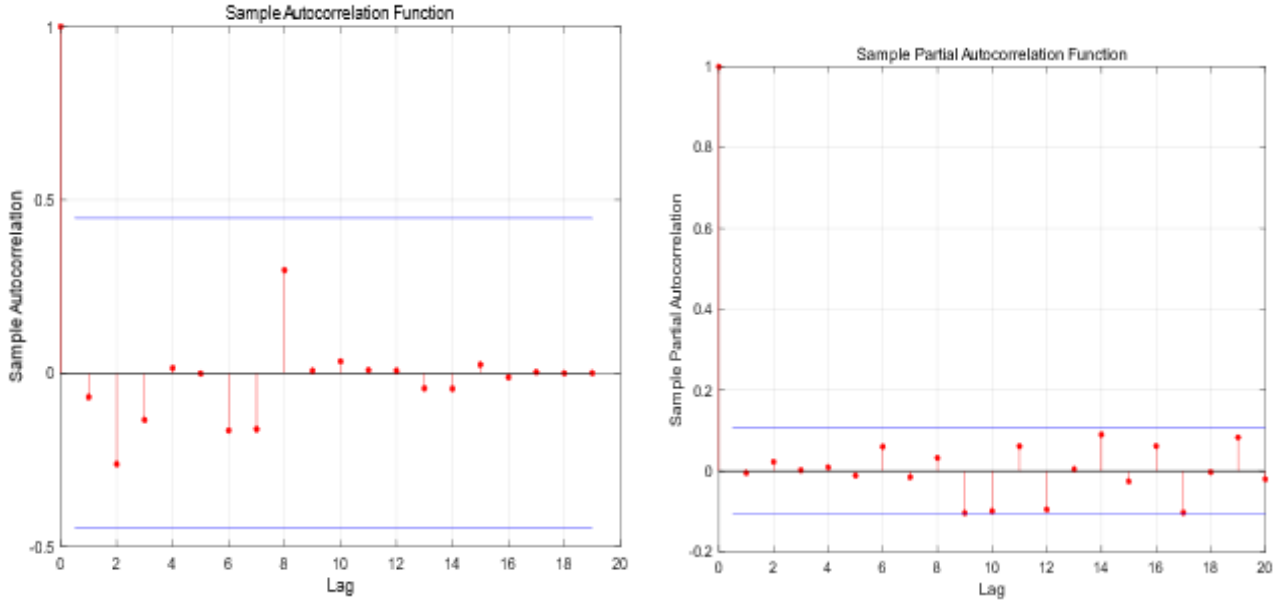

Figure 3. The Sample and Sample Partial Autocorrelation Function

As is mentioned in Section 4.4, we now have a series of influence index changing by sessions. After many attempts, we finally choose the Fourier series, which is an efficient tool to solve periodic problem. The fitting process is shown below:

$$f(t) = {a_0}/{2} + \sum_{n=1}^{\infty}\left[a_n \cos(n\omega t) + b_n \sin(n\omega t)\right] \tag{5}$$

where a_0, a_n, and b_n are each calculated using the following formulas:

$$\begin{cases} a_0 = \frac{2}{T}\int_{t_0}^{t_0+T} f(t)\cos(n\omega t)dt \\ a_n = \frac{2}{T}\int_{t_0}^{t_0+T} f(t)\cos(n\omega t)dt \\ b_n = \frac{2}{T}\int_{t_0}^{t_0+T} f(t)\sin(n\omega t)dt \end{cases} \tag{6}$$

In this series of formulas, $f(t)$ is the series, t is the time, $t_0 + T$ represents an arbitrary period, and ω is the rotational speed.

By calculation, we get the fit curve and the $R - square = 0.8192$, which proves the accuracy of the curve. The values of variables are shown below:

$$\begin{cases} a_0 = 0.02088 \\ a_n = -0.02256 \\ b_n = 0.003543 \\ \omega = 2.23 \\ n = 1 \end{cases} \tag{7}$$

The final result is shown in Figure 4 below:

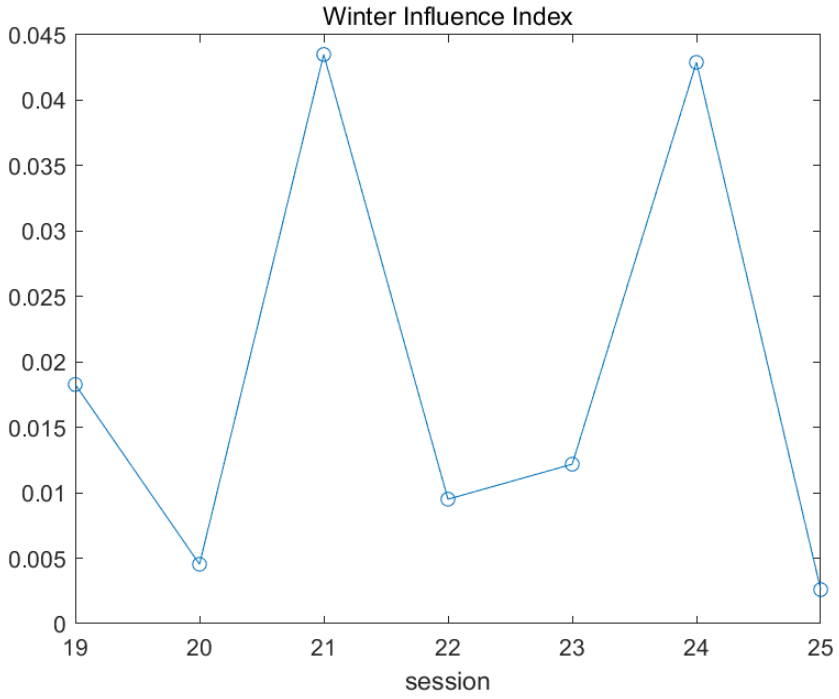

Figure 4. Winter Influence Index

4.2. The solution of Olympic Hosting Influence Forecasting Model:

Averaging the forecast value in Section 5.1 and the influence index of the US in the past session, the final influence index of the next session Winter Olympic Game (in 2026) is decided. Then we can use the influence index and the score forecast curve to estimate the score of the US after hosting the next Winter Olympic Game to prove if the project is accessible. The result is shown in Figure 5 below (the blue dots are the curve after hosting and the black line is the no-disturb curve of the score):

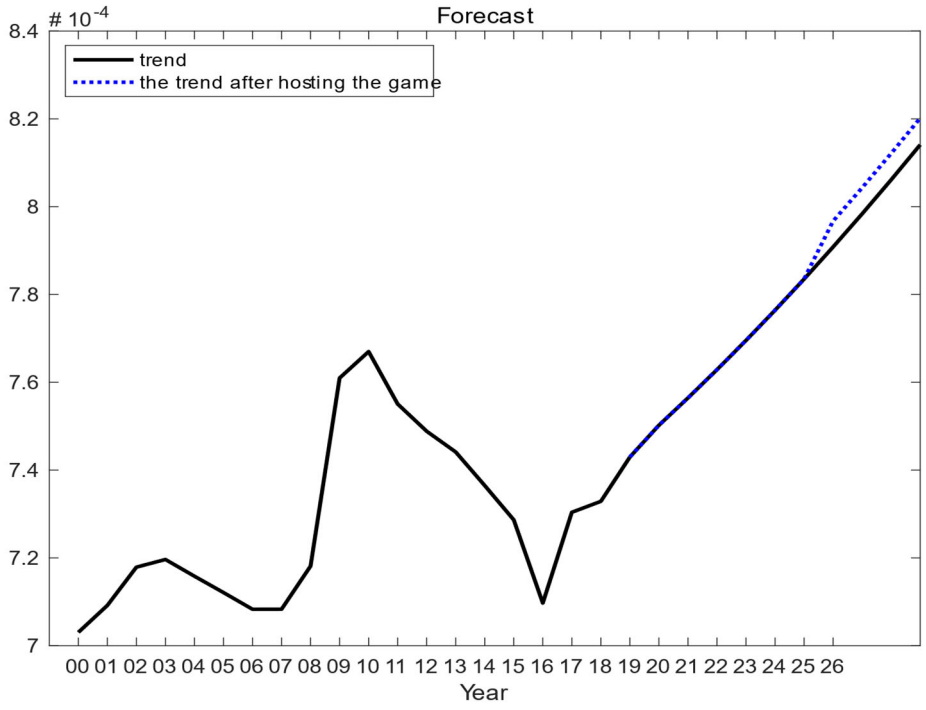

Figure 5. The Trend Before and After Hosting the Olympic Games

5. Conclusions

The Olympic Games, with their global prominence, have always been at the center of international attention. As nations strive for the honor of hosting these games, it is essential to evaluate their readiness and capacity comprehensively. This article's implementation of the Olympic Hosting Capacity Assessment Model offers a systematic approach to this assessment, shedding light on the capacities of 11 countries that have previously taken on the hosting mantle. The findings underscore the significance of adaptive capacity. Notably, while many nations aspire to host, the aftermath for some has proven to be counterproductive, leading to diminished scores. This highlights the need for a judicious selection process, ensuring that the nations chosen can both benefit from and contribute positively to the Olympic legacy.

By integrating the EWM-AHP method with the TOPSIS method, the Olympic Hosting Capacity Assessment Model was formulated to evaluate and score these 11 countries. Based on the scores, nations that have previously hosted the Olympics were ranked. The research further emphasizes the importance of experience, especially for the Winter Olympics, resulting in the identification of China, the US, and Russia as ideal hosts for a rotational system. For the Summer Olympics, Greece, Japan, and Australia emerge as frontrunners.

The adoption of the ARIMA model, in tandem with the Olympic Hosting Influence Forecasting Model, provides a forward-looking approach, elucidating the potential impact of hosting on a nation's developmental trajectory. The positive forecast for the US post their Winter Olympic hosting is a reassuring affirmation of the model's effectiveness.

In conclusion, as the dynamics of global geopolitics and economics evolve, it is imperative that the process of selecting Olympic hosts be both strategic and evidence-based. This study offers a robust framework to that end, ensuring that the Olympics continue to be a celebration of human achievement while also fostering sustainable development in host nations.

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