Problem Chosen	2023 MCM/ICM Summary Sheet	Team Control Number
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Reviving Olympic Hosting Interest: A Sustainable Strategy

Summary

With the aim of analyzing the impact of hosting the Olympics on the hosts and rekindling interest in hosting, we undertake three main tasks: **task 1**, quantitatively analyze the effects of hosting the Olympics on the host city/country; **task 2** propose and evaluate potential plans for site selection and time scheduling; **task 3**, select the optimal plan and further elucidate its feasibility.

For task 1, we focus on the sustainability of the host country and construct the Olympic sustainability index **(OSI)**. The OSI incorporates 9 second-level indicators from the economic, social, and ecological perspectives and quantifies both short-term impacts such as direct costs and revenues, as well as the long-term viability of venue usage and national prestige measured through media influence. We use a Vector Autoregression time series model **(VAR)** to forecast these indicators' values in the absence of hosting the Olympics. We then employ the Difference-in-Differences model **(DID)**, an effective method for inferring causal effects of hosting the Olympics on various indicators, to estimate the impact. Finally, we give the changes of OSI in 2012 London Olympic Games.

For task 2, firstly, for each plan, we conduct a preliminary screening of **candidate cities** based on their environmental and socioeconomic conditions, and split the Olympic **events** based on their climate requirements and venue costs. We construct an optimization model with Olympic Game Scale Indicator **(OGSI)** as the decision variable and maximizing OSI and its changes as the objective function. The evaluation scores for each plan are determined using Kernel Ridge Regression **(KRR)** and Analytic Hierarchy Process and Entropy Weight Methods **(AHP-EWM)**. We then utilize the Augmented Lagrangian Method and Alternating Direction Method of Multipliers **(ALM-ADMM)** to solve the model and obtain the optimal OGSI for each plan. Finally, based on the optimal scores of each plan, we determine that **Plan 3, a hybrid method of fixed and rotating venues**, with the highest score of **72.71**, is the optimal plan.

For task 3, we further elaborate on the content and feasibility of the optimal plan. Firstly, we combine the results of the ALM-ADMM model to present the specific timeline and project arrangement of plan 3. The Olympic Games still follow a **four-year cycle**, with the **Winter Olympics fixed in Vancouver or Sochi** in February of the first year, **key events fixed in Sydney or Los Angeles** in October of the third year, and **other events held in different cities** in August of the second and fourth years. And "Key events" include **marathon, cycling, swimming, tennis, and gymnastics**. Then, we analyze the feasibility of the plan from five perspectives: **economy, ecology, safety and fairness, humanization, and society**. Finally, we use Sydney as one of the locations for the Summer Olympics to implement plan 3, predict the changes in OSI in Sydney and Vancouver, and compare them with the traditional hosting model. We found that the economic pressure on Sydney was significantly **reduced** (with PG and GG scores increasing by **3** and **13**, respectively), and although Vancouver's PG score slightly decreased, its GG score increased by **4**, showing a clear upward trend for the future.

Keywords: The Olympics; Sustainability; Fixed and Rotating; DID; KRR; ALM-ADMM

Contents

1 Introduction

1.1 Problem Background

The Olympics have a century of history, global appeal, and thrilling competition. Hosting often prompts ambitious construction projects to showcase progress and revitalize urban areas, but these initiatives can become financial burdens, resulting in unoccupied structures known as white elephants. We can evidently see the diminishing interest of countries and cities in hosting the Olympics in Figure 1.

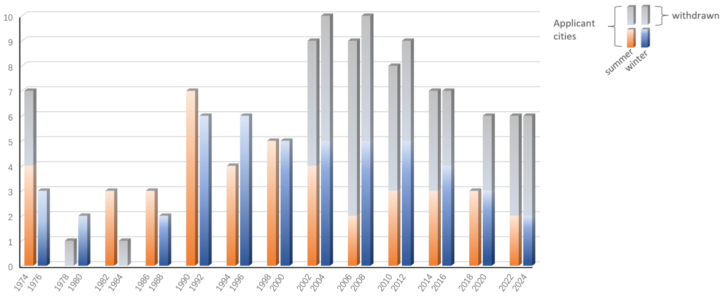


Figure 1: Bids to host Olympic Games from 2002 to 2024

The data above comes from the website **Olymstats**[1]. Amid the impact of the pandemic and other disruptions, the number of cities bidding for the Olympics has gradually declined since around 2000. In fact, no one applied for the hosting rights for the 2028 Olympic Games, and Brisbane, Australia was awarded the hosting rights for the 2032 Olympics without a bidding process. Faced with such challenges, the IOC proposed the **"New Norm"** reform plan to improve the organization of the Olympic Games. It promotes sustainability, efficiency, cost reduction, and stakeholder cooperation by encouraging innovation, simplifying processes, optimizing projects, and fostering partnerships.

1.2 Restatement of the Task

In response to the question, we have broken down the task into three parts:

Part 1 involves constructing an evaluation system. To measure the impact on the host of the Olympics, we need to select comprehensive and quantifiable indicators that cover the economic, social, and environmental aspects. Based on this, we will build specific metrics using a reasonable weighting method. It should be noted that the collected data needs to be pre-processed before analysis.

Part 2 involves comparing the implementation effects of different Olympic hosting schemes. By adjusting the location and timing of the event, we aim to challenge the traditional model of hosting the Olympics every two years, alternating between winter and summer events, and selecting the host through bidding.

Part 3 involves evaluating feasibility, implementation timeline, and the potential strategic impact on the indicators. We need to choose a specific host city and explain the feasibility from an economic, social and ecological point of view.

1.3 Literature Review

Currently, there are relatively few interdisciplinary studies analyzing the impact of hosting mega-events on the host country. A systematic review conducted by MCCARTNEY G et al. examined studies from 1978 to 2008 on the health and socioeconomic impacts of hosting, finding mixed results with some events leading to positive impacts and others to negative ones[2]. Similarly, MüLLER M et al. critically analyzed the studies and synthesized the findings to evaluate the sustainability of the Olympic Games, suggesting that the Olympic Movement adopts a more holistic approach to sustainability[3]. In addition, some scholars used **quasi-experimental methods** to compare the GDP per capita of regions that successfully bid for the Olympics with those that did not, evaluating the causal effect of the Olympics on the host country's economy, and they generally found that **the long-term financial benefits for the host regions were minimal** [4, 5]. However, they did not discuss ways to improve the hosting model of the Olympics. Recent research proposed a 16-week heat preparation approach for marathon runners and strategies[6] to adapt to hot and humid weather conditions[7]. However, more direct and effective methods, such as changing the event's schedule or location, have not been explored.

In summary, research on the Olympics' impact on the host country faces challenges such as a lack of sufficient evidence, unpredictability due to socioeconomic events like COVID-19, and a lack of in-depth exploration of strategies to improve hosting patterns.

1.4 Our Work

The problem requires us to fight fires by optimizing the locations of two type of drones. Our work mainly includes as Figure 2:

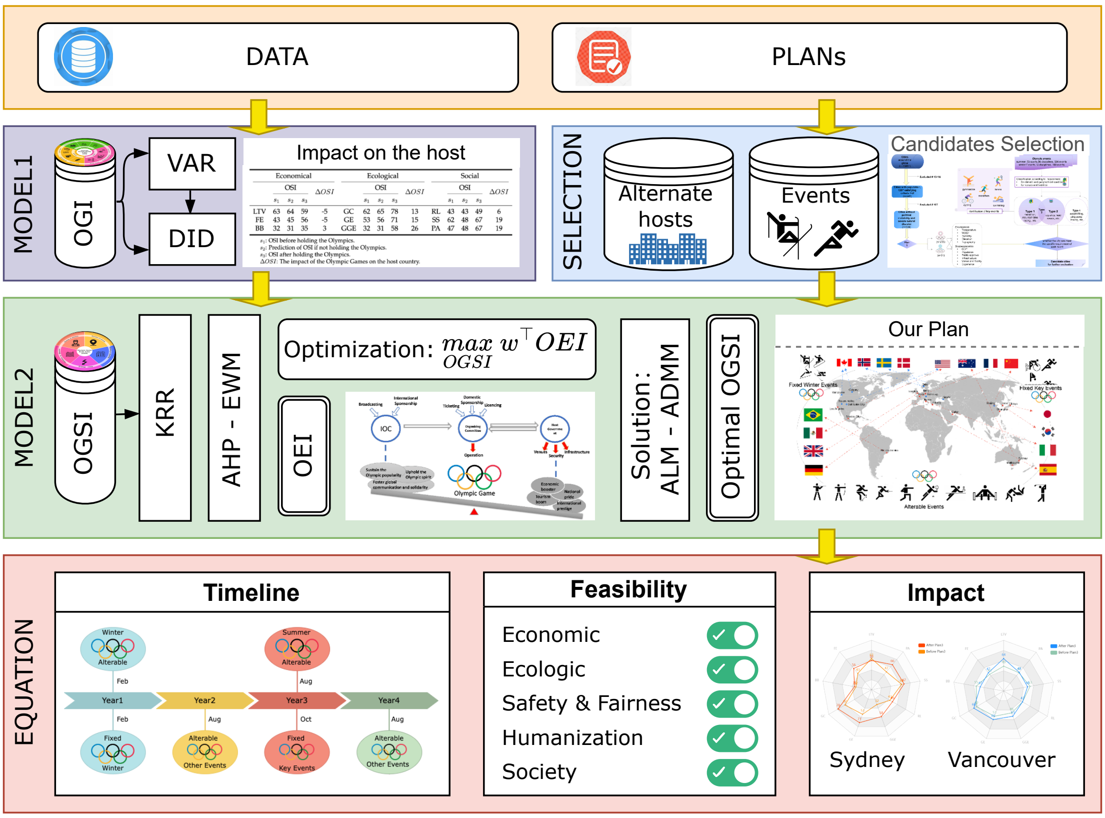


Figure 2: Flowchart of our Work

2 Assumptions and Explanations

Assumption 1 **Olympic Games events are aligned with the Tokyo 2020 Summer Olympics and the Beijing 2022 Winter Olympics.**
Explanation: The International Olympic Committee (IOC) may introduce new sports or modify existing ones, but for the purpose of subsequent discussion and analysis, we do not consider the possibility of adding or removing new events.

Assumption 2 **The economic impact of the Olympic Games on the host city is reflected in the economic dynamics of the country.**
Explanation: Olympic bids are made on a city-by-city basis, but we can use country-level indicators, such as GDP and growth rate, to assess the impact on the host city.

Assumption 3 **External factors in the implementation of the strategy are constant or controllable.**
Explanation: External factors such as policy environment, international relations and market conditions are stable and do not have significant impact on the implementation of the strategy.

Assumption 4 **Global events like wars, plagues and natural disasters do not affect the staging and promotion of the Games.**
Explanation: We do not consider the impact of unpredictable global events on the staging and promotion of the Games.

Additional assumptions are made to simplify analysis for individual sections. These assumptions will be discussed at the appropriate locations.

3 Notations

Some important mathematical notations used in this paper are listed in Table 1.

Table 1: Notations used in this paper

Symbol	Description
OSI	Olympic sustainability indicator.
$OGSI$	Olympic games scale indicator.
OEI	Olympic effect indicator.
δOSI	The impact of the Olympic Games on the host country.
ΔOSI	The rate of impact of the Olympic Games on the host country.
p	The log order of VAR.
$z_k(t)$	Values of each OSI indicator in VAR.
$\gamma_{k,i}$	The impact of hosting the Olympic Games on the countries that actually hosted the Olympic Games.
ω	Weight of each OSI indicator in AHP - EW.
$g_i(x)$	Constraints in optimization.

*There are some variables that are not listed here and will be discussed in detail in each section.

4 Model Preparation

4.1 Reasons for the declining hosting interest

To assist COMAP's Interdisciplinary Committee on Modern Games (ICMG), we will examine reasons for the Olympics' declining competitiveness and propose creative solutions. One factor contributing to the declining competitiveness is the high cost of hosting the Olympics. For example, the 2016 Rio Olympics cost around 13 billion US dollars[8], and the budget for the 2020 Tokyo Olympics was estimated to be around 28 billion US dollars [9]. Additionally, the ecological cost of hosting the Olympics is also a concern due to the large amount of greenhouse gases produced by transportation and construction[10]. Furthermore, social support and security measures are crucial for a successful event, and overlooking these factors may lead to social dissatisfaction, opposition, and criminal activity. Overall, successful Olympic Games require the host country to overcome multiple difficulties to provide the world with a spectacular sporting event.

4.2 Potential plans of hosting the Olympics

Considering the potential reasons for the declining interest in hosting the Olympics, we propose the following potentially feasible solutions:

Plan1: Establishing permanent venues for both Summer and Winter Olympic Games, thereby eliminating the need for recurring host city selection.

Plan2: Segmenting Olympic sports into four distinct categories, resulting in the organization of four smaller-scale Olympic events distributed across Winter, Spring, Summer, and Fall seasons.

Plan3: A hybrid strategy that merges aspects of the first two proposals, whereby a select number of Olympic disciplines are conducted at fixed locations, while the remainder continue to be hosted in rotating cities.

In the following stages, we will conduct a thorough evaluation of each proposition and ultimately determine the most advantageous solution, outlining the specifics of the selected strategy.

4.3 Data Overview

The question did not provide us with data directly, so we need to consider which data to collect in the model building. In order to evaluate the impact of hosting the Olympics on the host country/city as accurately as possible, we need to collect multiple indicator data from various aspects such as economics, society, and ecology, and divide these data into time periods: **Pre Olympics** (usually covers an 11-year period, starting with the bidding stage), **Olympic year**, and **Olympic Legacy period**. Based on data from previous years before the Olympics, we can use various methods to obtain predicted values of indicators under the condition of not hosting the Olympics. Using the idea of background trend, the impact of hosting the Olympics can be quantitatively reflected by the difference between the actual value and the predicted value.

1) Data Collection

We primarily use the following data: project preparation plans for each host country (from the 1968 Winter Olympics in France to the 2016 Olympics in Rio de Janeiro), including detailed information on dates, locations, number of participants, competition events, venues, budgets, marketing and promotion, security measures, volunteers, environmental protection measures, etc. Besides, other data are accumulated in Table 2.

Table 2: Data used in our work and its sources

Category	Time coverage	Data sources
Olympics	1896 - 2022	https://data.world/datasets/olympics
socioeconomic	1960 - 2016	https://doi.org/10.1177/0308518X20958724[1]
	1960 - now	https://data.worldbank.org/ [2]
	2000 - now	https://www.worldpop.org/datacatalog/[3]
ecological	1990 - now	https://www.ipcc.ch/data/ [4]
	1981 - now	https://doi.org/10.1016/j.rse.2017.06.031 [5]

[1] cost overrun for hosting the Olympics
[2] comprehensive development indicators of countries all over the globe, including GDP, CPI, etc.
[3] the distribution of residential population for each country and city
[4] greenhouse gas emissions
[5] greenspace distributions at high resolution.

2) Descriptive analysis of the data

A statistical analysis of the budget data for the Olympic Games over the years is as Figure 3 [12]:

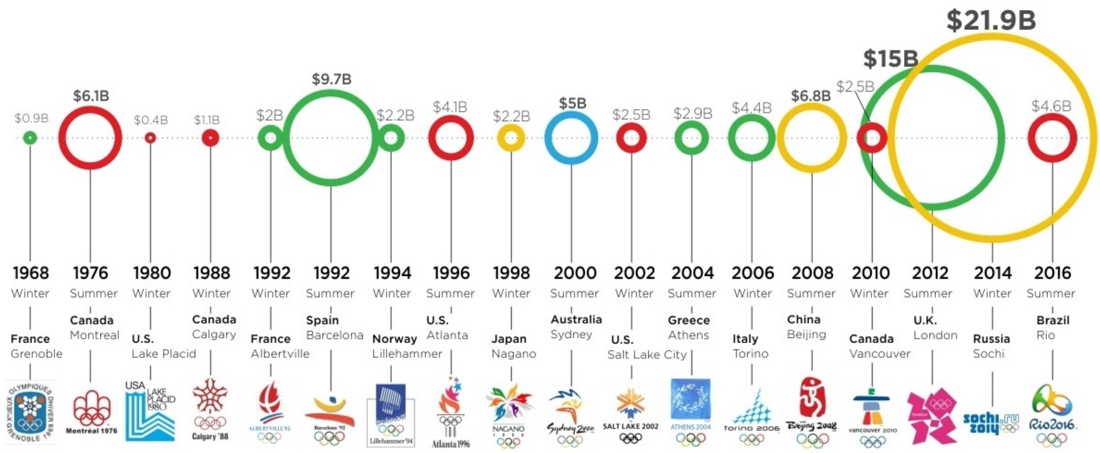


Figure 3: The cost of holding the Olympics from 1968 to 2016

As it can be seen, the budget spent on the Olympic Games varies from country to country but essentially all Olympic host countries have budget overruns. The budget data was further processed to facilitate the subsequent model analysis.

3) Data processing

In the follow-up, it is necessary to eliminate dimensional differences. Therefore, we standardize the data by min-max normalization and convert them to percentiles as equation 1:

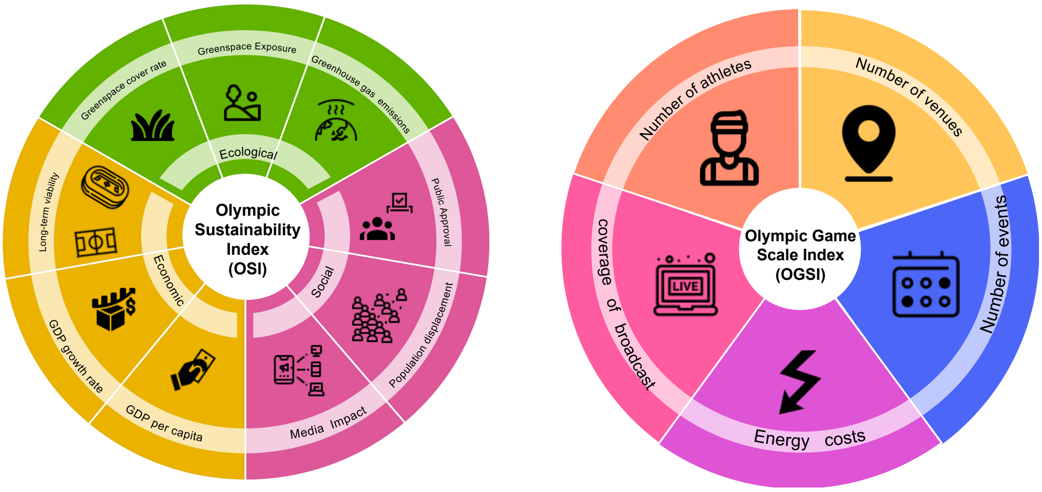
$$x^* = \frac{x - min\ x}{max\ x - min\ x} \times 100 \tag{1}$$

5 Model 1: Estimation of OSI based on VAR - DID

As the background indicates, the Olympic Games is a huge undertaking. The conditions for hosting the Games are very strict, which also leads to a high economic, social, political, and environmental cost for the host country. Moreover, the existence of epidemic risks has made many countries cautious about hosting the Olympic Games. In order to propose reasonable improvement strategies, we first select appropriate evaluation indicators and use time series analysis and double difference models to quantify the impact of hosting the Olympic Games on the host region. Based on the results obtained, we preliminarily propose alternative options for improving the Olympic Games hosting model.

5.1 Selecting indicators for the impact of hosting the Olympics

As depicted in Figure 4(a), we introduce the Olympic Sustainability Indicator to represent the influence of hosting Olympic events as well as the capacity to accommodate such events in a sustainable manner.



(a) OSI (b) OGSI

Figure 4: Indicators of Olympic sustainability index (OSI) and Olympic Game Scale Index (OGSI)

1) **Economic impact**
   To evaluate the impact of hosting the Olympics on the host economy, we use two commonly used indicators: **per capita GDP, (PG)** and **GDP growth rate(GG)**. We acknowledge that these indicators are based on a country-level observation, but they are reasonable choices since the development of a city can reflect on the development of a country. We also include the indicator of **long-term viability** to estimate the after-use of venues, as the common reason for losses in hosting the Olympics is the unde-rutilization or abandonment of venues built for the event.

   Furthermore, it is necessary to analyze the costs and revenues of bidding for and hosting the Olympics. The costs can be divided into **operational costs** and **sports venue costs**, excluding indirect and opportunity costs. Besides, it is challenging to measure the intangible and indirect benefits of hosting the Olympics. In our analysis, we focus on three primary revenue sources: **broadcasting rights**, **sponsorship**

(domestic and international), and **ticket sales**, which make up over 90% of the total revenues[11].

2) **Social impact**
Considering that the impact of mega-events and media coverage show a positive correlation and synchronous increase and decrease over time, we use the number and length of positive media reports as an indirect reflection of prestige and satisfaction. Thus, we construct the **media impact index (MI)** as equation 2:

$$MIi_j = \left(Nr_j \Big/ \sum_{j=1}^{n} Nr_j + Wr_j \Big/ \sum_{j=1}^{n} Wr_j \right) \Big/ 2 \tag{2}$$

Prestige and national pride can't be measured in dollars and cents. Researchers often use questionnaire surveys as a way of gathering relative statistics. Here, We introduce two indicators **public approval** and **social safety** based on the results of a literature review[3].

3) **Ecological impact**
The construction of Olympic venues and population mobility can have a significant impact on the land use structure and ecological environment of the host region. To more accurately assess the changes in the local ecological environment, we have selected three indicators to measure the ecological impact in a more intuitive way.

- **greenspace cover rate (GCR)**
We develop a metric to measure changes in greenspace coverage before and after the Olympic Games, which is defined by the following equation.5:

$$\Delta GCR = \sum_{t=s-4}^{s-1} G_{t/4} - \sum_{t=s+1}^{s+4} G_{t/4} \tag{3}$$

where G_t is the mean GCR in year t within a specific extent and s is the host year of the Olympics.

- **greenspace exposure (GE)**
We further investigate the spatial distribution of population and compute the yearly greenspace exposure that is weighted by population for the host cities.5:

$$GE = \frac{\sum_{i=1}^{N} P_i \times G_i}{\sum_{i=1}^{N} P_i} \tag{4}$$

In this equation, P_i represents the population of the $i-th$ grid and G_i represents the greenspace fraction of the $i-th$ grid. N refers to the total number of grids in the host city, and GE is the estimated level of greenspace exposure for the host city. Similar to the processing of equation 2, we can further obtain the change of GE.

- **greenhouse gas emissions (GGE)**
We also select this effective indicator of the environment pressure calculated as 5:

$$GGE_i = \sum_j A_{ij} \times EF_{ij} \tag{5}$$

where GGE_i is the total greenhouse gas emissions for the reporting period i, $EF_{ij}$is the emission factor of fuel j, and A_{ij} is the data on the production. In this way, we take different fuels like solid, gaseous, liquid into account. We can easily obtain the data from the official website of Intergovernmental Panel on Climate Change (IPCC).

We acknowledge that the tourism industry is complex, encompassing food, transportation, and culture. Hosting the Olympic Games can significantly benefit the local economy, social and cultural development by increasing tourist numbers, enhancing landmarks, and elevating local reputation. As we have already covered the primary impacts on the tourism industry through selected indicators, we will not discuss it separately.

5.2 Assessing the impact based on VAR-DID model

5.2.1 Forecasting the indicators based on VAR time series model

In this paper, we adopt the Vector Autoregression (VAR) model to capture the interdependencies among various OSI indicators over time series and predict the trends of changes in the OSI indicators of the host country without holding the Olympic Games. Then, we use the idea of baseline trend to quantitatively reflect the impact of the Olympic Games by comparing the actual indicator values when holding the event with the predicted values. Based on VAR, we construct the following model 7:

$$z_k(t) = A_1 z_k(t-1) + A_2 z_k(t-2) + ... + A_p z_k(t-p) + \epsilon(t) \tag{6}$$

where $z_k(t) = [z_{k,1}(t), z_{k,2}(t), ..., z_{k,9}(t)]$ indicates the observed values for each indicator of city k in the year t, A_i is a 9×9 matrix that represents the autoregressive coefficients, and A_is a 9-dimensional vector representing the random error terms in the time series.

In order to fit a Vector Autoregression (VAR) model, we first need to determine the lag order p. Information criteria, such as the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), can be employed to select the optimal lag order.

After determining the lag order p, we can estimate the coefficient matrices $\mathbf{A_1}$, $\mathbf{A_2}$, $\ldots$, $\mathbf{A_p}$, of the VAR model using the Ordinary Least Squares (OLS) method. The specific steps are as follows:

Step 1: Construct the lagged data matrix $\mathbf{X}$, and the dependent variable matrix $\mathbf{Y}$. $\mathbf{X}$ is a $T(K_p)$ dimensional matrix, while $\mathbf{Y}$ is a $T \times (K_p)$ dimensional matrix.

Step 2: Estimate the coefficient matrix $\mathbf{B}$ using the OLS method, i.e, $\hat{\mathbf{B}} = (X^\top X)^{-1} X^\top Y$.

Step 3: Partition the estimated $\hat{B}$ according to the lag order p into K×K dimensional coefficient matrices $\hat{\mathbf{A}}_\mathbf{1}$, $\hat{\mathbf{A}}_\mathbf{2}$, ..., $\hat{\mathbf{A}}_\mathbf{p}$.

Once the VAR model is fitted, we can predict future OSI values using the recursive forecasting method.

5.2.2 Difference-in-Differences estimation

In this section, we employ a difference-in-differences (DID) approach to provide highly accurate estimates of the impact of hosting the Olympic Games on the host country.

The DID model effectively eliminates potential confounding factors by comparing the changes in both the treatment group and the control group before and after hosting the Olympics. This allows us to infer the causal effects of hosting the Olympic Games on various OSI indicators. In our analytical framework, the treatment group consists of countries that have hosted the Olympics, whereas the control group includes the same countries but under the assumption that they did not host the Olympics. We use forecasted OSI indicator values for the period after the actual hosting of the Olympics. Additionally, since the OSI data for our treatment and control groups is identical before the intervention, we can disregard potential interference from consistent trends and omit the parallel trend test step in the DID model.

We select the year of hosting the Olympics as the intervention point, with a time span of one year after hosting the Olympics. Based on the DID method, we construct the following model:

$$y_{k,[i,t,d_k]} - y_{k,[i,t-1,d_k]} = \lambda_{k,t} + \gamma_{k,i} d_k * post_{k,t} + \varepsilon_{i,t} \tag{7}$$

here, d_k represents whether country k hosts the Olympics (0 or 1); $y_{k,[i,t,d_k]}$ denotes the OSI indicator i value for country k at time t when hosting ($d_k = 1$) or not hosting ($d_k = 0$) the Olympics; $post_{k,t}$ is the time variable for whether country k has already hosted the Olympics at time t (0 before hosting/1 after hosting); $\gamma_{k,i}$ represents the impact of hosting the Olympics on OSI indicator i for country k, i.e., the DID estimate; and $\varepsilon_{i,t}$ is the error term.

By employing the DID model described above, we have successfully quantified the impact of hosting the Olympic Games on various OSI indicators for the host countries.

5.3 Case study: 2012 London Summer Olympics

In this section, we preliminarily apply the OSI evaluation system to the study of London (UK), which hosted the 2012 Summer Olympics, to observe changes in various indicators before hosting the event, after event if not holding the event, and after hosting the event as shown in Table 3.

Table 3: Case study of 2012 London Olympic Games

Economic					Ecological					Social				
	OSI			δOSI		OSI			δOSI		OSI			δOSI
	s_1	s_2	s_3			s_1	s_2	s_3			s_1	s_2	s_3	
PG	63	64	59	-5.4	GC	62	65	78	13.9	RL	43	43	49	5.3
GG	43	45	56	-5.2	GE	53	56	71	16.1	SS	62	48	67	18.1
LTV	32	31	35	3.7	GGE	32	31	58	27.9	MI	47	48	67	19.9

s_1: OSI before holding the Olympics.
s_2: Prediction of OSI if not holding the Olympics.
s_3: OSI after holding the Olympics.
δOSI: The impact of the Olympic Games on the host country.

We found that the ecological and social aspects generally improved, but public approval declined. This may be due to London having already hosted two Olympic Games in the past, and as a developed country, it has long had a high international status and influence, and the social benefits brought by the Olympics are no longer as significant as during its first hosting. In terms of the economy, we found that the per capita GDP and GDP growth rate have decreased, but the LTV has increased.

6 Model 2: Preliminary selection of candidate cities

Based on official documents, literature, and the hosting situations of previous Olympic Games, we have screened candidate cities for Plans 1, 2, and 3 through the following steps:

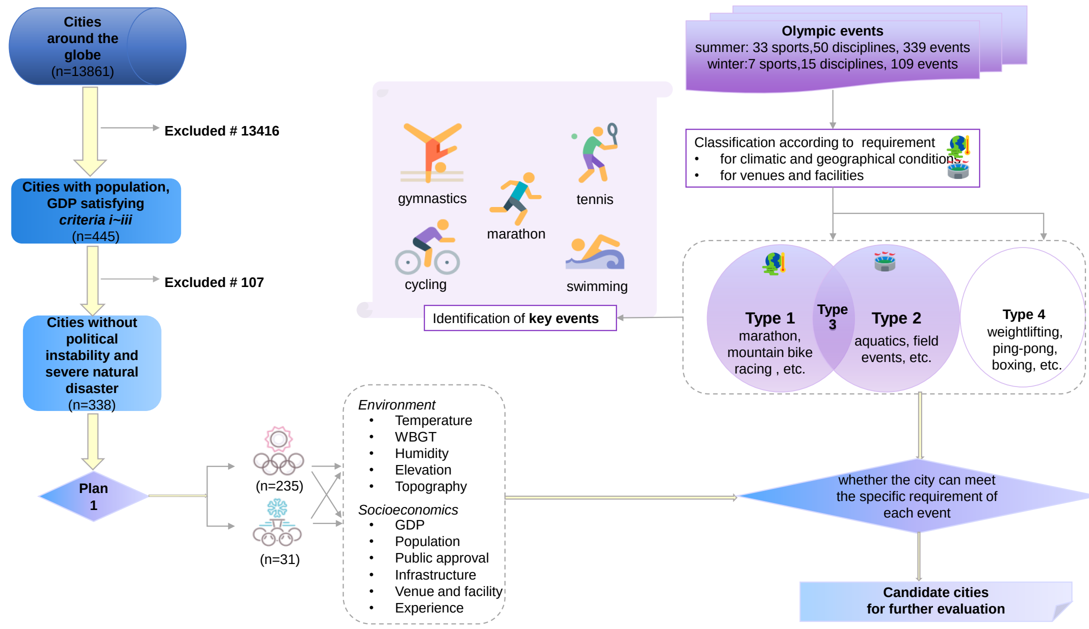


Figure 5: Results of events classification and cities selection

Step 1: We follow the requirements of the International Olympic Committee (IOC) and related literature to eliminate cities that lack basic conditions for hosting the Olympic Games.

Step 2: We consider the political environment, including human rights protection, public support, government management level, and political risks, among other factors, before further identifying regions suitable for hosting different events.

Step 3: For Plan 1, we separately screen cities suitable for hosting the Winter and Summer Olympics.

Step 4: For Plans 2 and 3, we classify all events based on their natural environment and venue requirements and then screen cities that meet the needs of different events for subsequent analysis.

6.1 Specific criteria for inclusion and exclusion

Due to the opaqueness of this definition, we further explore relative literature, analyze the situations of previous Olympic host countries to explicitly define the basic conditions for hosting the Olympics as follows:

i) A city with a **population** of **2.5 million or more** is an important factor for being selected as a host city according to a study analyzing bids for the 1992-2020 Summer

Olympic Games.

ii) To be considered as a potential host city, the **national GDP** should be at least **$300 billion**. We set this threshold based on the fact that no host city after the 1992 Barcelona Summer Olympics had a national GDP of less than $300 billion 10 years before the Games.

iii) A **positive GDP growth rate** (above 0%) is required for a potential host city, based on data from the 1992 Barcelona Summer Olympics that showed no host city had an average national GDP growth rate of less than 0% from 15 to 10 years before the Games [6].

iv)Political stability is a multifaceted concept that is challenging to measure and quantify. To establish exclusion criteria, we consider any location that has experienced any of the following events within the past three years as politically unstable: **riots, civil wars, and terrorism and cyber attacks**. Additionally, **severe and irreversible natural disasters** are also considered. We also acknowledge that social disruption, such as protests, strikes, and demonstrations, is an important indicator of political instability. However, such events are more likely to occur in democratic and open countries and are not considered exclusion criteria unless they are directly related to hosting the Olympics.

6.2 Classification of Olympic events

Currently, there are 33 events in the Summer Olympics that can be categorized into five types: **aquatics**, **athletics**, **gymnastics**, **ball sports** and **other sports**. The Winter Olympics includes 15 events that cover three main categories: **ice sports**, **snow sports**, and **skiing events**.

- **Winter and Summer Games**

To begin with, we will focus on the differences between the Winter and Summer Olympics. The requirements for host cities for the Winter and Summer Olympics differ in many ways, mainly in terms of climate conditions, facilities, and infrastructure. According to Müller M, Winter Games have a significantly lower visitor footprint and public approval, and the sizes of the required venues are generally smaller due to the distinct event content[3]. The International Olympic Committee (IOC) does not have specific requirements for temperature, humidity, altitude, and other data when selecting host cities. However, in practical evaluations of candidate cities, to ensure the smooth running of the Games and the safety of athletes, we provide the following empirical suggestions based on literature reviews and analysis of relevant data from previous host countries:

Table 4: General criteria for hosting the Winter and Summer Games

Season	Tempreture[1] (° F)	Snowfall (mm/month)	Elevation (m)	Humidity[2]
Winter	$1.4 \sim 50$	≥ 30	≤ 1800	$30 \sim 50$ %
Summer	$8 \sim 86$	-	≤ 1600[3]	$50 \sim 60$ %

[1,2] Here, we consider that a city meets the temperature and humidity requirements if, in the corresponding season of the past three years, there have been at least 20 consecutive days where the 90th percentile of the values of these two indicators is within the ideal range.

[3] We set the altitude limit at 1600m to ensure the health of athletes in events such as marathons.

As the winter Olympics is smaller in scale than the Summer Olympics and has specific requirements for events and environmental conditions, especially for climate conditions, subsequent classification will only be conducted for the Summer Olympics.

- **Sports with varying levels of climate and site requirements**

To connect candidate cities with sports events, we consider their requirements for geographical and climatic conditions, venues, and specialized facilities. We categorize sports events into four types based on their requirements, with Type 4 (such as table tennis, badminton, martial arts like boxing) having the greatest flexibility in scheduling and Type 3 (such as rowing, sailing and canoeing) having the smallest selection range. The results are presented in Figure 11.

6.3 Candidate cities for Plan 1, 2 and 3

- **Plan 1: Setting permanent venues**

We screened candidate cities based on the criteria mentioned above for Plan 1. For the Winter Olympics, candidate cities mainly come from Nordic countries, including Lillehammer (Norway) and Innsbruck (Austria), as well as Vancouver (Canada) and Sochi (Russia). 19 out of 31 of these cities have previously hosted the Winter Olympics and are located within the range of 30° to 60° north latitude, relying on mountainous terrain such as the Alps and the Rocky Mountains. For the Summer Olympics, we selected 235 cities from 72 countries, including Sydney (Australia), Tokyo (Japan), Los Angeles (United States), Paris (France), Athens (Greece), Barcelona (Spain), Rio de Janeiro (Brazil), Shanghai (China), Osaka (Japan), and Doha (Qatar), among others. Compared to the Winter Olympics, there are significantly more candidate cities for the Summer Olympics, and 216 cities (91.9%) have no previous hosting experience.

Permanent Olympic venues in a single city have advantages, but also drawbacks such as depriving other cities and countries of the opportunity to display their culture, infrastructure, and sports dedication on the global stage.

Plan 2: Splitting into four smaller events

First, we split the 33 major Olympic events according to our previous classification. Events with less strict climate requirements, including Type 2 and Type 4, can be held in spring and autumn. Additionally, we pay attention to events that may no longer be suitable for summer due to global warming: **marathon, cycling, triathlon, and tennis**, as shown in Figure 5. These events require extended outdoor activity and can be impacted by high temperatures and humidity, particularly for athletes with disabilities. Therefore, we consider rescheduling them to spring or autumn.

Next, to determine suitable countries for hosting the Olympics, we refer to the climatic and geographical conditions of past Summer and Winter Olympics, as well as other sports events held in each season. We screen out alternative countries suitable for hosting the Olympics according to Plan 2:

- **Spring Olympic** are suitable for hosting in regions with relatively mild climates, such as southern Europe, the Mediterranean coast, East Asia, and Australia. Suggested cities include **Rome, Madrid, Barcelona, Tokyo, and Sydney**.
- **Autumn Olympics** are suitable for hosting in regions with cooler climates, such as northern Europe, North America, and northeastern China. Suggested cities include **Stockholm, Vancouver, and Chicago**.

Plan 3 : A hybrid approach of Plan 1 and 2

Based on Plan 2, we further calculate the several most expensive events in terms of venue construction costs using data from previous Olympic Games and identify them as the **key events** suitable for fixed hosting.

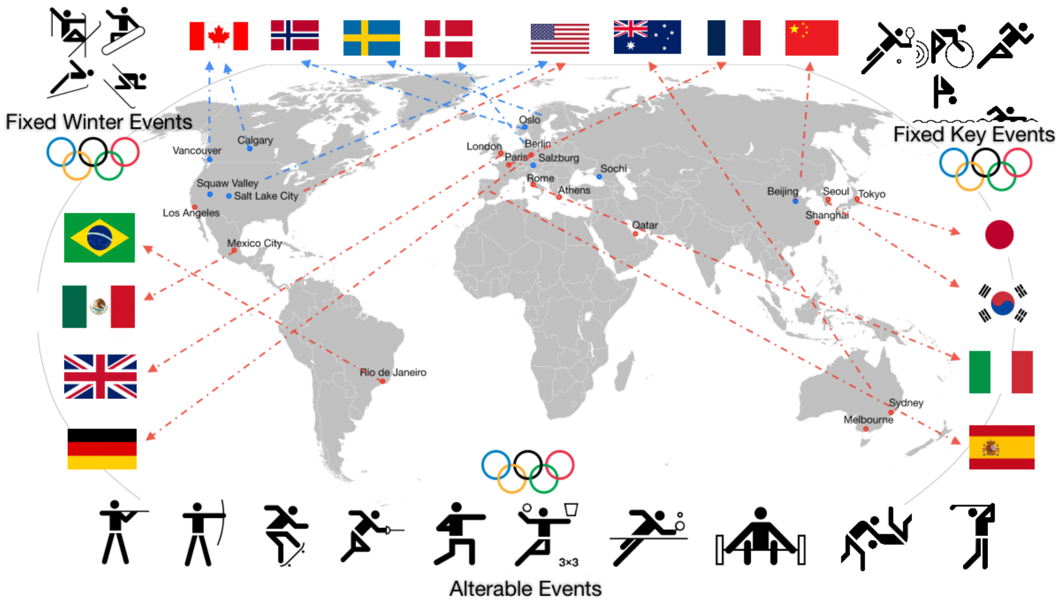


Figure 6: Candidate cities for different types of events

- **Marathon** is considered as one of the most emblematic, costly and most-watched events in the modern Summer Olympic Games, and the wet bulb globe temperature (WBGT) level of sites should be below level 3 suggested by the International Institute for Running Medicine (IIRM).
- **Cycling**, here we refer to **road cycling** and **mountain bike racing**, both require high-quality facilities and safety measures, as well as suitable weather and terrain conditions, to ensure athlete safety and fair competition.
- **Tennis** matches are typically held outdoors and require high standards for natural conditions such as temperature, humidity, and lighting. According to data from previous Olympic Games, construction costs for tennis facilities usually range from millions to billions of US dollars.
- **Swimming and Gymnastics** are also included due to the high cost of constructing and maintaining the venues and facility.

In addition to climate conditions, historical performance is also a crucial factor in determining fixed events. We analyzed past Olympic results and added cities with a strong track record to the candidate list as follows: New York, Tokyo, Berlin, London, Boston, Chicago, and Seoul for marathon; Pila, Colorado Springs, Fichtelberg, and Mont-Tremblant for cycling and London, Paris, New York, and Melbourne for tennis.

7 Model 2: Optimization of OGSI for each plan

In order to assist the International Olympic Committee (ICMG) in selecting the optimal proposal among the three plans, we attempt to employ the OGSI optimization model to optimize each proposal, with OGSI as the optimization variable.

7.1 Construction of the Olympic Effect Index

to measure a country's sustainable capability to host the Olympic Games, which comprehensively evaluates a country's economic, ecological, and social capacities. These aspects are highly correlated with the capability to host the Olympic Games, so we have sufficient reason to believe that the higher the OSI, the more outstanding a country's ability to host the Olympic Games.

The organizing committee aims to expand the impact of the Olympic Games and earn sufficient economic profits. Thus, they seek countries with strong hosting capabilities, which involve economic strength, international influence, and supporting infrastructure. In Model 1, we use OSI to measure a country's sustainable capability to host the Olympic Games, which comprehensively evaluates economic, ecological, and social capacities. However, it is crucial to consider the **different visions** between the host country and the organizing committee, as shown in Figure 7. The change of OSI before and after hosting reflects the impact on the host country, where an increase in OSI indicates an enhanced capability and future improvement in economic strength. However, if hosting results in minor OSI increase and unexpected costs, the host country would avoid taking on the responsibility.

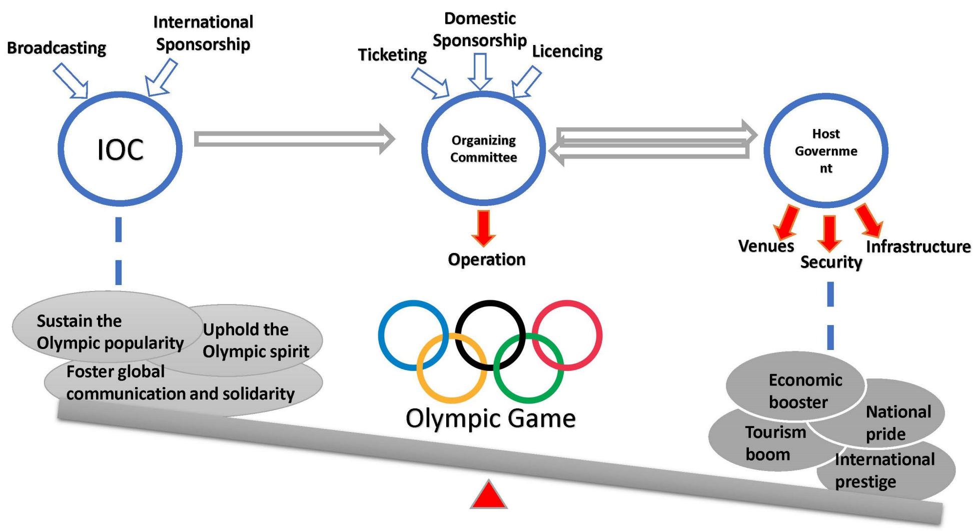


Figure 7: Cost and revenue streams and what is valued by the IOC and hosts

Taking into account the above two points, the organizing committee values the host country's fundamental strength, namely OSI, while the host country prioritizes the rate of improvement in national strength before and after hosting the Olympic Games, i.e., ΔOSI. To comprehensively consider the objectives of both the organizing committee and the host country, we define the **Olympic Effect Index (OEI)**.

$$OEI = \Delta OSI + \theta OSI \quad (\theta < 1) \tag{8}$$

where θ represents the relative proportion of OSI and ΔOSI, and since the final decision on whether to host the Olympic Games depends on the host country, we believe that the organizing committee's objective has a smaller weight compared to the host country's objective.

7.2 Calculation of OEI using Kernel Ridge Regression

To obtain ΔOSI, we employ the **Kernel Ridge Regression (KRR)** method to accurately fit the relationship between the impact of hosting the Olympic Games on the host country's OSI index and the OSI index value before hosting the Olympic Games and Olympic Games parameters (OGSI).

Kernel Ridge Regression (KRR) is a regression method that combines Ridge Regression with the Kernel Trick. KRR can capture non-linear relationships while regularizing the complexity of the model to reduce the risk of overfitting.

We use the **Gaussian Radial Basis Function (RBF)** as the kernel function to achieve the mapping from the original feature space to a high-dimensional or infinite-dimensional feature space, thereby revealing non-linear associations. Let the kernel matrix be **K**, defined as:

$$\mathbf{K}_{i,j} = e^{-\gamma||\phi(x_i)-\phi(y_j)||^2} \tag{9}$$

where the variablesx_i and y_j represent the OSI and OGSI indices, respectively, for the $i-th$ and the $j-th$ groups of data. The bandwidth parameter of the kernel function is denoted by gamma, and the L2 norm is represented by ||·||.
par The objective function for kernel ridge regression is defined as follows:

$$\alpha = argmin(\alpha)||Z - \mathbf{K}\alpha||^2 + \lambda\alpha^T\alpha \tag{10}$$

where Z represents the impact of hosting the Olympic Games on the OSI indices of the host country in the training data, K is the kernel matrix, lambda is the regularization parameter, and omega is the optimal coefficient vector.
par By minimizing the objective function, the weight vector alpha is obtained. The following formula is then used to predict the impact of hosting the Olympic Games on the OSI indices of the host country:

$$\hat{z} = \mathbf{K} * [\hat{x}, \hat{y}] * \alpha \tag{11}$$

then we can obtain the changing rate of OSI as $\Delta OSI = \hat{z}/OSI$ In order to fully utilize the available resources of the host country and maximize the influence of the Olympic Games, this paper constructs an OGSI optimization model, which allows the OEI of the three alternative plans to reach their maximum values under constraints. Hence, the objective function is:

$$\underset{OGSI}{max}\ w^\top OEI \tag{12}$$

Where w is the weight between each component obtained through the combined method of **Analytic Hierarchy Process (AHP)**and **Entropy Weight Method (EWM)**.

7.3 Weight determination using AHP-EWM

The **AHP-EWM** algorithm is a comprehensive evaluation method for multi-index decision-making. To be specific, the Analytic Hierarchy Process (AHP) and Entropy Weight Method are two frequently utilized techniques for ascertaining weights in multi-criteria decision-making problems. AHP generally requires domain experts to comparatively evaluate each element in pairs across multiple hierarchical levels, perform consistency assessments on the judgment matrices produced by each expert, and subsequently employ the weighted arithmetic mean methodology to aggregate the scores, ultimately deriving the AHP weights. The Entropy Weight Method (EWM) constitutes an objective weight assignment technique that ascertains the weight of each index predicated on its information entropy.

While AHP exhibits a high degree of systematicity, its grading process relies predominantly on the subjective expertise of specialists. The Entropy Weight Method can mitigate the subjectivity inherent in experience-based evaluations, yet the resulting weight rankings may not be accurate. To establish more precise index weights, this research integrates AHP and EWM to determine the index weight of customer perceived value. Initially, AHP is employed to ascertain the evaluation index's weight, followed by EWM to establish the objective weight. By optimizing both subjective and objective weights via the Lagrangian multiplier method, the combined weight, founded upon the principle of minimum relative information entropy, is obtained. For all countries' OEI, the final formula for weight calculation is:

$$w_k = \frac{\sqrt{w_{ik} w_{jk}}}{\sum_{k=1}^{m} \sqrt{w_{ik} w_{jk}}} \; k = 1, 2, ...9 \tag{13}$$

Herein, w_{ik} denotes the objective weight obtained through the Entropy Weight Method (EWM), while w_{jk} represents the subjective weight derived from the Analytic Hierarchy Process (AHP).

7.4 Model calculation based on ALM-ADMM

Visualized in Figure 4(b), the Olympic Game Scale Index (OGSI) is a metric utilized for measuring the scale of the Olympic Games, encompassing five aspects: the number of participating athletes (an), the number of venues (vn), the number of competition events (en), organizational and promotional energy costs (c), and the coverage of live broadcast signals (cr).

The optimization model aims to maximize the Olympic Effect Index (OEI) under the constraints of these components.

$$\begin{aligned} & \max_{OGSI} \; w^{\top} OEI \\ & s.t. \begin{cases} 0.9b \leq cost^{\top} OGSI \leq 1.27b \\ vn \leq S \\ \frac{en}{vn} \leq 4 \\ a_{min} \leq an \leq a_{max} \end{cases} \end{aligned} \tag{14}$$

- **Cost** Among the constraints of the optimization model, the first pertains to cost. Considering that Olympic Games have historically exceeded their initial budgets, the 1984 Los Angeles Olympics' budget overrun is referenced. Economically speaking, the 1984 Los Angeles Olympics was the first profitable Games, and is also regarded as the most cost-effective, with a budget overrun of merely **27%**. Given that the five indices of the OGSI do not encompass all aspects of hosting the Olympic Games, it is assumed that the budget for these five indices can exceed the planned budget by a maximum of 27%, otherwise considered overspending.

- **Area restrictions** The second constraint involves area restriction. As the venue construction area is explicitly planned in the project initiation documentation of the Olympic host nation, it is assumed that any subsequent changes will not affect the allocated land area.

- **Venue load** According to the International Olympic Committee's regulations, *a single venue can host a maximum of one event final during an Olympic Games, but it can accommodate multiple preliminary and semi-final events*. Therefore, the number of events held at a venue is typically limited to ensure operational efficiency and safety. Generally, hosting an excessive number of events in a short time frame at a single venue could burden its usage and maintenance, potentially impacting the quality and safety of competitions. Thus, when planning venues and scheduling events, it is crucial to consider the load and usage efficiency of venues to ensure the smooth execution of competitions and sustainable long-term usage. We believe that on average, a venue should not host more than **4** events throughout the entire Olympic season.

- **Number of athletes** Due to limited accommodation resources surrounding the Olympic Games, and taking into account the publicly disclosed athlete numbers from each Olympic Games, as well as absentees due to injuries and accompanying coaching staff and family members, a constraint on the number of participating athletes is necessary. Referring to historical data on the number of participating athletes, the maximum and minimum values are used as the upper and lower limits for the athlete count, respectively.

The optimization problem at hand is a typical constrained optimization problem, which can be solved using the **Augmented Lagrangian Method (ALM)**. The Augmented Lagrangian Function is one of the commonly employed methods for addressing constrained optimization problems. It transforms the constraint conditions of the original problem into the form of Lagrangian multipliers while adding a penalty term to approximate the constraint conditions. This method effectively simplifies models with multiple constraints by converting constrained optimization problems into unconstrained ones. The form of the Augmented Lagrangian Function for this constrained optimization problem can be abstracted as equation 15:

$$L_\rho(x, \lambda) = f(x) + \sum_{i=1}^{n} \lambda_i g_i(x) + \frac{\rho}{2} \sum_{i=1}^{n} g_i^2(x) \tag{15}$$

where $g_i(x)$ represents the i-th constraint. The **Alternating Direction Method of Multipliers (ADMM)** can be employed to solve the constrained optimization problem. Namely, the parameters x are found by minimizing $L_\rho(x, \lambda)$ while keeping λ fixed, and then λ is found by minimizing $L_\rho(x, \lambda)$ with x fixed. Iterating until convergence yields the optimal solution to the original problem.

First, we construct optimization models for the three alternative proposals of countries and solve them separately. For different host countries, we assume that their Olympic budget is proportional to their GDP, the area of the Olympic venue is proportional to their city area and inversely proportional to their city GDP, and the cost of venue construction is inversely proportional to the product of city GDP and the number of city venues (data can be obtained from the World Bank and national statistical bureaus). For Proposal 2, which involves splitting the Summer Olympics into two seasons - Spring and Autumn, and Proposal 3, which is a mixed approach of Plan 1 and 2, we believe that the number of Olympic events held in each season should be proportional to the Olympic budget. By utilizing the Scipy module in Python, we can easily solve the Augmented Lagrangian Function optimization. We ranked the scores of the three plans in descending order and obtained the following results as Table 5.

Table 5: Candidate Cities

Rank	Plan1		Plan2			Plan3		
						Stable		Unstable
	Summer	Winter	Summer	Winter	Spring & Autumn	Winter Games	Key Events	
1	Sydney	Vancouver	Tokyo	Vancouver	Sydney	Vancouver	Sydney	London
2	Barcelona	Sochi	Los Angeles	Sochi	Beijing	Sochi	Los Angeles	Sydney
3	Tokyo	Oslo			Rio de Janeiro			Tokyo
4	Los Angeles	Zurich			Munich			Rio de Janeiro
5	Seoul	Oslo						Munich
Score	67.83		68.95			72.71		

Score: The average score of the objective function of all candidate countries selected under the plan after ALM-ADMM optimization.

8 Evaluation of the optimal plan

According to the optimization results of Model 2, we have taken a comprehensive approach and concluded that the implementation of Plan 3 can achieve the maximum value of OEI (Optimal Event Index) with statistical significance. Therefore, we consider adopting Plan 3, which involves selecting fixed venues for events with stringent climate requirements or high venue costs, while employing a mobile approach for other sports events. In the following sections, we will present the detailed arrangements of the optimal plan, including the timetable, discuss the feasibility of the optimal plan, and analyze the impact of implementing this plan.

8.1 Timeline

In our Plan 3, the Olympic Games still follow a four-year cycle, but the number of events and the hosting arrangements have changed. Certain sports events with strict climate requirements or high venue costs will be held at fixed venues, and we recommend selecting fixed venues for the Winter Olympics. In addition, we have selected some events to be held at another fixed venue, including marathons, cycling, swimming, tennis, and gymnastics. Other events will be held in two separate stages during one Olympic cycle. According to our plan, the specific schedule is shown in Figure 8 :

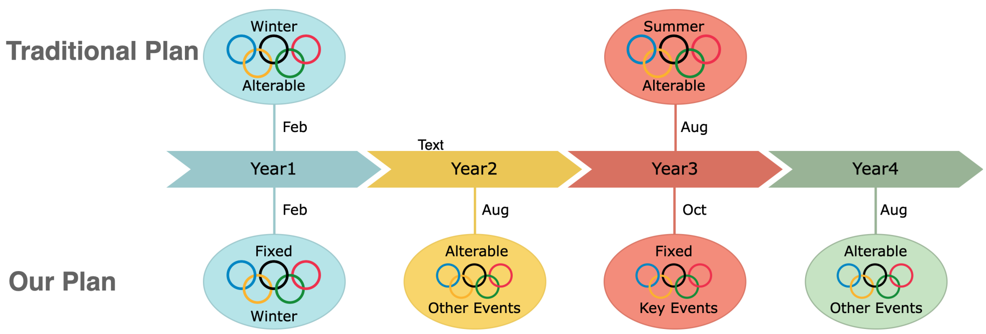


Figure 8: Timeline of Plan 3

8.2 Feasibility

We will discuss the feasibility of our plan from the implementation perspective, drawing on the experiences and lessons learned from hosting the Olympic Games in previous years, as well as results obtained from our model.

8.2.1 Analysis of Plan 3's feasibility

In Plan 3, we take into account that winter events, as well as marathon, swimming, cycling, tennis, and gymnastics events, have higher climate requirements and higher venue construction costs. Therefore, these events require fixed host countries, while the remaining events will be hosted on a rotating basis. This plan combines the advantages of Plan 1, which involves cost-saving fixed hosting, and Plan 2, which divides the events into smaller projects, easing the hosting pressure on the host countries. The hosting costs for each Olympic Games are reduced, alleviating the financial burden on the host countries.

Hosting the Olympic Games requires a large number of venues and accommodation facilities, which may necessitate clearing vast areas of land. This could lead to habitat destruction for wildlife and ecosystem disruption, even potentially damaging sensitive ecosystems such as wetlands, forests, and beaches. Venue construction also involves significant carbon emissions. In our plan, by fixing the host countries for events with high venue costs, these venues only need to be built once, thus avoiding resource waste and environmental damage caused by repeated construction.

For the fixed Olympic events, since the venues only need to be built once and used long-term, we can focus more on safety and fairness considerations when constructing venues and tracks, such as incorporating more advanced safety facilities and technologies during design and construction. Moreover, due to the stability of the venue's climate conditions, athletes can perform at their best without having to face sudden changes in weather conditions. For the non-fixed Olympic events, with a reduced number of projects and lower venue construction costs, more resources can be allocated to enhancing safety and fairness in competitions.

By fixing the venues for some events, athletes can train at the competition sites in advance, making it more convenient for spectators and volunteers to purchase tickets and plan their trips. The mobile hosting of the other events still provides opportunities for countries that aim to enhance their international influence and promote economic development through hosting the Olympic Games, reflecting the human-centered nature of our plan.

In summary, our Plan 3 is feasible from economic, environmental, safety and fairness, and human-centered perspectives.

8.2.2 Determination of potential hosts

In the following section, we will discuss the results obtained from the ALM-ADMM model, taking into account the specific characteristics of each city. Some potential host cities are shown in Table 5.

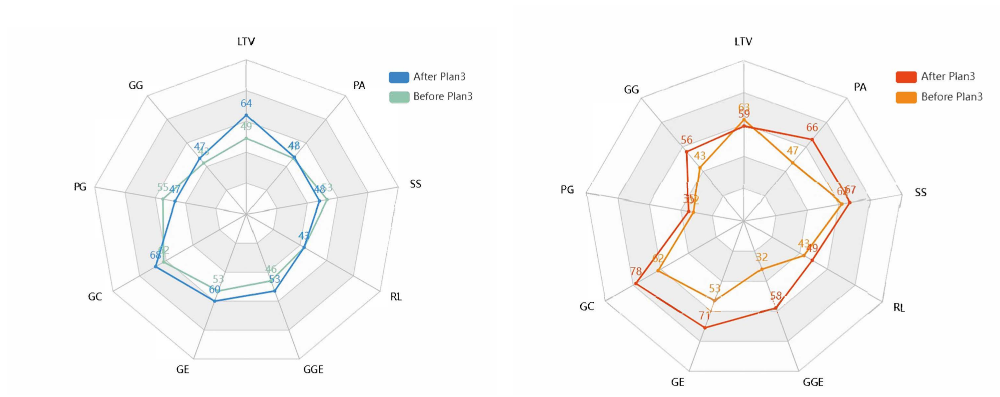
Sydney, Australia, stands out as the top fixed host city for key events, boasting numerous modern sports venues, such as Sydney Olympic Park, which served as the main venue for the 2000 Summer Olympic Games. The city's favorable climate, year-round mild temperatures, and low rainfall make it ideal for various outdoor sports. Sydney's well-developed infrastructure, economic prosperity, and political stability ensure its suitability for hosting large-scale international sports events without conflicts.

For winter events, Vancouver, Canada, ranks highest as a fixed host city. Located on Canada's west coast, Vancouver offers a mild climate, moderate snowfall, and excellent snow quality, making it a prime location for winter sports. The city successfully hosted the 2010 Winter Olympic Games, with modern venue facilities still operational today. As a major economic center with a stable political environment, excellent infrastructure, and good public safety, Vancouver is well-equipped to host large-scale international events without conflicts during the January and February months.

In conclusion, the ALM-ADMM model has effectively identified Sydney, Australia, and Vancouver, Canada, as the optimal fixed host cities for key events and winter sports, respectively. Their well-developed infrastructure, favorable weather conditions, and stable environments make them excellent choices for hosting large-scale international sports events.

8.3 Impact on OSI of Sydney and Vancouver

In Model 2, we obtained the impact of Plan 3 on the Olympic Sustainability Index (OSI) for host countries, taking Sydney and Vancouver, both of which are suitable for hosting the Olympic Games and have expressed interest in doing so, as examples. The impact is shown in Figure 9:



(a) Sydney (b) Vancouver

Figure 9: Comparison of OSI under traditional hosting pattern (before plan 3) and the optimal plan (after plan 3)

From Figure 9, it can be concluded that if the optimal plan - Plan 3 is implemented, the economic pressures (GG, PG) and environmental pressures (GE, GGE) of hosting the Olympic Games for these two countries will be relatively small. Furthermore, it promotes the enhancement of the Global Competitiveness Rating (GCR), which is beneficial to the improvement of national social security and the perfection of the legal system to some extent. This can lead to increased social support and improve the long-term viability of the host countries.

9 Sensitivity analysis of the model

To test the robustness of the optimization problem expressed in equation 14, we explore the option of relaxing the constraints. Specifically, we introduce a parameter λ to allow for fluctuations in the constraints pertaining to resources, area, venue capacity, athlete numbers, and other relevant factors. By observing the resulting changes in the final ranking of scores, we aim to assess the model's capacity to withstand variations in input parameters. To conduct these tests, we focus on the main candidate countries and regions involved in holding key events, as follows:

$$\max_{OGSI} w^{\top} OEI$$
$$s.t. \begin{cases} 0.9(1+\lambda)b \le cost^{\top} OGSI \le 1.27(1+\lambda)b \\ vn \le (1+\lambda)S \\ \frac{en}{vn} \le 4(1+\lambda) \\ (1+\lambda)a_{min} \le an \le (1+\lambda)a_{max} \end{cases} \tag{16}$$

According to the sensitivity analysis results, it can be seen that there is not much change in the final OEI scores among countries. Moreover, there has not been a significant change in the relative positions of the countries. Therefore, our ALM-ADMM optimization model is robust.

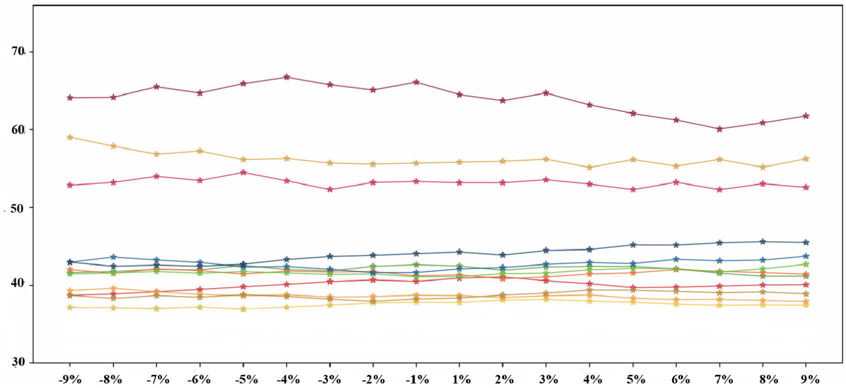


Figure 10: OEI score changes. The vertical axis represents the OSI score, and the horizontal axis represents the percentage change in each constraint, λ. The line chart from top to bottom shows the following cities: Sydney, Los Angeles, Vancouver, Sochi, London, Tokyo, Beijing, Rio de Janeiro, Shanghai, Seoul, Munich, Athens, and Rome.

10 Strengths and Weaknesses

Strengths

- This paper takes into account the social, economic and ecological aspects of hosting the Olympic Games for the host country, and uses nine secondary indicators for quantitative calculations. The evaluation indicator system is well constructed.
- This paper uses the DID-VAR algorithm to quantify the impact of hosting the Olympic Games on the host country through a quasi-experimental approach. Eliminating the endogeneity problem caused by sample selection bias.
- This paper uses an optimization model to solve for each scenario score. We set the Olympic Games resource constraints and use the maximization of the OEI as the objective function, and use the ALM-ADMM algorithm to obtain the optimal score under the resource constraints. The resource usage is also given.

Weaknesses

- The international political environment is not fully considered in this paper. It is difficult to predict and quantify because it involves international relations, social networks, etc.
- Although the DID method is capable of eliminating the influence of unobserved variables on policy effects, the effectiveness of the DID method is influenced by data quality, sample size, timing and magnitude of policy interventions, and other factors. Therefore, it requires empirical analysis and model validation.

11 MEMO

TO: The International Olympic Committee (IOC)
FROM: Team 2330003
DATE: April 3, 2023
SUBJECT: A Reformative Olympics Hosting Plan

The Olympic Games represent the largest comprehensive sporting event worldwide, serving as a torch of human spirit and an indispensable part of the global cultural stage. Over the past decade, enthusiasm for hosting the Olympics has waned in various regions. The traditional hosting model, held every four years across two seasons, may need to be updated with options such as establishing permanent venues (Plan 1), dividing the games into smaller-scale events (Plan 2), or holding some events in fixed locations while others rotate among different cities (Plan 3). This memo outlines our understanding of the current challenge, our interdisciplinary approach to analyzing the impact of hosting the Olympics, and our recommended plan with accompanying justifications.

To comprehensively measure the impact of hosting the Olympics and assess the effectiveness of adjusting host locations and schedules, we have developed two fundamental models: one that encompasses economic, social, and ecological aspects with nine secondary indicators, and another that combines optimization and evaluation. Overall, our models take in the plan and candidate city data as inputs and output the optimal plan with its specific parameters. Moreover, we have meticulously categorized current Olympic projects and identified a series of key events as the link between the two models. The model results indicate that Plan 3 is optimal, maintaining the Olympics on a

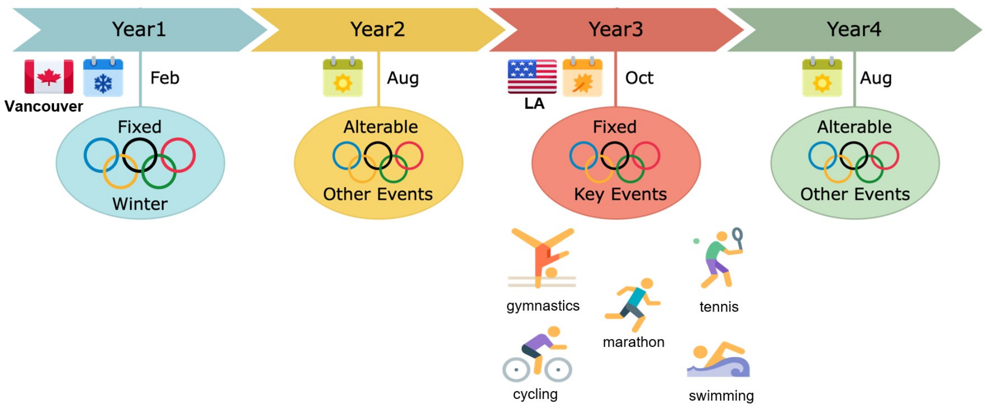


Figure 11: Cost and revenue streams and what is valued by the IOC and hosts

four-year cycle with the Winter Olympics held in Vancouver every February of the first year, key events hosted in Los Angeles every October of the third year, and the remaining events rotating among different cities every August of the second and fourth years. To further demonstrate the effectiveness of our plan, we have conducted in-depth analysis from five perspectives: economic, ecological, safety and fairness, human-centered, and social. We have selected Sydney from the candidate cities for alterable events and Vancouver for permanent venues, comparing the changes in OSI indicators under both the traditional hosting model and our proposed plan. This quantitative analysis illustrates the effectiveness of our approach.

We sincerely hope that our insights, models, and proposed plan can provide valuable information to assist in making informed decisions regarding the future of the Olympic Games.

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