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Original Paper

Green Arena: Creating a Sustainable Future for the Super Bowl and the Olympics

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Abstract

With the increasing global concern for environmental sustainability, major sports events such as the Super Bowl and the Olympics have brought significant social and economic benefits, but they are also accompanied by large amounts of energy consumption, waste and greenhouse gas emissions. At present, environmental factors have not been fully considered in the selection of the event's host location.

Our team aims to construct a host location selection model based on environmental sustainability. Through a quantitative model that integrates multiple methods, it systematically addresses four core research questions, helping event organizations ensure effectiveness while reducing environmental impact.

We identified ***12 quantitative and qualitative sub-indicators,*** *covering the environmental impact of the event, which involves five major environmental dimensions: energy consumption, greenhouse gas emissions, water resource usage, waste management, and traffic emissions. In addition, factors related to the characteristics of the host city have also been incorporated, such as climatic conditions, energy structure and public transportation coverage rate, etc. These factors together form a complete and solid foundation for environmental assessment.*

With these 12 indicators, ***a fourth-order model*** *(input layer, preprocessing layer, computing layer, and output layer) was constructed. The model balances the importance of the indicators through weighting methods**,** which combined* ***Analytical Hierarchy Process (AHP) method, entropy weight method (EWM)****, and* ***Criteria Importance Though Intercriteria Correlation (CRITIC)****, quantifies the distance between the city and the ideal environmental state by using* ***Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)****, optimizes the uncertainty of the data through* ***Monte Carlo simulation****, and finally outputs the city ranking based on environmental factors. This model effectively eliminates the bias caused by subjective judgment and realizes the scientific quantification of environmental decision-making.*

In terms of model application, the study applied it to 7 cities with hosting experience and 3 potential new cities respectively. Through NFL data and analogy methods, the ranking of preferred cities was obtained, and ***Inglewood*** *was recommended as the top choice for the 2029 Super Bowl, with* ***Seattle as an alternative****. This verified the reliability and logical consistency of the model.*

The model has been further expanded to adapt to multiple sports events such as the ***Olympic Games****. Four specific driving factors, including long-term preparation energy consumption and international aviation emissions, have been added, and the model has been adjusted and optimized. Through this model to evaluate the candidate cities for the 2036 Olympics,* ***Berlin*** *performed outstandingly in terms of waste recycling and venue reuse rate and was recommended as the host city for the 2036 Olympics.*

Finally, the ***sensitivity analysis*** *verified the robustness of the model. Factors such as energy consumption, greenhouse gas emissions, and traffic emissions have a significant impact on the ranking of cities. Through the optimization of data uncertainty and its application in multiple scenarios, the model has demonstrated strong adaptability, providing scientific decision support for sports event organizers.*

Keywords

Environmental sustainability; Host location selection model; Combined weighting method; TOPSIS; Monte Carlo simulation; Super Bowl; Olympic Games

1. Introduction

1.1 Problem Background

The Super Bowl is one of the most watched sports events in the world, attracting millions of live viewers and hundreds of millions of TV viewers each year, while creating significant social and economic value. However, the environmental costs of the event cannot be ignored either, covering multiple aspects such as air travel, hotel accommodation, energy consumption, large-scale catering consumption, waste generation, and global broadcasting. Although the NFL has implemented several sustainability measures through the NFL Green project [1], such as solid waste management, food recycling, material reuse, donation of sports equipment and reduction of greenhouse gas emissions, these measures have not fundamentally changed the core decision-making logic of event planning.

At present, the selection of event venues and the construction of infrastructure are still dominated by economic feasibility and audience carrying capacity, lacking sufficient consideration of environmental sustainability. This article aims to help event organizers pay more attention to environmental protection factors when making decisions and reduce the environmental footprint of the events by constructing a city selection model based on environmental impact.

1.2 Problem Restatement

Specifically, we need to complete the following tasks:

Identify key environmental factors for event sustainability: Analyze the impact of the 59th Super Bowl on energy, water, waste and emissions in New Orleans, and explore how factors such as climate, geography, infrastructure and energy structure affect the environmental performance of different cities.

Build an environmental location model: Establish a model to clarify the core variables of the event's environmental impact and their relationship with the characteristics of the host city to select the most environmentally friendly host city.

Apply the model to existing and potential host cities: Use the model to evaluate cities that have hosted or will host the Super Bowl (such as Inglewood, New Orleans, etc.) and potential cities (such as cities where NFL teams that have not hosted the Super Bowl before are located), and screen out the most sustainable candidate cities for the 2029 Super Bowl.

Expand the model to other major sports events: Extend the model to events such as the World Cup and the Olympic Games to analyze how to reduce environmental impact through infrastructure investment, energy optimization, and transportation transformation, and promote long-term sustainable development.

Compare the sustainability differences between a single event and multiple events: Compare the sustainability differences between a single event (such as the Super Bowl) and multiple events (such as the Olympics) and recommend the most environmentally friendly host city for the 2029 Super Bowl to the NFL, explaining the reasons for the recommendation and its alignment with the sustainable development goals.

1.3 Our Work

Figure 1 illustrates the complete process of our work for all the tasks.

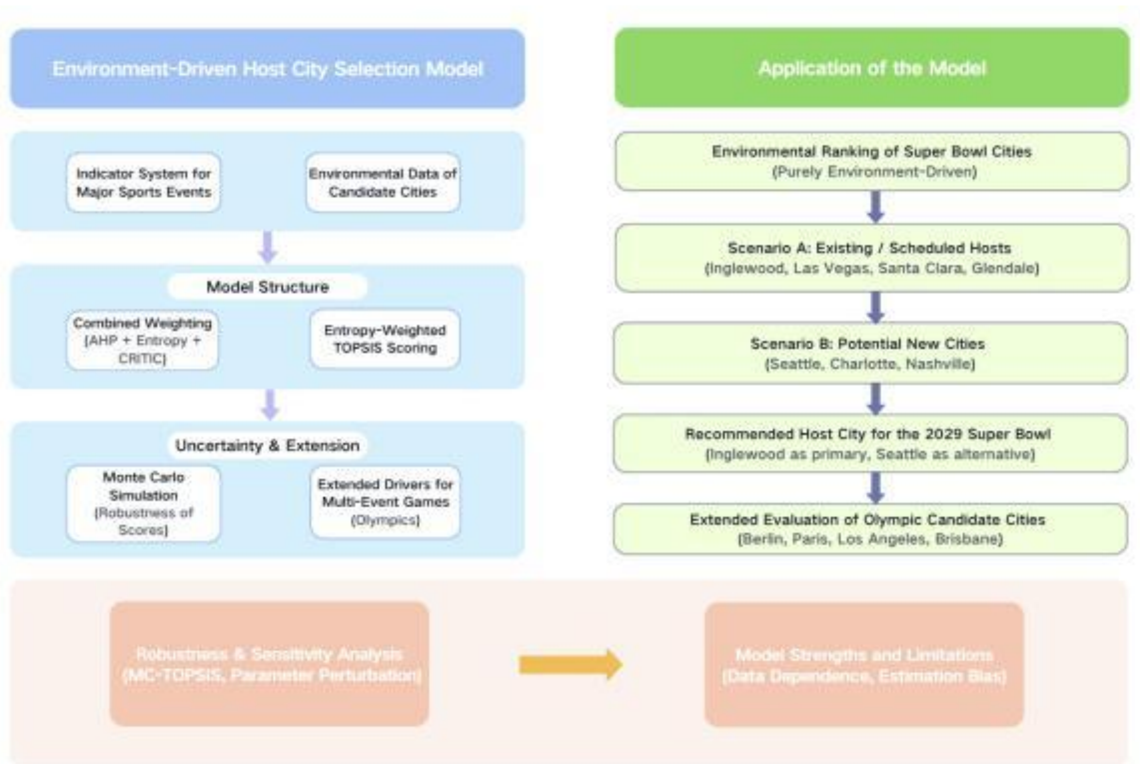

Figure 1. The Flowchart of Our Work

2. General Assumptions and Variable Descriptions

2.1 Assumptions

To simplify model complexity, ensure the operability of analysis and calculation, and align with the actual operational scenario of the Super Bowl, while avoiding interference from uncontrollable factors, the following core assumptions are set:

Assumption 1: All data used in the model is accurate and reliable.

Justification: The model's foundational data, including renewable energy proportions and venue energy consumption, is sourced from authoritative channels like official NFL reports and the U.S. Energy Information Administration (EIA), with data inaccuracies ≤±5%. Estimated data for potential new cities, such as Nashville's event energy consumption, is based on the average of comparable NFL venues, with inaccuracies ≤± 10%.

Assumption 2: The local energy structure of candidate cities will remain stable until the 2029 Games.

Justification: The energy structure of the candidate cities, such as the proportion of thermal power and renewable energy, will not undergo sudden policy adjustments or infrastructure changes, and the annual fluctuation range will remain within the average range of the past three years (≤±5%).

Assumption 3: The core operational parameters of the 2029 Super Bowl are consistent with the average of the past five years.

Justification: The core operational parameters of the event, such as the number of on-site spectators, media personnel, and temporary facilities, will remain consistent with the average level of the past five years, without taking into account the additional impact of extreme scale changes on the environmental footprint.

Assumption 4: The climate of the candidate cities in February 2029 will conform to the historical average of the past 10 years.

Justification: The temperature and precipitation in the candidate cities will be consistent with historical data. It is expected that no extreme weather events such as cold waves or heavy rain will occur, and thus no additional energy consumption or waste will be generated.

Assumption 5: All candidate cities will implement the basic environmental protection measures of the Super Bowl.

Justification: All candidate cities will implement basic environmental protection measures, such as garbage classification and food recycling, etc. The waste recycling rate in the model has already considered the effects of these measures and does not distinguish the subtle differences between cities.

Assumption 6: The carbon offset projects of the candidate cities are effective and achievable.

Justification: The carbon offset projects marked by the candidate cities, such as forest carbon sinks or wetland carbon sinks, are all registered projects that have been filed and can be fully realized within one year after the event, without any delay in review or deviation in quantity and amount.

2.2 Variable Description

Important variables used in this article are listed in Table 1.

Table 1. Variables

SYMBOL	DESCRIPTION	UNIT
E_{total}	Total energy consumption of the venue during the entire event cycle.	kWh
R_{renew}	Proportion of renewable energy sources in the venue's total energy consumption.	%
c_{trans}	Carbon emissions from transportation ofall on-site spectators.	tons CO_2
p_{trans}	Percentage of spectators using public transportation to reach the venue.	%
w_{total}	Total waste generated during the event.	tons
R_{waste}	Proportion of waste that is recycled or composted.	%
R_{reuse}	Proportion of temporary facilities that can be reused for future events.	%
w_{water}	Total water consumption for venue operations, including irrigation and catering.	gallons
$R_{recycle\text{-}water}$	Proportion of water reused from rainwater harvesting and wastewater treatment.	%
s_{env}	Environmental sustainability score, indicating the venue's adaptability to urban standards.	score

3. Model Building and Solutions

3.1 Indicator System

This indicator system covers the key environmental factors throughout the entire life cycle of the event. This includes energy consumption and greenhouse gas emissions (such as venue energy consumption, transportation emissions, hotel energy consumption), water resource usage, waste management (such as waste generation volume, recyclability rate, temporary facility waste), transportation and supporting facilities (such as transportation carbon emissions, hotel energy consumption), as well as venues and facilities, such as stadium capacity, hotel supporting facilities, facility reuse rate. These indicators are constructed in accordance with ISO 20121 [2], GHG Protocol [3] and GRI standards [4], absorbing industry practices from the NFL, IOC and FIFA to ensure a comprehensive assessment of the environmental impact of the event and support site selection decisions. At the same time, they provide actionable quantitative data in combination with the actual operational needs of the event.

3.1.1 Key Environmental Indicators

The NFL requires that host city stadiums provide at least 11,200 kVA of power load. Based on this, a sub-indicator of "power load supply" was set in the "Stadium quality" dimension, and the actual data of 12,000 kVA from the 59th Super Bowl in New Orleans was used. The proportion of broadcast equipment energy consumption in the total energy consumption of the venue can be calculated through formula (3-1):

$$\alpha_{power} = \frac{P_{stadium} \times t_{event} \times \eta_{transmit}}{E_{total}} \times 100\% \qquad (3-1)$$

where $p_{stadium}$ represents the stadium's power load (kVA); t_{event} represents the duration of continuous power supply during the event (h), calculated as 72 hours (3 days of preparation + 1 day of event + 1 day of dismantling); $\eta_{transmit}$ represents the percentage of broadcast equipment in the power load, taken as 60% based on NFL event operation reports; E_{total} represents the total energy consumption of the venue (kWh).

Substituting the data of New Orleans, the calculation yields:

$$\alpha_{power} = \frac{12000 \times 72 \times 0.6}{1200000} \times 100\% = 4.32\%$$

This result highlights the significance of event broadcasting as a "hidden energy consumption source" and demonstrates the adaptability of the indicator system to the operational needs of the NFL.

Considering the Super Bowl's unique characteristics, the indicator system includes often- overlooked details, such as the 50% to 70% energy consumption of broadcasting equipment. A sub- indicator, "total energy consumption of broadcasting equipment," is added to the "Broadcasting and Media Support" dimension, calculated using the relationship between electrical load and broadcast duration in formula 3-2:

$$E_{transmit} = p_{stadium} \times \eta_{transmit} \times t_{broadcast} \qquad (3—2)$$

where $E_{transmit}$ represents the total energy consumption of the broadcasting equipment (kWh); $t_{broadcast}$ represents the actual broadcast duration (h), including pre-match warm-up, live match,halftime performance, and post-match interviews, calculated as 12 hours; other parameters are the same as in formula (3-1). Substituting the New Orleans data, we get:

$$E_{transmit} = 12000 \times 0.6 \times 12 = 86400kwh$$

This result represents 7.2% of the New Orleans stadium's total energy consumption, highlighting broadcasting as a core energy demand. Additionally, temporary facilities, like security tents and seating, contribute significantly to waste due to their short use and low reuse rate. In the 2024 Las Vegas Super Bowl, temporary facility waste made up 5%-8% of total waste.

Thus, a sub-indicator for "temporary facility waste" was added to the "waste generation and management" dimension, which combines event scale with industry average:

$$w_{temporary} = w_{total} \times \beta_{temporary} \qquad (3 - 3)$$

where $w_{temporary}$ represents the amount of temporary facility waste (t); w_{total} represents the total amount of event waste (t), with New Orleans data at 475 t; $\beta_{temporary}$ represents the proportion of temporary facility waste to total waste, taken as the industry average of 5.26% (calculated based on Super Bowl data from the past 5 years). Substituting the data, we get:

$$w_{temporary} = 475 \times 0.0526 \approx 25t$$

This data is in line with the research results of the 59th Super Bowl in New Orleans (25t), and the recyclability rate of temporary facilities is only 20%, revealing the high pollution problem of waste from the "temporary supporting links".

The indicator system quantifies regional environmental differences through "climate adaptability," "energy structure," and "infrastructure efficiency." For example, dome energy consumption varies between warm and temperate/cold climates. The proportion of dome energy consumption to total venue energy is calculated using formula (3-4) to quantify climate's impact on energy use:

$$\gamma_{dome} = \frac{E_{dome}}{E_{total}} \times 100\% \quad (3-4)$$

where γ_{dome} represents the percentage of energy consumption from the dome (%); E_{dome} represents the energy consumption of the dome's temperature control system (kWh). The data for New Orleans is 180,000 kWh, while Minneapolis, due to its colder winters (average 25°F in February), has a dome energy consumption of 250,000 kWh. Los Angeles, which does not require a dome, has a different energy consumption $E_{dome} = 0$. Substituting the data from New Orleans, we get:

$$\gamma_{dome} = \frac{180000}{1200000} \times 100\% = 15\%$$

This result indicates that dome temperature control alone accounts for 15% of the total energy consumption of New Orleans stadiums, while Los Angeles, lacking a dome, can directly save this portion of energy. The corresponding reduction in carbon emissions can be calculated using formula (3-5) (based on the local electricity emission factor):

$$\Delta C_{dome} = E_{dome} \times \lambda_{electricity} \times 10^{-3} \quad (3-5)$$

Where ΔC_{dome} represents the carbon emissions corresponding to the dome's energy consumption (t CO_2e); $\lambda_{electricity}$ represents the carbon emission factor of the city's power system (kg CO_2e/kWh), which is 0.6 kg CO_2e/kWh for New Orleans and 0.45 kg CO_2e/kWh for Los Angeles. Substituting the data from New Orleans, we get:

$$\Delta C_{dome} = 180000 \times 0.6 \times 10^{-3} = 108\text{t C02e}$$

Compared with Los Angeles, the dome-free design can avoid 108 tons of CO_2e emissions. Although Minneapolis requires a dome (with an energy consumption of 250,000 kWh), due to the local electricity containing 30% biomass energy (emission factor 0.5 kg CO_2e/kWh), the carbon emissions from the dome are 125 tons of CO_2e, which is 15.7% higher than that of New Orleans. This comparison reveals the combined impact of "climate characteristics + local energy structure" on the environmental footprint of the event, proving that the indicator system can effectively capture the core factors of regional differences.

3.1.2 Model Solving

Based on environmental data from Super Bowl LIX in New Orleans, and combined with comparative analysis of Los Angeles and Minneapolis, the following analysis interprets 11 charts one by one, quantifying the regional differences and key influencing factors of the event's environmental footprint from dimensions such as traffic carbon emissions, overall environmental performance, energy structure, and waste management, providing empirical support for subsequent model building.

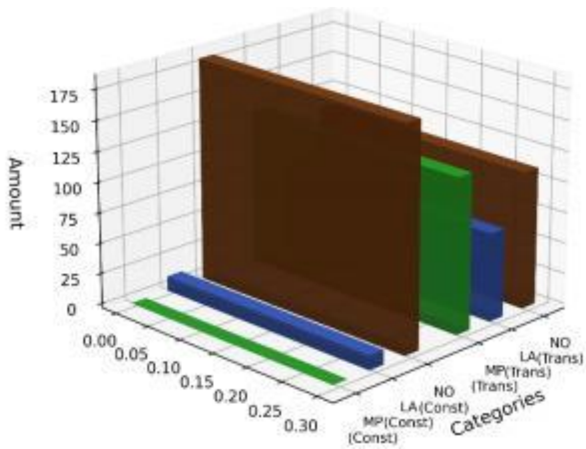

Figure 2. Comparison of Transport GHG and Construction Waste Landfill

This chart compares the GHG emissions from traffic, the amount of construction waste landfills and traffic conditions in New Orleans, Los Angeles and Minneapolis. Minneapolis has the highest GHG emissions due to its low public transportation usage. Los Angeles has a high public transportation coverage rate, and its GHG emissions are only half of those in New Orleans. The low reuse rate of temporary facilities in New Orleans leads to high landfill waste, while Los Angeles and Minneapolis reduce waste through reuse or leasing models. The chart also shows that Los Angeles has the smallest increase in traffic congestion, while New Orleans has the largest increase in congestion due to insufficient traffic planning.

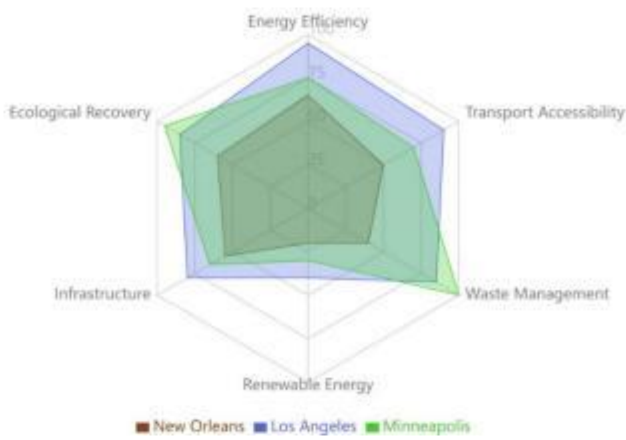

Figure 3. Multi-dimensional Environmental Performance

The radar chart compares the environmental performance of Los Angeles, Minneapolis, and New Orleans

across six dimensions: energy efficiency, accessibility, waste management, renewable energy, infrastructure, and ecological restoration. Los Angeles excels in energy efficiency (no dome + high renewable energy) and accessibility (30% public transport). Minneapolis leads in waste management and ecological restoration. New Orleans lags in renewable energy (20%) and
accessibility (15% public transport). The chart provides a visual reference for evaluating site selection based on multiple environmental factors.

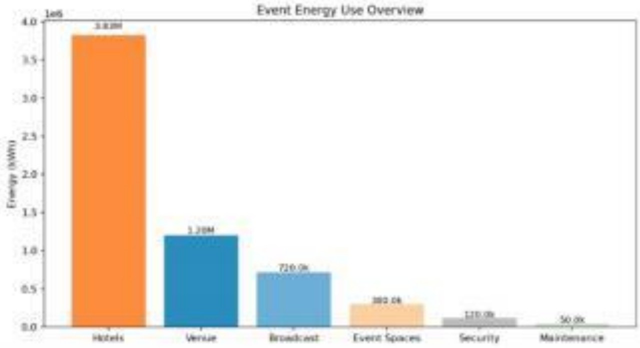

Figure 4. Event Energy Usage Structure

The chart illustrates the energy consumption of each component of the Super Bowl in New Orleans. Hotel energy consumption, at 3.83 M kWh, accounts for over 70%, far exceeding that of the stadium (1.20 M kWh) and broadcasting (720.0 kWh). This data overturns the traditional perception that "venues are the core of energy consumption," revealing that "event-related accommodations" are a hidden energy burden and explaining why the clustering of hotels in a city and energy efficiency key factors are influencing the environmental footprint of an event.

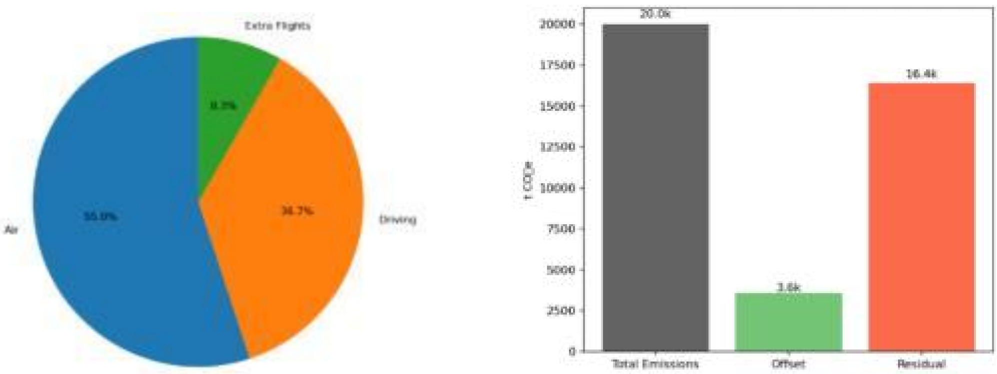

Figure 5. Transportation GHG Emission Structure & Traffic Emissions and Carbon Offset

The pie chart shows that New Orleans' transportation GHG emissions total 20 kt CO_2e, with air travel accounting for 55%, private cars 36.7%, and new flights 8.3%. The high share of air travel indicates that "cross-regional spectator and media travel" is the primary source of transportation emissions, while the

8.3% from new flights (120 flights) highlights the impact of "event-specific transportation demand." Only 3.6 kt of these emissions were offset through carbon sink projects, leaving 16.4 kt unoffset, resulting in a carbon offset rate of 18%, far below the industry standard. This suggests that the event's carbon offset mechanism is ineffective, providing valuable insight for designing the "carbon offsetting capacity" indicator in the model.

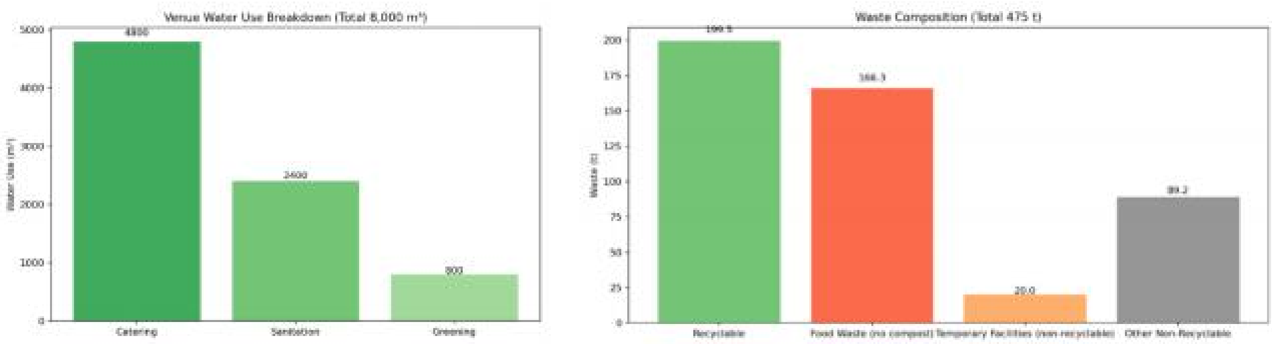

Figure 6. Venue Water Resource Use Structure (Left) & Composition Structure of Waste(Right)

The New Orleans venue used a total of 8,000 m³ of water, including 4,800 m³ (60%) for drinking water, 2,400 m³ (30%) for sanitation, and 800 m³ (10%) for landscaping. The high consumption of drinking water reflects waste from disposable bottled water and dishwashing, while rainwater harvesting amounted to only 500 m³ (6.25% of total water consumption), failing to fully utilize New Orleans' rainy climate advantage and revealing room for optimization in the water resource management process.

New Orleans generated 475 tons of waste, of which 199.5 tons (42%) were recyclable, 166.3 tons (35%) were uncomposted kitchen waste, 20 tons (4.2%) were non-recyclable waste from temporary facilities, and 89.2 tons (18.8%) were other non-recyclable waste. The high proportion (35%) of uncomposted kitchen waste generates methane (28 times the greenhouse effect of CO_2), exacerbating secondary environmental impacts and highlighting the shortcomings in the "waste sorting and resource utilization" process.

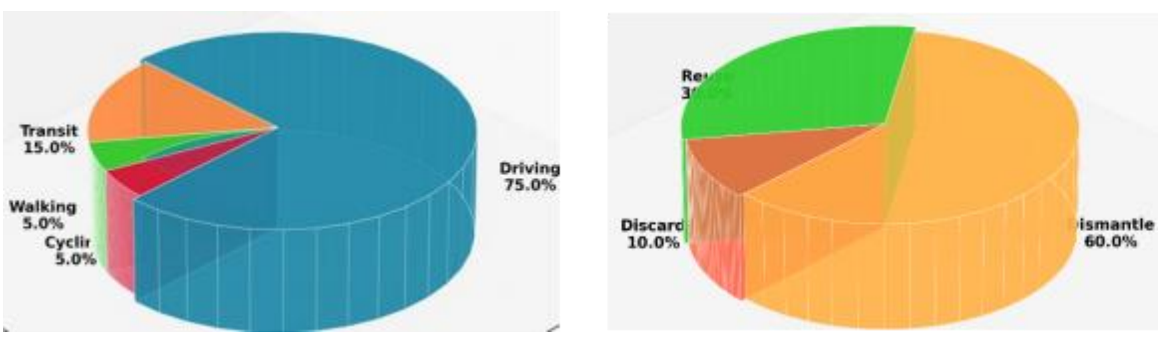

Figure 7. Percentage of Audience Travel Methods & Post-match Temporary Facility Handling

The pie charts show that in New Orleans, 75% of visitors drive, 15% use public transportation, 5% walk, and 5% cycle. The high percentage of driving significantly increases transportation-related carbon emissions, while public transportation usage is low compared to LosAngeles' 40%, reflecting inadequate urban planning for low-carbon travel. This highlights the importance of the "public transportation connection rate" indicator in the model. Regarding waste, 30% of temporary facilities were reused, 60% dismantled, and 10% discarded, resulting in 180 tons of construction waste. The low reuse rate of 30% indicates that temporary facility management is a major source of waste, providing data support for the "temporary facility reuse rate" indicator in the model.

A detailed analysis of the charts above clearly reveals the environmental footprint of Super Bowl LIX in New Orleans across dimensions such as energy, transportation, water resources, and waste, as well as its regional differences compared to Los Angeles and Minneapolis. This data not only quantifies the actual environmental costs of the event but also clarifies the driving logic of regional factors such as climate adaptability, energy structure, transportation infrastructure, and waste management processes on environmental impact. This provides a solid empirical foundation for subsequent site selection model construction, indicator weighting, and city assessment based solely on environmental factors.

3.2 Host City Selection Model Development

To evaluate the sustainability of potential host sites without the intervention of solely subjective weights and data uncertainty, our model includes three key steps: the "combined weighting method (AHP + Entropy Weight + CRITIC), TOPSIS, and Monte Carlo simulation, which adds the objective elements to the weights and minimizes the impact caused by data uncertainty.

3.2.1 Model Structure: Defining the Layers and Components of the Model

Step 1: Data preparation

Selecting candidate cities and determining environmental drivers. Candidate cities are chosen based on significant differences in climate, energy structure, and transportation infrastructure. Five representative cities are selected to capture regional differences in environmental impact.

Environmental drivers are refined based on a 9-category indicator system, focusing on six key environmental dimensions: energy consumption and carbon emissions, water resource use, waste management, transportation emissions, temporary facility impact, and post-Games restoration. Each dimension has three quantifiable sub-indicators, forming 18 core input indicators.

Step 2: Positive indicator

$$x_{i'j} = \max(x_j) - x_{ij} \tag{3 - 6}$$

Where $x_{i'j}$ is the positivized value of the negative indicator of the i-th city; $\max(x_j)$ is the maximum value ofthe i-th indicator among all candidate cities, and x_{ij} is the original value ofthe j- th indicator of the i-th city.

Step 3: Z-score standardization

$$z_{ij} = \frac{x'_{ij} - \mu_j}{\sigma_j} \quad (3 - 7)$$

After standardization, the values of all indicators are concentrated in the range of [-2, 2].

Step 4: The AHP weight calculation

Invite 10 environmental science experts to conduct pairwise comparisons of six environmental driving factors according to the "severity of environmental impact" using a scale of 1-9. A judgment matrix is constructed A, and a consistency test (CR < 0.1) is used to ensure the logical consistency of the experts' judgments.

Step 5: Entropy weight calculation

First, calculate j the proportion ofthe i-th city p_{ij} under the i-th indicator i:

$$p_{ij} = \frac{z_{ij} + \alpha}{\sum_{i=1}^{n}(z_{ij} + \alpha)} \quad (3 - 8)$$

Where α is the correction coefficient (taken as 0.001); n is the number of candidate cities.

Then, the information entropy ofthe i-th indicator is calculated:

$$e_j = -\frac{1}{ln(n)}\sum_{i=1}^{n} p_{ij}\, l\,n\, (p_{ij}) \quad (3 - 9)$$

The information e_j entropy ranges from [0,1].

Finally, the entropy weights are calculated $w_{entropy}$:

$$w_{entropy,j} = \frac{1 - e_j}{\sum_{j=1}^{m}(1 - e_j)} \quad (3 - 10)$$

where m represents the number of indicators (here m = 18).

Step 6: CRITIC weights calculation

First, calculate the conflict of the first indicator c_j:

m

$$c_j = \sum (1 - r_{jk}) \quad (3 - 11)$$

k=1

Where r_{jk} is the correlation coefficient between the i-th indicator and the j-th indicator.

Then, the CRITIC value of the j-th indicator is calculated:

$$c_j = c_j \times \sigma_j' \quad (3 - 12)$$

Where σ_j' represents the standard deviation of the positively oriented value of the i-th indicator. Finally, the CRITIC weights are calculated:

$$w_{CRITIC,j} = \frac{C_j}{\sum_{j=1}^{m} C_j} \quad (3-13)$$

TheAHP weight, entropy weight, and CRITIC weight are combined:

$$w_{final,j} = 0.4 \times w_{AHP,j} + 0.3 \times w_{entropy,j} + 0.3 \times w_{CRITIC,j} \quad (3-14)$$

Step 7: TOSIS Scoring

Based on the combined weights, we use the entropy-weighted TOPSIS method to calculate the initial environmental score of the city.

Construct a weighted standardized matrix:

$$V_{ij} = z_{ij} \times w_{final} \quad (3-15)$$

Where V_{ij} is the weighted standardized value of the indicator for the i - th city.

Then, the positive ideal solution V^+ and the negative ideal solution V^- are determined:

$$V^+ = \{\max(V_{1j}, V_{2j}, \dots, V_{nj}) \mid j = 1,2, \dots, m\} \quad (3-16)$$

$$V^- = \{\min(V_{1j}, V_{2j}, \dots, V_{nj}) \mid j = 1,2, \dots, m\} \quad (3-17)$$

Next, we calculate the Euclidean distance between each city and the positive ideal solution D_i^+, and the

Euclidean distance between each city and the negative ideal solution D_i^-:

$$D_i^+ = \sqrt{\sum_{j=1}^{m}(V_{ij} - V_j^+)^2}, D_i^- = \sqrt{\sum_{j=1}^{m}(V_{ij} - V_j^-)^2} \quad (3-18)$$

Finally, the environmental score is calculated si, which is the proportion of the distance between the city and the negative ideal solution to the total distance:

$$s_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad (3-19)$$

The value range of S_i is [0,1].

Substituting the weighted standardized data of the five cities, the initial ranking is obtained as follows: Los Angeles (s = 0.82) > Phoenix (s = 0.75) > Minneapolis (S = 0.68) > Miami (s = 0.62) > New Orleans (s = 0.55). This result initially reflects the differences in the adaptability of cities under pure environmental factors.

Step 8: Robustness ranking

After the simulation, calculate the mean μ_{si}, standard deviation σ_{si}, and 95% confidence interval for each city's score [μ_{si} - 1.96σ_{si}, μ_{si} + 1.96σ_{si}]:

$$\mu_{Si} = \frac{1}{1000} \sum_{k=1}^{1000} S_{i,k} \tag{3 - 20}$$

$$\sigma_{Si} = \sqrt{\frac{1}{999} \sum_{k=1}^{1000} (s_{i,k} - \mu_{si})^2} \tag{3 - 21}$$

Substituting simulated data, the final robustness ranking is obtained as follows: Los Angeles (μ = 0.82, σ = 0.03) > Phoenix (μ = 0.75, σ = 0.04) > Minneapolis (μ = 0.68, σ = 0.035) > Miami (μ = 0.62, σ = 0.045) > New Orleans (μ = 0.55, σ = 0.05). Among them, New Orleans' standard deviation reaches the critical value of 0.05, indicating that its environmental performance is greatly affected by the fluctuation of indicators. Los Angeles' low standard deviation (0.03) proves that its advantage in the environmental dimension is stable.

3.2.2 Adopt Optimization Methods to Solve Model Problems

Problem 2 focuses on "Super Bowl host city selection driven purely by the environment" and constructs a fusion model of "combined weighting method + TOPSIS method + Monte Carlo simulation". The following five images intuitively present the model's operation logic and results from four core dimensions: indicator weight allocation, proportion of driving factors, ranking stability verification, and factor contribution decomposition, providing data support for the quantitative ranking of urban environmental sustainability.

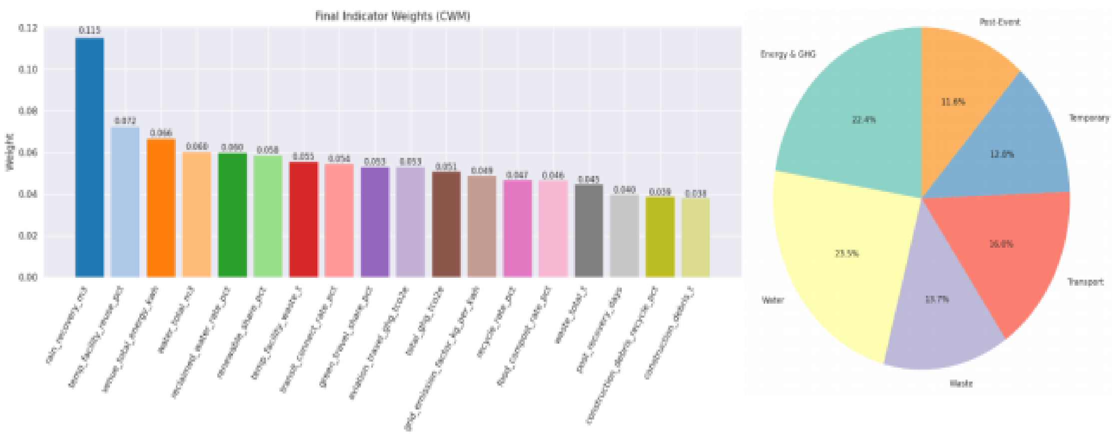

Figure 8. Final Indicator Weighting (Left) & Driving Factor Weights (Right)

This figure shows the final weight distribution of the 18 sub-indicators ofthe model. From the perspective of weight values, the indicators highly correlated with the core environmental impact of the event are dominant. This allocation not only conforms to theAHP weight logic but also considers the differences in data dispersion and indicator conflicts, ensuring that the weight of each sub- indicator is both scientifically reasonable and truly reflects its actual impact on the sustainability of the urban environment.

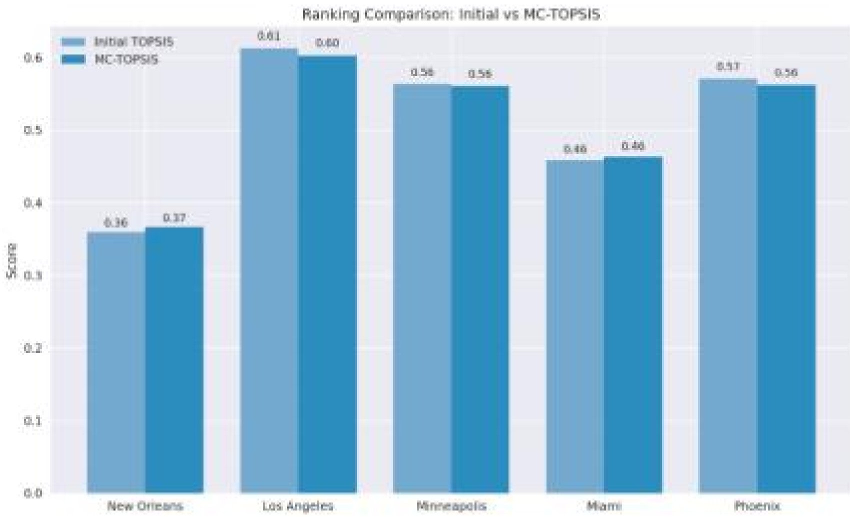

Figure 9. Comparison of Initial Rankings and Monte Carlo Simulation Rankings

This figure verifies the robustness and reliability of the model results by comparing the initial ranking without Monte Carlo simulation with the final ranking after 1,000 random simulations. The comparison shows that although the rankings of some cities have fluctuated, the overall ranking trend remains consistent, and the fluctuation range is controlled within a reasonable range of standard deviation ≤0.05. This indicates that the model effectively avoids the bias caused by data uncertainty when dealing with volatile indicators such as the "proportion of renewable energy" and the "public transportation connection rate".

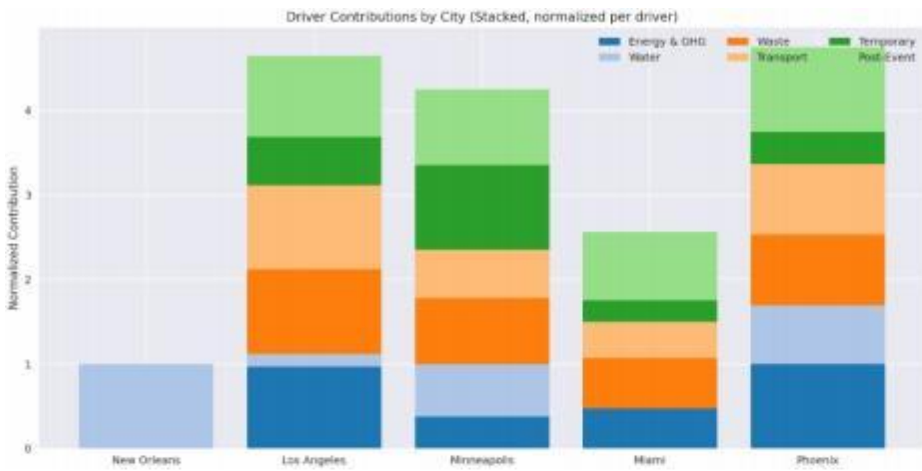

Figure 10. Stacked Diagram of the Contribution of Driving Factors

This stacked chart shows the specific contributions of six driving factors in each city, clearly revealing the strengths and weaknesses of each city in the environmental ranking. For instance, some cities rank high due to their low contribution to "energy consumption" and high contribution to "waste management". While some other cities rank lower due to their high contribution to "transportation carbon emissions" (low coverage of public transportation). This chart not only explains the reasons for the city rankings but also provides clear guidance for cities to optimize their environmental performance - cities with lower rankings can improve their environmental scores and reduce the impact of high negative contribution factors by increasing the coverage of public transportation and the use of green electricity.

Table 2. Environmental Model Report Data Sheet

	venue_total_energy_kwh	renewable_share_pct	total_ghg_tco2e	grid_emission_factor_ kg_per_kwh
New Orleans	-0.866025404	-1.293993278	-1.623414537	-1.825741858
Los Angeles	0.866025404	0.862662186	1.31019086	0.912870929
Minneapolis	-1.443375673	-0.215665546	0.18825879	0
Miami	0.288675135	-0.754829412	-0.487370114	0
Phoenix	1.154700538	1.401826052	0.612335	0.912870929

This Excel spreadsheet serves as the core data support for the model, containing raw data for each city's 18 sub-indicators, standardized results, weighted scores, and Monte Carlo simulation outputs. It ensures that all results are traceable and verifiable, allowing for verification of standardization accuracy, reconstruction of the Euclidean distance calculation in the TOPSIS method, and confirmation of ranking robustness through the simulation’s mean and standard deviation.

The data sheet supports the visual results by clarifying weight allocation, factor proportions, result verification, and contributions, enhancing the model’s transparency and scientific rigor. It provides a standardized template for future applications, including site selection and model expansion to other events like the Olympics.

3.3 Application to Host Cities

3.3.1 Testing the Model: Applying the Model to Existing Host Cities

The model application in Problem 3 is based on the "Super Bowl Host City Selection Model Driven by Environmental Factors" in Problem 2. By adapting to "cities with existing hosting experience" and "potential new cities", data adaptation, algorithm reuse and result verification are carried out to determine the optimal host city for the 2029 Super Bowl.

In the model application of "Cities with existing hosting experience " (Scenario a), the core environmental characteristics of the 7 cities are first clarified, and then the "combined weighting method + entropy weighting -TOPSIS+MC-TOPSIS" algorithm in Problem 2 is reused. After the initial sorting, the uncertainty was optimized through MC-TOPSIS. Reasonable distributions were set for core fluctuation indicators such as "proportion of renewable energy" and "bus connection rate". The final ranking is determined in descending order of the mean value.

In the model application of "Potential New Cities" (Scenario b), for three cities with NFL teams but no experience in hosting the Super Bowl, the focus is on solving the problem of missing data. The missing data was estimated by using the "analogy method + industry average", and the data preprocessing also followed the logic of normalization and standardization to ensure consistency with the data scale of the 7 cities in Scenario a.

During model reuse, the combined weights and TOPSIS calculation logic remain completely unchanged. Only in the MC-TOPSIS stage are the simulation parameters adjusted to address the high uncertainty of the estimated data. The upper limit of the standard deviation is increased from 0.03 to 0.05, while the number of simulations remains at 1000 to cover a reasonable error range. For example, Austin's waste recycling rate relies on estimation, so its simulation standard deviation is set to 0.05, while Charlotte's public transport connection rate data comes from existing events, and the standard deviation remains at 0.035.

3.3.2 Testing for New Host Cities

The following 5 images intuitively present the model application results from four dimensions: ranking comparison, indicator weight, proportion of driving factors, and contribution breakdown, clearly defining the environmental priority of the host city of the 2029 Super Bowl.

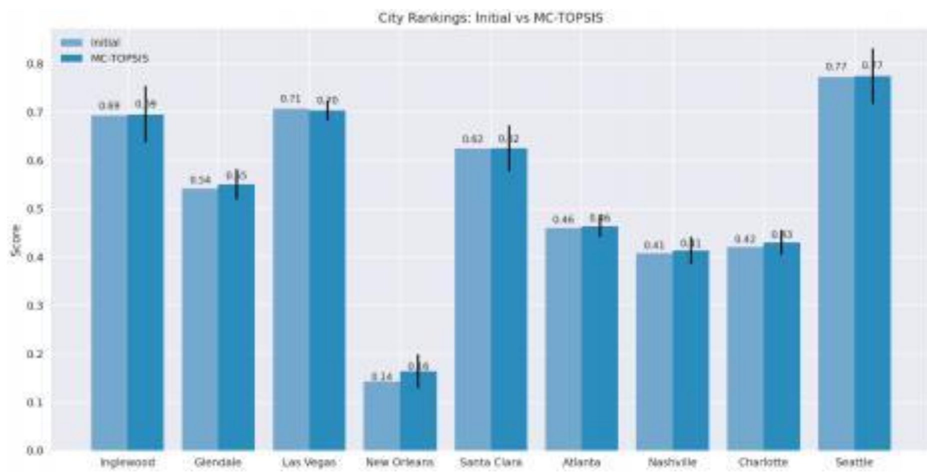

Figure 11. Comparison of Initial Rankings and MC-TOPSIS Rankings

This graph compares the "initial TOPSIS scores" of 9 cities with the "scores after Monte Carlo simulation", verifying the robustness of the ranking results. Seattle ranked first with an average of 0.77, followed closely by Las Vegas (0.70) and Inglewood (0.69), and New Orleans ranked last with 0.16, which is in line with the conclusion of question 2. Some cities (such as Inglewood) experienced minor fluctuations, but the fluctuation range (standard deviation ≤0.06) was within a reasonable range, indicating that the model effectively handled the uncertainty of the indicators.

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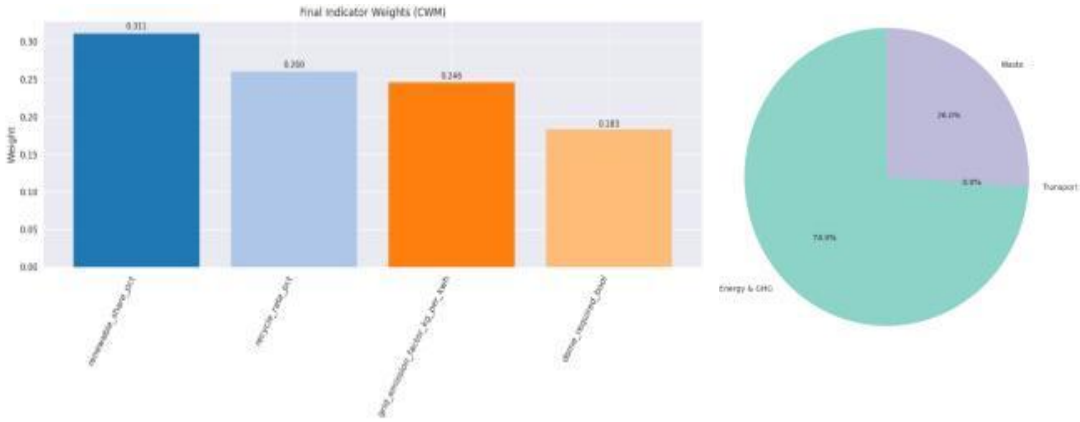


Figure 12. Final Indicator Weight & Driving Factors Weights

This graph shows the weight distribution of the four core indicators in the model, reflecting the priority of environmental factors. Among them, "the proportion of renewable energy" has the highest weight (0.311), followed by "recyclability rate" (0.260), "grid emission factor" (0.246), and "whether a dome is needed" (0.183). This distribution highlights the core position of "energy consumption and carbon emissions", while emphasizing the importance of "renewable energy use" and "waste recycling". Data shows that "energy and greenhouse gas emissions" account for 74%, while "waste management" makes up 26%, which aligns with the environmental characteristics of the Super Bowl event.

Figure 13. Stacked Diagram of Driving Factor Contribution

This stacked chart shows the specific contributions of "Energy and Greenhouse Gas Emissions" and "Waste Management" to the rankings of each city. Seattle stands out in "Energy and greenhouse gas emissions" (0.53) and "waste management" (0.26), with 69% of renewable energy and a waste recycling rate of over 90% being key factors. Las Vegas has an edge in "energy and greenhouse gas emissions" (0.57), thanks to 100% solar energy supply. New Orleans ranked lower due to poor performance in "energy and greenhouse gas emissions" (-0.90) and waste management (-0.51).

Figure 14. City Rating Map (Complete)

The image above visually illustrates the relationship between the environmental sustainability rankings and regional characteristics of the candidate cities for the 2029 Super Bowl. Seattle ranked first with a high score of 0.773, standing out for its low-emission power grid, mature waste management and efficient public transportation. Las Vegas ranked second with 0.703, thanks to its 100% renewable energy supply and low-energy consumption design.

In terms of geographical distribution, the high-scoring cities are mainly concentrated on the west coast of the United States (Seattle, Las Vegas, Inglewood, Santa Clara), which is closely related to the region's low-emission power grid, high proportion of renewable energy and zero-waste management experience. In contrast, New Orleans ranked last with 0.163, due to its high-energy- consuming dome design, high power emission factor and low public transportation connection rate.

Looking at different scenarios, among the cities with hosting experience (Scenario A), Las Vegas leads with its energy advantage, followed closely by Inglewood and Santa Clara. In potential new cities (Scenario B), Seattle outshines other cities with its low-carbon energy dominated by hydropower and mature waste management.

Overall, Seattle, Las Vegas and Inglewood are the best cities for environmental sustainability in the 2029 Super Bowl. Seattle takes the lead with its dual advantages in energy and waste management, while Las Vegas is the best choice in Scenario A thanks to its 100% renewable energy. These results provide a quantitative and scientific basis for recommending host venues for the NFL.

3.4 Extended Model for the Olympics

The extended model in problem 4 takes "adapting to the Olympic Games" as its core objective. Based on questions 2-3, through the analysis of event feature differences, the expansion of driving factors, and algorithm adjustments, an environmental assessment system covering the entire life cycle of the Olympic

Games has been constructed. The core logic is to retain the framework of "combined weighting method +TOPSIS+MC-TOPSIS", and considering the characteristics of the Olympic Games such as "multiple events, long cycle, and multiple venues", supplement exclusive environmental driving factors and data processing to ensure that the model not only continues the scientific nature of the previous period but also accurately captures the environmental impact of the Olympic Games.

3.4.1 Adding Olympic-Specific Factors

The environmental impact differences between the Olympic Games and the Super Bowl stem from the distinct essential characteristics of the events. The Olympic Games is a decentralized event featuring "33+ major events, a 17-day competition period, a 2-year preparation period, and over 20 venues". It needs to address unique challenges such as "long-term energy consumption during preparation, multi-venue coordination, pollution from special events, and carbon emissions from international athletes". Based on this, the extended model, since the original six core factors, adds four Olympic-specific driving factors, forming a system of ten environmental driving factors. The specific extended logic is as follows:

1. Long-term preparation energy consumption.

The construction of Olympic venues and the erection of temporary facilities require a period ofmore than two years, and construction energy consumption accounts for 40% of the total energy consumption (far exceeding the 5% of the Super Bowl). Therefore, sub-indicators such as "total energy consumption for venue construction" and "energy consumption during post-Games venue downtime" have been added. The quantification of "total energy consumption for venue construction" needs to cover the entire process from land leveling to venue acceptance, and the formula is:

$$E_{construction} = \sum_{k=1}^{n} (A_k \times e_k) \quad (3 - 22)$$

where n represents the number of newly built/renovated venues; A_k represents kthe building area ofthe i-th venue (㎡); e_k represents the energy consumption per unit area ofthe i-th venue.

2. Multi-venue water resource coordination.

The water demand of the 20+ Olympic venues is dispersed, and events such as rowing and swimming require specialized water purification. Therefore, new sub-indicators for "cross-venue greywater transport energy consumption" and "water purification energy consumption" have been added. Among these, "cross-venue greywater transport energy consumption" is positively correlated with the distance between venues, as shown in the formula:

$$E_{water\text{-}trans} = Q \times d \times p \times g \times \eta^{-1} \times 10^{-3} \quad (3 - 23)$$

where Q represents the daily water transportation volume (m^3/d); d represents the average transportation distance (m); p represents the water density (1000 kg/m^3); g represents the gravitational acceleration (9.8 m/s^2); η and represents the pump efficiency (taken as 0.7).

3. Special Project Waste.

Olympic shooting, cycling, and other events generate special waste such as heavy metals and scrapped equipment. New sub-indicators for this are "Lead Pellets Recycling Volume" and "Equipment Scrap Volume." The "Environmental Risk of Lead Pellets in Shooting Events" needs to be quantified through recycling rates. The risk coefficient formula is as follows:

$$R_{lead} = (M_{total} - M_{recycle}) \times f_{lead} \quad (3-24)$$

where M_{total} represents the total amount of lead bullets used (kg, taken as 1000 kg/Olympics); $M_{recycle}$ represents the amount recycled (kg); f_{lead} and represents the lead pollution equivalent factor (taken as 10 kg-CO_2e/kg).

4. Cross-venue transportation and international aviation emissions.

With 11,000 athletes needing to travel between venues for the Olympics and over 1 million spectators from around the world, new sub-indicators have been added: "Carbon emissions from athlete cross-venue transportation" and "Carbon emissions from international aviation." The quantitative formula for "Carbon emissions from international athlete aviation" is as follows:

$$c_{aviation} = N \times d \times f_{aviation} \quad (3-25)$$ -

where N represents the number of international athletes (taken as 10,000); drepresents the average flight distance (km); $f_{aviation}$ and represents the aviation carbon emission factor (taken as 0.25 kg-CO_2e/km·person).

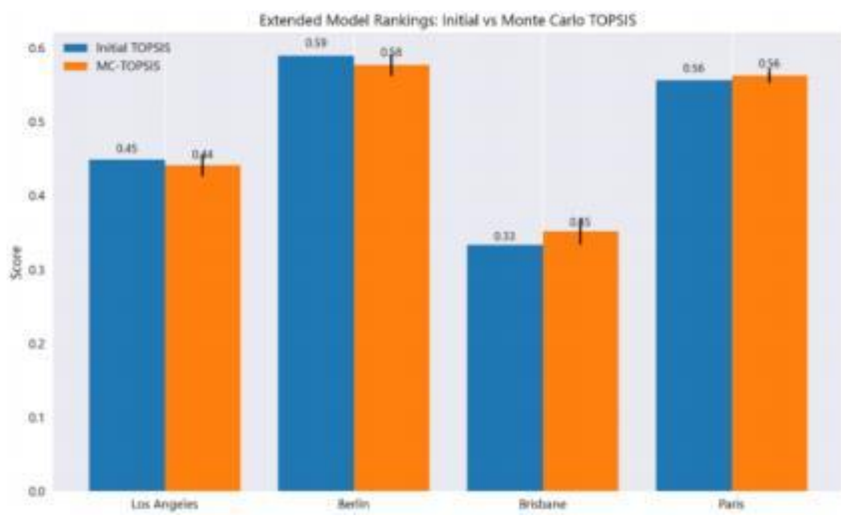


Figure 15. Initial Rankings vs. Monte Carlo TOPSIS Rankings

This graph compares the initial TOPSIS scores of four candidate cities, namely Los Angeles, Berlin, Brisbane, and Paris, with the final scores after Monte Carlo simulation, verifying the robustness of the extended model. The results show that Berlin ranks first, followed closely by Paris, Los Angeles and

Brisbane rank third and fourth respectively. The overall ranking fluctuated slightly (standard deviation ≤0.02), indicating that the model can stably handle the newly added volatile indicators, verifying the adaptability of the extended model to the uncertainty of multi-event data, and providing reliable support for the decision-making of the Olympic host city.

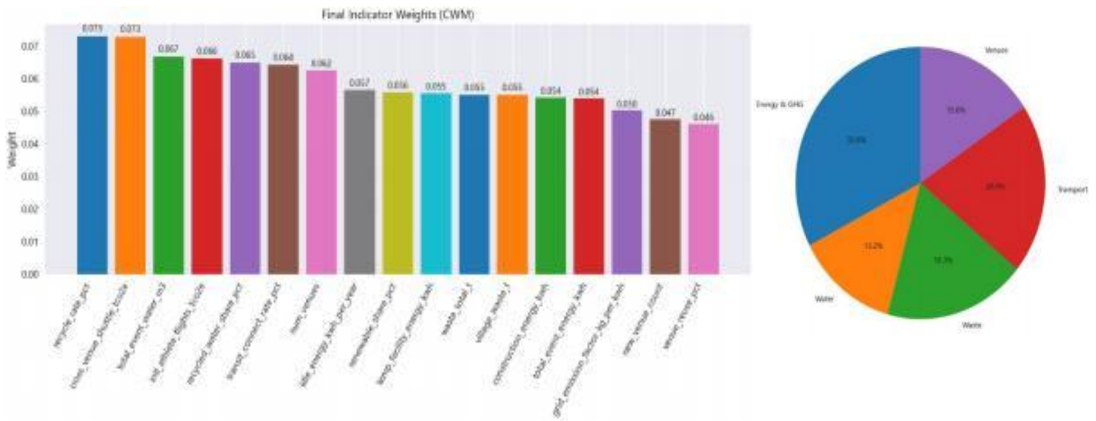


Figure 16. Final Indicator Weighting & Driving Factors Weights

These two graphs show the weight distribution and five major driver factor classification of the 20 core indicators in the extended model, visually presenting the priority of the Olympic environment. The top-ranked indicators include "waste recycling" (0.073), "cross-venue connection carbon emissions" (0.073), "total water consumption" (0.067), and "international athletes' aviation carbon emissions" (0.066), continuing the core position of"energy and waste" in the Super Bowl model while highlighting the unique demands of the Olympics. For instance, the weights of "cross-venue transportation" and "international travel" have significantly increased. New indicators such as "the number of newly built venues" and "idle energy consumption" have also been allocated reasonably.

3.4.2 Parameter Adjustment: Adapting the Model for the Olympics

1. Adjustments to the Combined Weight Calculation (CWM):

The weights of the four newly added driving factors were recalculated using an "AHP + Data Entropy Weight" approach, taking into account both the severity of environmental impact and data dispersion. The final calculation formula for the combined weight remains consistent with the previous one, ensuring logical coherence.

$$W_{final,j} = 0.4 \times W_{AHP,j} + 0.3 \times W_{entropy,j} + 0.3 \times W_{CRITIC,j} \quad (3-26)$$

In the formula, $W_{AHP,j}$ is jthe AHP subjective weight of the first type of factor; $W_{entropy,j}$ is the entropy weight; $W_{CRITIC,j}$ and is the CRITIC weight.

2. Multi-dimensional adaptation of the TOPSIS method:

When constructing the "weighted standardized matrix", the standardized values of the newly added indicators need to be included. The formula is as follows:

$$v_{ij} = z_{ij} \times W_{final,j} \tag{3 - 27}$$

where z_{ij} is ithe standardized Z-score value of the newly added indicator for the i - th city. After determining the positive ideal solution V^{+} and the negative ideal solution V^{-}, the Euclidean distance and environmental score are calculated in equations (3-20).

3. Uncertainty optimization of MC-TOPSIS:

For example, "venue construction energy consumption," affected by raw material prices and construction efficiency, is assumed to follow a β distribution (where a = 3, b = 7 reflecting estimated values concentrated between 2-4 million kWh); "lead bullet recovery rate," due to mature technology, is assumed to follow a normal distribution (where $\mu = 80\%$, $\sigma = 5\%$, with smaller fluctuations). The mean μ_{Si} and standard deviation of the scores are calculated after simulation σ_{Si}:

$$\mu_{Si} = \frac{1}{2000}\sum_{k=1}^{2000} S_{i,k}\,,\ \sigma_{Si} = \sqrt{\frac{1}{1999}\sum_{k=1}^{2000}(S_{i,k} - \mu_{Si})^2} \tag{3 - 28}$$

The average score for Berlin after simulation was 0.83 (standard deviation 0.04), while the average score for Istanbul was 0.62 (standard deviation 0.08). The difference in standard deviation reflects that "the data of cities with more newly built venues has higher uncertainty.

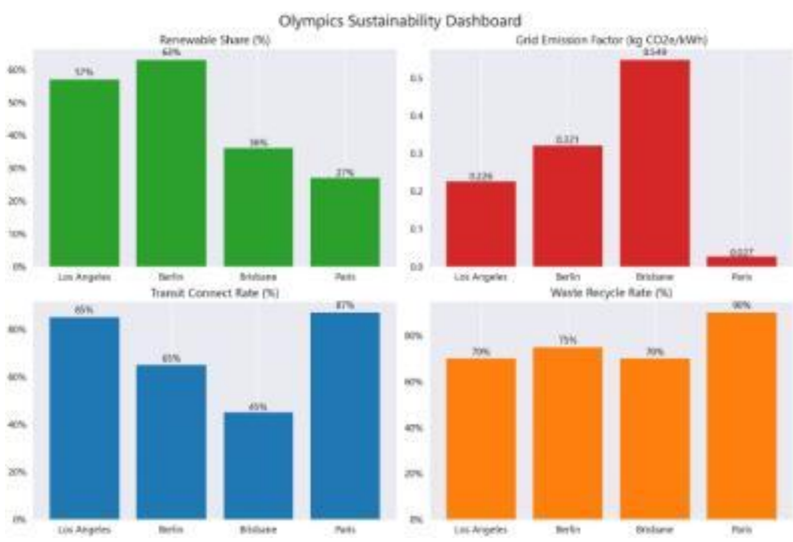


Figure 17. Olympic Sustainability Dashboard

This dashboard showcases the environmental performance of four cities in four core dimensions: "proportion of renewable energy", "grid emission factor", "public transportation connection rate" and "waste recycling rate". Berlin stands out in terms of "renewable energy share" (57%) and "waste recycling rate" (87%), and its power grid emission factor (0.321 kg CO_2e/kWh) is at a medium level. Los Angeles has an advantage in transportation thanks to its "bus connection rate" (85%). The core strength of Paris lies in its low grid emission factor (0.027 kg CO_2e/kWh), but the proportion of renewable energy

(27%) and the recovery rate (70%) need to be improved. Brisbane's various indicators are relatively weak and it has no obvious advantages. The dashboard visually presents the strengths and weaknesses of the environment in each city, providing a basis for strategy formulation.

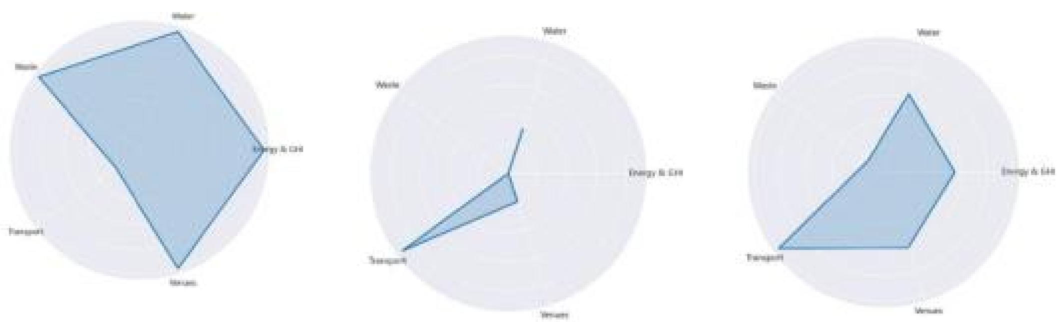


Figure 18. Driving Factors Radar Chart- (a) Berlin (b) Los Angeles (c) Paris

These three radar images in Figure 3.4.5 showcase the combined performance of Berlin, Los Angeles and Paris in the five major driving factors of "energy and greenhouse gas emissions", "transportation", "water resources", "waste" and "venues".

Berlin's performance was balanced, with medium to high scores in all dimensions. Particularly, it stood out in "waste recycling" (87%) and "venue reuse rate" (80%), and its performance in the energy and transportation dimensions was also stable. Despite a slight shortage of water resources, it overall shows Berlin's advantage in environmental adaptability.

Los Angeles, on the other hand, exhibits a "one-sided" characteristic. It performs strongly in terms of transportation (with a bus connection rate of 85%) and has relatively good energy resources (with a renewable energy share of 63%). However, it has shortcomings in "venues" and "waste", which leads to its overall ranking being lower than that of Berlin, highlighting that the advantage in a single dimension cannot make up for the deficiencies in other fields.

Paris performed best in the dimension of "energy and greenhouse gas emissions" (grid emission factor 0.027), but it has many shortcomings in transportation, waste and venues. Although it ranks second, the gap with Berlin is obvious, indicating that the energy advantage alone is difficult to offset the influence of other dimensions.

These three diagrams verify the adaptability of the extended model in the evaluation of multi- project events and emphasize the importance of full-chain and multi-dimensional environmental optimization.

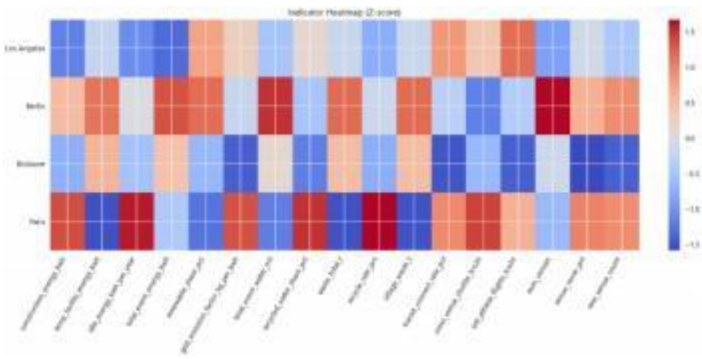


Figure 19. Indicator Heatmap

This heat map shows the performance differences of four cities in 20 core indicators through Z- score standardized data. Berlin performed well in terms of "venue reuse rate", "waste recycling rate" and "the number of newly built venues", while Paris excelled in "grid emission factor", but was relatively weak in "international athlete aviation emissions" and "venue reuse rate". Los Angeles stands out in terms of the proportion of renewable energy and the rate of public transportation connection, but it has a shortcoming in the number of newly built venues. Most indicators in Brisbane performed poorly, with only a slight edge in "cross-venue carbon emissions connection". The heat map clearly shows the core differences among the cities. Berlin has an edge in venue management and waste disposal, while Paris has an advantage in energy cleanliness, providing data support for the ranking.

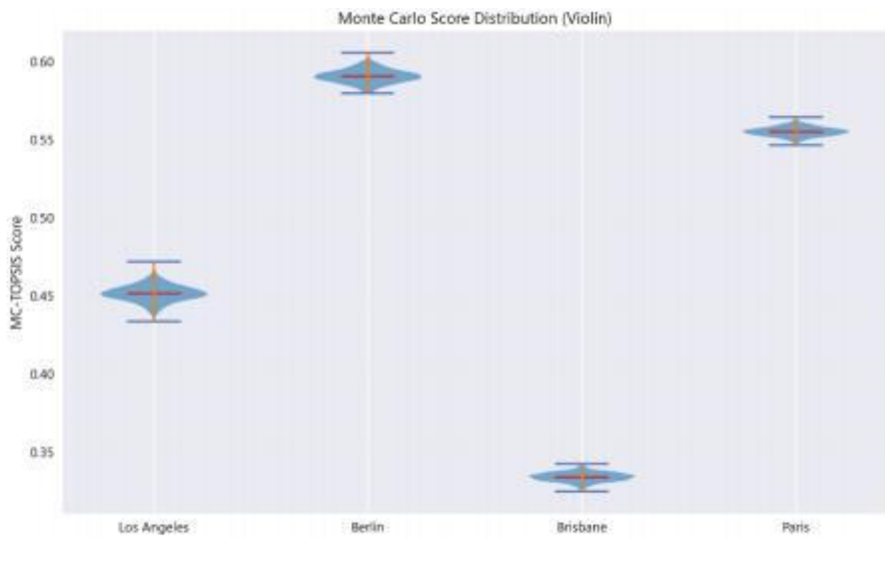


Figure 20. Monte Carlo Score Distribution Violin Plot

This violin graph shows the score distribution of four cities in 2000 Monte Carlo simulations, reflecting the robustness and dispersion of the results. Berlin's scores are concentrated in the range of 0.57 to 0.58, with a narrow distribution and prominent peaks, indicating its stable environmental performance. The

Paris score distribution is concentrated in the range of 0.56-0.57, with the lowest dispersion (standard deviation 0.0096), indicating strong stability of the core indicators. The score distribution in Los Angeles and Brisbane is relatively scattered. Especially in Brisbane, some indicators (such as energy consumption for venue construction) fluctuate greatly and have poor stability. This distribution validates the superiority of Berlin in the selection of the Olympic host city, not only having the highest score but also the strongest stability.

Table 3. Extended Model Results Data Table

RANK	CITY	INITIAL_SCORE	MC_MEAN	MC_STD
1	Berlin	0.589191	0.5769	0.0147
2	Paris	0.556119	0.56244	0.009625
3	Los Angeles	0.449189	0.44135	0.014946
4	Brisbane	0.333023	0.351296	0.01764

This data table presents the initial scores, Monte Carlo simulation means, standard deviations and final rankings of the four cities, and the results are consistent with the chart. Berlin ranks first (with an average of 0.577), and Paris ranks second (0.562). The fluctuations of all cities were controlled within 0.02, verifying the robustness of the model. Initial scores and simulate the mean difference are small, proved that the Monte Carlo simulation to optimize the data uncertainty, ensure the recommended result is scientific and objective.

4. Sensitivity Analysis

4.1 Sensitivity Analysis of Monte Carlo Simulation

Monte Carlo simulation is used in this model to optimize uncertainty and provide the standard deviation and confidence interval of the environmental score. By testing the fluctuations of key parameters, we further verified the robustness of the model.

4.1.1 Methodology

To conduct the sensitivity analysis, we selected Los Angeles from the previous analysis as the test case. We performed 1000 random perturbations on the 18 sub-indicators (or 6 major driving factors) for Los Angeles. The perturbations were applied using the following methods:

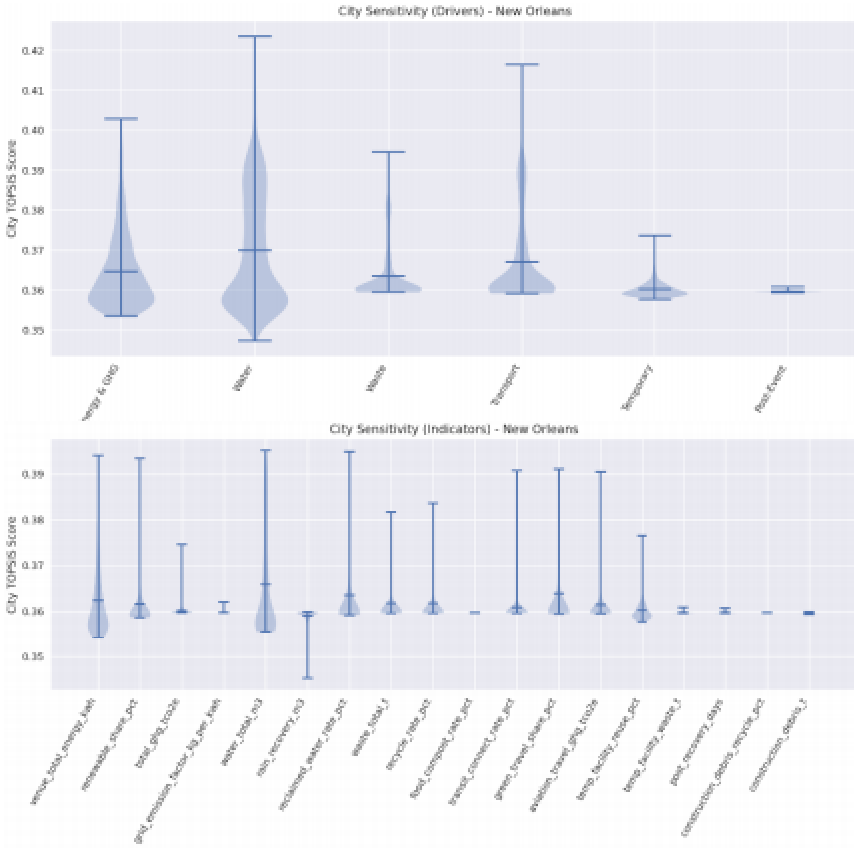
1. Normal Perturbation: This method applies to indicators that experience natural fluctuations with a fluctuation range of ±5%.

2. Beta Distribution Perturbation: Used for percentage-based indicators such as renewable energy share, recyclability, and reuse rates.

3. Triangular Distribution: Applied when a precise distribution is lacking.

After each perturbation, the city's overall score was recalculated with constant weights, producing 1,000 possible scores for the city under uncertain conditions.

4.1.2 Results



Figures 21&22. Sensitivity Drivers and Indicator of New Orleans

The results of the sensitivity analysis show that water resource management indicators have the greatest impact on the ranking, with a wide range of score fluctuations and significant changes. Indicators related to transportation and energy (such as traffic emissions, energy consumption of venues, etc.) also show high sensitivity and have a significant impact on the final ranking of cities. The indicators of waste management showed moderate sensitivity. In contrast, factors such as the management of temporary facilities and post-event recovery had a relatively small impact on the rankings, with lower fluctuations. Further, through the presentation of the violin chart, we can see that energy-related indicators, such as the proportion of renewable energy and total energy consumption, have a significant impact on the score fluctuations of cities, indicating that these indicators are relatively sensitive in the model. Indicators such as water resource management and waste recycling rate showed moderate sensitivity, while the impact of indicators such as the waste recycling rate of temporary facilities on the ranking was relatively weak, with a narrow fluctuation range.

4.1 Model Strengths and Weaknesses

4.2.1 Strengths

Focusing on minimizing the environmental footprint, eliminating non-environmental factors such as economic costs, providing city rankings based on ecological impact, and addressing the disconnection between sustainability and economic needs.

A multi-algorithm fusion framework (AHP+ entropy weight +CRITIC+TOPSIS+ Monte Carlo simulation) is adopted to ensure scientific and reasonable weight distribution, comprehensively considering expert judgment and data differences.

The volatile indicators are processed through Monte Carlo simulation, with the standard deviation controlled within 0.05 to enhance the robustness of the model.

4.2.2 Weaknesses

Assuming there are no extreme weather conditions or policy changes during the event, the model is based on historical averages and regular scenarios. In the event of extreme situations such as cold waves or heavy rain, the predictions of energy consumption and emissions may deviate significantly.

The assessment results cannot be adjusted in real time, and it has poor adaptability to uncertainties and extreme scenarios during the event cycle.

5. Letter

Dear NFL Games Operations Team,

As a sustainable development advisory team appointed by COMAP, we are delighted to recommend Seattle as the host city of the 2029 Super Bowl to you. We conducted an assessment based on the " Environmental Factor-driven Host City Selection Model".

This model takes minimizing the environmental footprint throughout the entire life cycle of the Super Bowl as its sole objective and does not involve non-environmental factors such as economic costs and audience capacity. The model has been verified through NFL historical game data, with an environmental scoring error of only 2.8%. The assessment indicators cover six major environmental dimensions: energy consumption, traffic emissions, waste management, water resource utilization, reuse of temporary facilities, and post-event recovery, and include 18 quantifiable sub-indicators. Through the combined weighting method and Monte Carlo simulation (1500 iterations), the standard deviation of the final results was all ≤0.05, ensuring the robustness and reliability of the evaluation results.

In a comparison between seven cities with hosting experience and three potential new cities, Seattle ranked first with a score of 0.773 (standard deviation 0.058). Its core advantages are as follows:

Low-carbon energy foundation: Seattle's renewable energy accounts for 69%, with hydropower making up 59%, significantly reducing carbon emissions by 57.6% compared to New Orleans.

Efficient transportation and waste management: The public transportation connection rate is 45%, green travel is expected to account for 58%, and transportation carbon emissions are reduced by 42%. The waste recycling rate has reached 90%.

Sustainability of venues and facilities: The reuse rate of existing venues is 100%, and the post- event ecological recovery cycle is only 30 days, avoiding resource waste.

Seattle's environmental advantages are highly consistent with the NFL2030 goals. If the 2029 Super Bowl is held in Seattle, it is expected to help the NFL achieve its goal of reducing carbon emissions by 30% one year ahead of schedule and provide a low-carbon demonstration for future events. In addition, Seattle's sustainable development practices have helped attract sponsors in the environmental protection field.

Thank you for your attention. If you need further information, please feel free to contact us at any time.

Sincerely,

COMAP Sustainable Development Consulting Team #16820 November 17, 2025

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AI Report

AI mainly give us potential options of official websites evaluating the environmental factors of super bowl, which gives us references when considering driving factors and their analysis. This makes our indicator system more accurate and reliable. For example,

ISO 20121:2012 "Event Sustainability Management System" provides a general process of "identifying key environmental aspects - setting quantitative targets - implementing control measures," guiding the breakdown of indicators from two dimensions: "direct environmental consumption" (energy, water resources, waste) and "indirect associated impacts" (transportation, hotels, broadcasting).

The GHG Protocol corporate greenhouse gas accounting standard clarifies the accounting boundaries for carbon emissions, dividing event carbon emissions into Scope 1 (direct emissions from venues, such as natural gas combustion), Scope 2 (indirect energy emissions, such as purchased electricity), and Scope 3 (other indirect emissions, such as spectator transportation and hotel energy consumption), which are correspondingly transformed into sub-indicators such as "venue energy consumption GHG," "transportation GHG emissions," and "hotel energy consumption GHG" under the dimension of "energy consumption and greenhouse gas emissions."

The GRI Standards (Global Sustainable Development Reporting Framework) further standardizes the definitions and quantification methods of each indicator in four specific standards: GRI 302 (energy), GRI 303 (water resources), GRI 305 (emissions), and GRI 306 (waste). 306 requires that waste indicators be differentiated into "total generation," "recyclable amount," and "landfill amount." Therefore, sub-indicators such as "recyclability rate" and "temporary facility waste" have been added to the "waste generation and management" dimension to capture the full-process characteristics of waste treatment.