Optimizing Host City Selection for Mega-Sporting Events: An Environmental Sustainability Perspective

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***Abstract*—Evaluating potential host cities for major sporting events increasingly requires rigorous consideration of environmental responsibility due to global environmental degradation. Existing site selection models often rely on limited qualitative indicators, focusing heavily on economic development and logistics, which fail to capture the complex environmental impacts of large-scale events. To bridge this gap, this study proposes a comprehensive multi-criteria environmental sustainability evaluation framework, using the NFL Super Bowl host city selection as a case study. Six core quantitative indicators are developed to represent environmental performance: Water Resource Index, Waste Circularity, Transit Carbon Control, Thermal Adaptability, Energy Efficiency and Cleanliness, and Ecological Quality. To integrate subjective expert knowledge with objective data variation, a Hybrid Weighting Method fusing the Analytic Hierarchy Process (AHP) and the Entropy Weight Method is employed, followed by the TOPSIS method for comprehensive ranking. Application of this framework to nine U.S. candidate cities reveals that Seattle, Washington, exhibits the optimal environmental sustainability profile, driven by its robust clean energy infrastructure and efficient waste circularity. Furthermore, sensitivity analysis demonstrates the high stability and robustness of the model under weight perturbations. This framework provides policymakers and sports organizations with a quantitative, scalable tool for prioritizing ecological integrity in mega-event planning.**

***Keywords*—site selection, environmental sustainability, multi-criteria decision making, TOPSIS, hybrid weighting**

I. INTRODUCTION

Major sporting events attract global attention and bring significant economic, social, and cultural impacts to host cities. Traditionally, the selection of host locations has been primarily based on economic strength, infrastructure capacity, tourism potential [1–3]. However, with the escalating severity of global climate change and resource depletion, the profound environmental consequences of these large-scale events have increasingly alarmed policymakers and researchers. The massive influx of spectators and athletes often triggers sharp, short-term spikes in transportation demand, energy consumption, water use, and municipal solid waste generation [4, 5]. Consequently, international sports organizations are shifting their paradigms; for instance, both the National Football League (NFL) and the International Olympic Committee (IOC) have begun integrating sustainability guidelines into their event planning strategies [6, 7].

Despite this growing awareness, existing research and practical frameworks for sports event location selection largely treat environmental considerations as secondary or qualitative metrics [5, 8]. Many conventional site selection models rely on a limited number of generalized indicators that fail to capture the complex, multi-dimensional ecological impacts—such as thermal climate adaptability, waste circularity, and local energy structures—associated with hosting mega-events [4, 9]. Ignoring these granular factors can lead to an incomplete assessment of a host city's true ecological carrying capacity. Therefore, developing a refined, highly quantitative environmental evaluation framework is imperative to support sustainable event planning and optimize the decision-making process.

To address this critical gap, this study proposes a comprehensive quantitative environmental sustainability evaluation framework for mega-sporting event site selection, utilizing the NFL Super Bowl as a primary case study. Specifically, we first construct a customized indicator system comprising six measurable, data-driven environmental metrics: Water Resource Index, Waste Circularity, Transit Carbon Control, Thermal Adaptability, Energy Efficiency and Cleanliness, and Ecological Quality, tailored to capture the precise ecological stresses induced by large-scale sporting events. Furthermore, to integrate subjective domain expertise with objective empirical data variation, we develop a hybrid multi-criteria decision-making (MCDM) framework featuring a Combined Weighting Method (CWM) that fuses the Analytic Hierarchy Process (AHP) with the Entropy Weight Method, thereby overcoming the inherent biases of single-weighting schemes. Finally, by applying the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), we evaluate nine candidate U.S. cities. Extensive sensitivity analyses confirm the model's exceptional robustness, ultimately providing policymakers and sports organizations with a scalable, reliable tool for green event planning.

II. METHODOLOGY

A. Construction of Environmental Evaluation Indicators

The foundation of the framework relies on six core indicators designed to capture the specific ecological footprints of large-scale events [10–12]. All metrics are normalized to a [0, 1] scale to ensure mathematical comparability.

Water Resource Index (Swat): This measures a city's capacity to handle short-term surges in water demand and is based on total available resources and local water renewal speed. It is calculated as:

$$S_{wat} = \alpha_1 \times \frac{P_i}{P_{max}} + \alpha_2 \times \left(1 - \frac{W_i}{W_{max}}\right), \qquad (1)$$

where P_i is monthly precipitation, W_i is the water stress risk score, and α_1 and α_2 are weight coefficients.

Waste Circularity (Swas): This metric assesses the local ability to handle waste generated during the event. Utilizing the waste diversion rate (WDR_i), the score is normalized as:

$$S_{was} = \frac{WDR_i}{WDR_{max}}, \tag{2}$$

where WDR_i is the waste diversion rate.

Transit Carbon Control (Stra): Recognizing that travel, especially long-haul flights, is a primary source of carbon emissions, this indicator captures both round-trip travel and local mobility:

$$S_{tra} = \lambda_1(1 - \frac{D_i}{D_{max}}) + \lambda_2 \frac{L_{con}}{L_{max,con}} + \lambda_3 \frac{C_{gre}}{C_{max,gre}}, \tag{3}$$

where D_i is weighted flight distance, L_{con} is local congestion, and C_{gre} is the green travel score.

Thermal Adaptability (Sthe): This reflects the energy required to maintain climate comfort standards in venues. For temperatures below the 10°C threshold:

$$S_{the} = \frac{T_i - T_{min}}{10 - T_{min}}. \tag{4}$$

For cities naturally meeting or exceeding 10°C, the score is an ideal 1.

Energy Efficiency and Cleanliness (Sene): This gauges local environmental policies and energy structures using clean energy power generation proportions (P_{ce}) and energy efficiency scores (C_{ees}).

$$S_{ene} = \gamma_1 \times \frac{C_{ees}}{C_{max,ees}} + \gamma_2 \times \frac{P_{ce}}{P_{max,ce}}. \tag{5}$$

Ecological Quality (Seco): This reflects ecological resilience against event-induced pollution, evaluated through air quality (PM2.5 emissions) and vegetation coverage:

$$S_{eco} = \delta_1 \times \left(1 - \frac{E_{PM2.5}}{E_{max,PM2.5}}\right) + \delta_2 \times C_{tree}. \tag{6}$$

B. The Hybrid MCDM Approach (AHP-Entropy-TOPSIS)

To avoid the inherent biases of using a single weighting technique, we employ a Combined Weighting Method (CWM) that optimally fuses subjective domain knowledge with objective data variance [6, 13].

First, the Analytic Hierarchy Process (AHP) was applied to derive subjective weights （w_{AHP}）. Unlike arbitrary assignments, the AHP judgment matrix in this study is meticulously constructed based on a comprehensive review of existing sustainability guidelines from international sports organizations (e.g., IOC and NFL) and recent environmental management literature [10–12]. The consistency of the matrix is rigorously verified (Consistency Ratio $CR < 0.1$). Simultaneously, the Entropy Weight Method calculates objective weights (w_{ENT}) by quantifying the information divergence of each indicator's dataset. The final combined weight vector (w_{com}) is integrated using a balance coefficient φ:

$$w_{com} = \varphi \sim w_{AHP} + (1 - \varphi) w_{ENT}\ , \tag{7}$$

In this study, φ is set to 0.6 to prioritize established ecological governance principles while respecting empirical data distributions.

Finally, the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is utilized to compute the comprehensive ranking. By multiplying the normalized data matrix with w_{com}, we obtain the weighted decision matrix. For each candidate city i, its Euclidean distances to the Positive Ideal Solution (D_i^+) and the Negative Ideal Solution (D_i^-) are calculated. The ultimate environmental sustainability profile is determined by the relative closeness (C_i):

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

A higher C_i value signifies that a city's environmental infrastructure is closer to the theoretical optimum, making it more capable of sustainably hosting a mega-sporting event.

III. Results

To evaluate and rank the nine candidate host cities, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) was applied to the weighted score matrix. By calculating the Euclidean distance of each city to both the Positive Ideal Solution (V^+) and the Negative Ideal Solution (V^-), the relative closeness (C_i) was determined. A higher C_i value signifies a stronger sustainability profile.

By applying the TOPSIS method to the weighted decision matrix, the relative closeness (C_i) of the nine candidate cities to the theoretical ideal environmental profile was calculated. As presented in Table 1, the evaluation yielded a distinct hierarchical tier of host city suitability based on ecological carrying capacity.

Table 1. Environmental sustainability ranking of candidate host cities

Ranking	City	Score
1	Seattle, Washington	0.7108
2	Santa Clara, California	0.6854
3	Inglewood, California	0.6316
4	Atlanta, Georgia	0.5407
5	Boston, Massachusetts	0.4742
6	New Orleans, Louisiana	0.4165
7	Glendale, Arizona	0.3988
8	Las Vegas, Nevada	0.3772
9	Kansas City, Missouri	0.2998

Seattle, Washington, achieved the highest environmental sustainability score (0.7108), followed closely by Santa Clara, California (0.6854), as shown in Fig. 1. Seattle's dominant performance is primarily driven by its abundant natural water resources, highly efficient municipal waste-recycling infrastructure, and an extensive clean-energy power grid. Santa Clara demonstrated exceptional waste circularity and clean energy penetration, securing its position as a highly viable alternative. Conversely, cities such as Kansas City ranked lowest among the candidates. This lower placement highlights significant regional vulnerabilities, particularly in energy efficiency and transit carbon control, indicating that hosting a mega-event there would entail a substantially higher ecological cost.

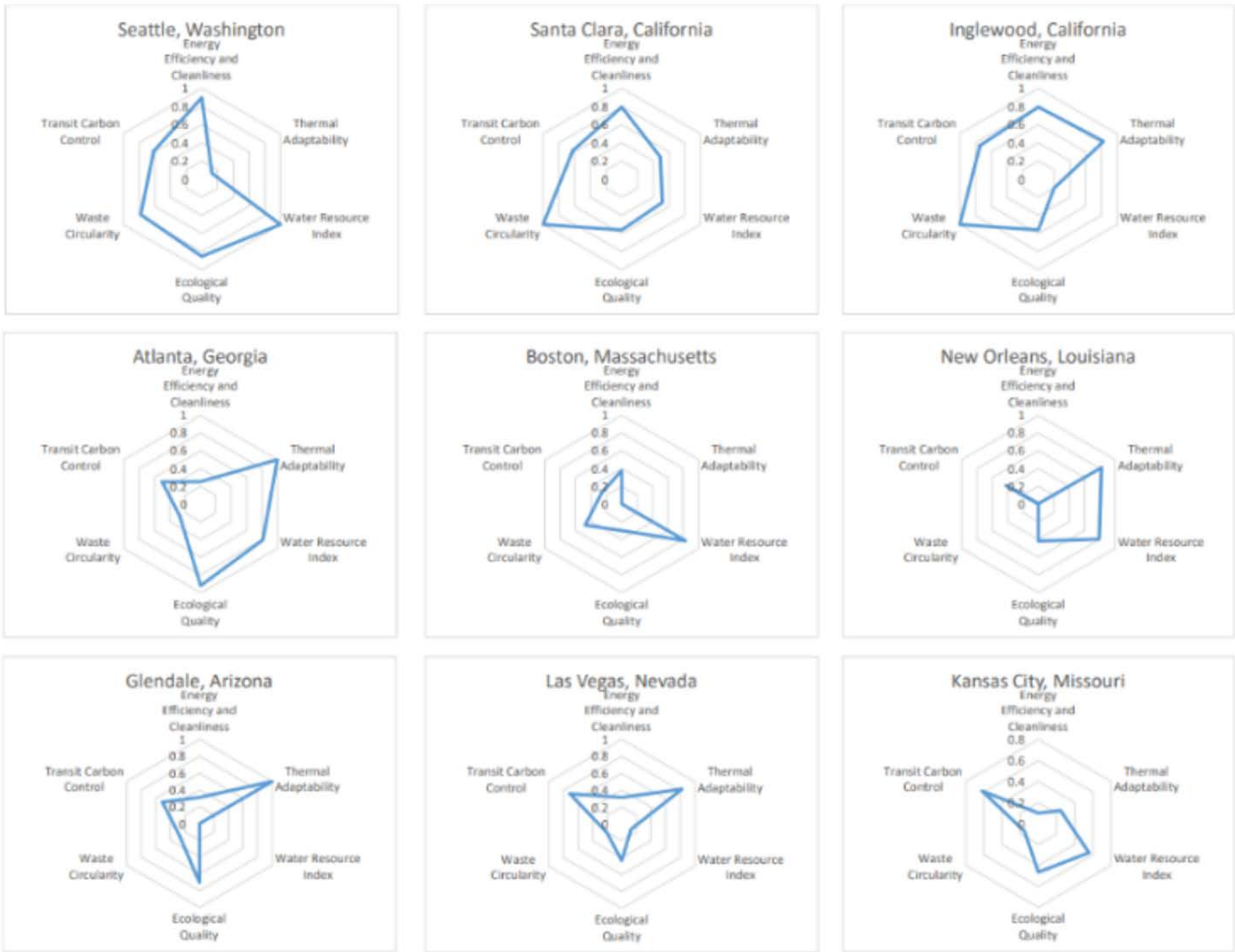

Fig.1. Environmental sustainability for nine cities.

IV. Discussion

A. Sensitivity Analysis

In the original model, the subjective -objective weight combination is set to AHP 0.6 + Entropy 0.4. To evaluate whether the final rankings depend heavily on this choice, we varied the AHP ratio from 0.4 to 0.8 in increments of 0.1, with the entropy weight adjusted to maintain a total weight of 1 [14].

For each ratio scenario, combined weights were recalculated, and suitability scores and rankings were recomputed. The results for all cities are shown in Fig. 2, which plots each city's score as a function of the AHP weight ratio.

To further examine model stability, we applied small perturbations (±5% and ±10%) to the weights of each of the six first-level indicators individually. After each perturbation, combined weights were renormalized and TOPSIS scores and rankings were recomputed. To assess ranking stability quantitatively, we computed the Spearman rank correlation coefficient between the perturbed ranking and the original ranking. The resulting stability matrix is shown in Fig. 3, where each cell reports the Spearman correlation coefficient for one indicator -perturbation combination.

Sensitivity analysis indicates that the AHP-entropy weight-TOPSIS model maintains high stability under weight perturbation. Within the weight variation range of ±5% and ±10%, the Spearman rank correlation coefficients between the rankings of all first-level indicators after disturbance and the original rankings are all between 0.90 and 0.99, and no significant reversal has occurred in the top-ranked cities. Although the sensitivity of indicators related to transportation and energy structure is slightly higher, their fluctuations are still within an acceptable range. This stability ensures that the evaluation results will not deviate due to the random selection of weights, supporting the reliability of this model [15] as a comparison tool for the selection of host cities.

B. Methodological Advantages

The main advantage of this model lies in its comprehensive assessment framework, especially in providing a relatively detailed analysis in the environmental dimension. The indicator system covers key environmental indicators such as water resource utilization, waste management, the proportion of clean energy, and ecological resilience. All these indicators are based on public data, facilitating horizontal comparison. By introducing expert experience judgment through the Analytic Hierarchy Process (AHP) and combining the entropy weight method to reflect the dispersion degree of the data itself, the model can strike a balance between subjective preferences and objective information, making the assessment results of environmental suitability more convincing. In practical applications, this framework can help event organizers identify cities that perform relatively well in terms of the environment more quickly and provide references for subsequent in-depth investigations.

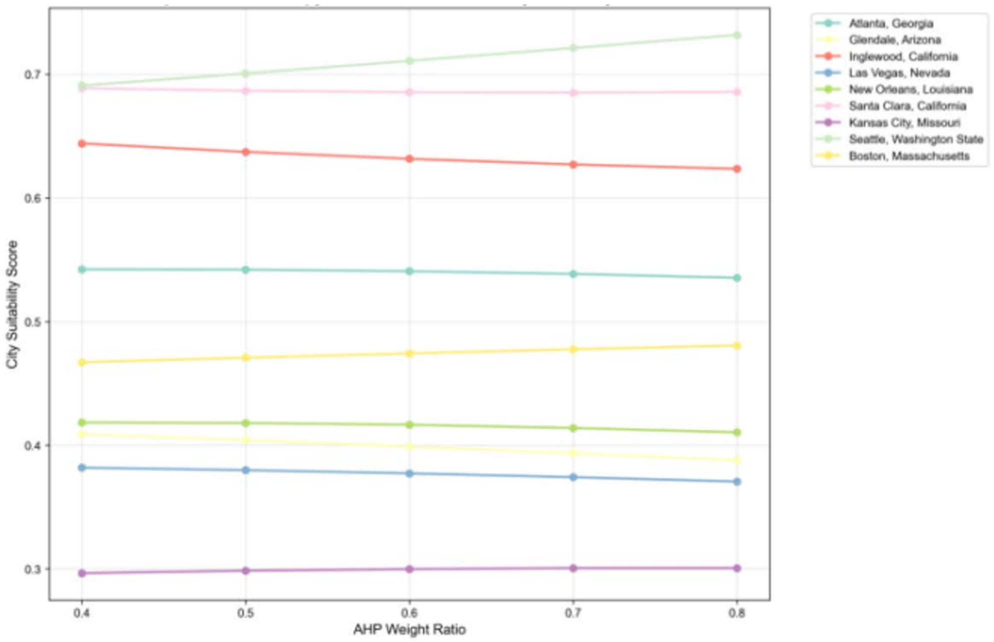

Fig. 2. Effect of AHP：Entropy weight ratio perturbation on city scores.

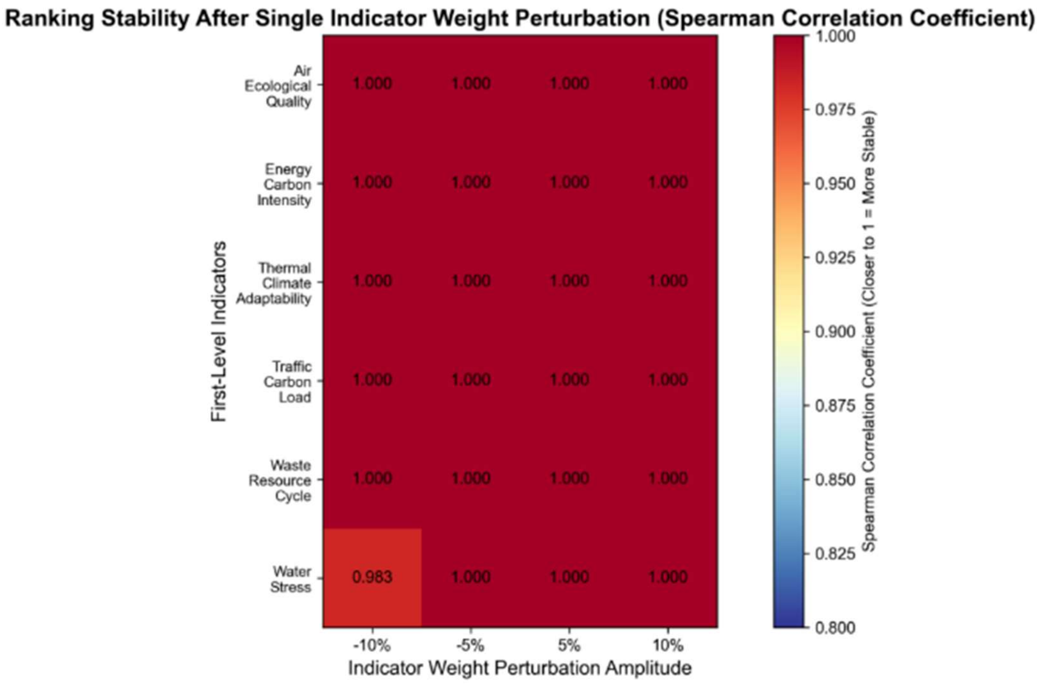

Fig. 3. Ranking stability heatmap under single indicator weight perturbations.

C. Limitations and Future Direction

Despite its robustness, the current evaluation framework presents certain limitations, primarily its reliance on static historical data. In regions with sparse or delayed environmental reporting, the accuracy and timeliness of the assessment may be constrained. Future research could address this by integrating real-time API streams from IoT environmental sensors to dynamically update the indicator weights. Such advancements would significantly enhance the model's responsiveness to sudden ecological shifts. Additionally, developing differentiated indicator weight templates tailored to various types of mega-sporting events (e.g., indoor vs. outdoor, winter vs. summer) could further expand the framework's global applicability.

V. Conclusion

This study proposes a comprehensive, quantitative environmental sustainability assessment model that integrates the Analytic Hierarchy Process (AHP), the Entropy Weight Method, and TOPSIS into a balanced hybrid decision-making framework. Using the NFL Super Bowl as a case study, the model systematically evaluates the ecological carrying capacity of candidate host cities across critical dimensions, including water resources, waste circularity, clean energy, and ecological resilience. The empirical application reveals that Seattle emerges as the optimal host city, demonstrating superior infrastructure capabilities in mitigating the environmental footprint of mega-sporting events. Furthermore, rigorous sensitivity analyses confirm the high stability and robustness of the evaluation outcomes under various subjective-objective weight perturbations. Ultimately, while the indicator weights can be dynamically adjusted to suit the specific environmental contexts of different sporting events, the core value of this framework lies in providing policymakers and sports organizations with a systematic, data-driven analytical tool for green site selection, rather than simply generating a ranking list.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Both authors contributed equally to the study design, data analysis, model implementation, and manuscript preparation. All authors have read and approved the final version.

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