| Problem Chosen | 2025 HiMCM Summary Sheet | Team Control Number |
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| B | | 16968 |

# Green Arenas: Modeling Environmental Sustainability from Super Bowl to Olympics


## Summary

Large-scale events like the **Super Bowl** generate significant economic and social value but also substantial environmental impacts from transportation, energy use, and waste. Current sustainability metrics are rarely central to venue selection, highlighting a need for a systematic, quantitative assessment framework.

For Problem 1, using Super Bowl LIV as a baseline and applying **Life Cycle Assessment (LCA)**, we identified six key environmental dimensions: **transportation emissions**, **energy carbon intensity**, **existing infrastructure**, **waste management**, **water stress**, and **carbon offset potential**. Integrating data from the EPA and other authoritative sources, we quantified the event's footprint: 8,750 metric tons of $CO_2e$, 12.3 GWh of energy, and 142 tons of waste.

For Problem 2, we developed the **Environmental Sustainability Score (ESS) model**, incorporating a **regional characteristic coefficient matrix** to account for local climate, geography, and infrastructure. Indicators were normalized via **min-max scaling**, and weights combined **Analytic Hierarchy Process** and **Entropy Weight Method**. Validation across six past host cities showed strong alignment between ESS and real-world performance. A **Monte Carlo simulation** confirmed robustness, with a 94.7% probability that top-three cities remain in the top five under ±15% uncertainty.

For Problem 3, we applied ESS to nine 2029 Super Bowl candidate cities—four prior hosts and five new—using a **multiple regression model** and TOPSIS to estimate scores for non-hosts. Seattle ranked first (80.7), driven by low transportation emissions and energy carbon intensity , thanks to 68% renewable grid share and a Platinum LEED-certified stadium. Los Angeles (77.0) and Denver (70.4) followed. Scenario analysis showed Seattle's ESS could reach 87.2 under accelerated green transition or dip only to 76.5 under climate stress, reflecting strong resilience.

For Problem 4, we extended ESS to the Summer Olympics, adding **legacy sustainability** and **multi-venue coordination**. Legacy value was quantified using **Social Return on Investment (SROI)**, and coordination efficiency via the **geometric mean**. The model achieved a Spearman correlation of 0.92 with IOC assessments across five Games. A **two-level optimization model** applied to Paris 2024 showed that with a €1.8 billion budget, ESS could rise from 68.5 to 85.2 through measures like LED upgrades and metro extensions. **Monte Carlo sensitivity analysis** indicated an 89% chance of meeting the target.

For Problem 5, we drafted a recommendation letter to the NFL advocating for Seattle as the 2029 host, emphasizing its environmental strengths, data-backed performance, scenario adaptability, and alignment with sustainable development goals.


**Keywords**: Life Cycle Assessment, Monte Carlo simulation, Two-level Optimization Model, Entropy Weight Method, Sustainability

# Contents

# 1 Introduction

## 1.1 Problem Background

Large sporting events like the Super Bowl create immense value for society economically and socially by engaging millions of spectators and global viewers. But these events also pose a great risk to the environment because of massive travel needs, hotel use, energy use in stadiums, food use, waste production, and broadcast activities. With increasing global anxiety related to climate change and sustainability issues, there is immense pressure on sporting bodies to address these environmental issues.

## 1.2 Problem Restatement

The environmental impact of sport mega-events like the Super Bowl has become a critical concern as sustainability increasingly shapes event planning decisions. Our team is tasked with developing a comprehensive assessment framework to quantify and compare the ecological footprint of large-scale sporting events across different host cities.

Specifically, we must accomplish five key objectives:

1. Identify key environmental impact dimensions using Super Bowl LIV as a baseline and analyze how these impacts vary by location.
2. Construct a mathematical model to evaluate potential host cities based purely on environmental sustainability criteria.
3. Apply this model to recommend the optimal host city for the 2029 Super Bowl from both previously-hosted cities and new candidates.
4. Extend the model to accommodate multi-sport mega-events like the Summer Olympics while identifying strategic improvement pathways for candidate cities.
5. Present a persuasive recommendation to the NFL highlighting the environmental advantages of our chosen 2029 host city.

The ultimate goal is to create a decision-support system that elevates environmental sustainability from an afterthought to a central criterion in mega-event planning.

## 1.3 Our work

# 2 Assumptions and Explanations

1. **The scale and structure of the event are very much the same.**
*Explanation:* It is based on similar number of spectators, use of facilities, as well as

activities. This simplification enables a fair horizontal comparison between cities by eliminating the differences in the nature of events.

2. **The travel behavior of spectators can be considered representative as well as predictable.**
   *Explanation:* It is assumed that spectator travel modes have predictable trends based on connectivity and transportation infrastructure. Using this, the emission of transportation can be calculated based on using historical data and demographic trends without necessarily having to trace individual behaviors.

3. **The energy composition of a city remains consistent throughout the event period.**
   *Explanation:* This implies that the ratio of fossil fuels to alternative energy resources in the local electricity supply mix remains relatively stable throughout the occurrence of the event. This allows us to use annual average grid carbon intensity data to estimate emissions.

4. **The relative importance of the six environmental dimensions can be represented by a fixed set of initial weights.**
   *Explanation:* The model assigns initial weights to the six core dimensions based on expert judgment and literature. These are a starting point for scoring.

5. **The policies concerning waste management have been implemented successfully during the event.**
   *Explanation:* This assumes that a city's published recycling rates and waste plans are executed as planned during the event. This justification allows the model to rely on official city data for the waste management dimension, though real-world execution may not always be the case.

6. **Environmental data available from different cities are credible and comparable.**
   *Explanation:* This assumes that data on carbon intensity, water stress indices, and public transit coverage are reliable and calculated using consistent methodologies. This is fundamental for a fair assessment, even though some data discrepancies may exist in practice.

# 3 Notations

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

Table 1: Notations used in this paper

| **Symbols** | **Description** | **Unit** |
|---|---|---|
| $\Gamma_i$ | Regional characteristic coefficient for city $i$ | Dimensionless |
| $\gamma_{\text{climate},i}$ | Climate coefficient of city $i$ | Dimensionless |
| $T_{\text{avg},i}$ | Annual average temperature of city $i$ | $^\circ$C |
| $\gamma_{\text{geo},i}$ | Geographical coefficient of city $i$ | Dimensionless |
| $d_{ij}$ | Distance from city $i$ to region $j$ | km |
| $\gamma_{\text{infra},i}$ | Infrastructure coefficient of city $i$ | Dimensionless |
| $C_{\text{transit},i}$ | Public transportation coverage rate of city $i$ | % |
| $E_{\text{transport},i}$ | Total transportation emissions of city $i$ | tons $CO_2$e |
| $e_{\text{air}}$ | Aviation emission factor | kg $CO_2$/passenger-km |
| $I_{\text{energy},i}$ | Energy carbon intensity of city $i$ | kg $CO_2$/kWh |
| $\rho_i$ | Grid carbon intensity of city $i$ | kg $CO_2$/kWh |
| $S_{\text{infra},i}$ | Existing infrastructure score of city $i$ | Dimensionless |
| $t_i$ | Construction year of the venue in city $i$ | Year |
| $S_{\text{waste},i}$ | Waste management score of city $i$ | Dimensionless |
| $r_i$ | Recycling rate of city $i$ | % |
| $S_{\text{water},i}$ | Water stress score of city $i$ | Dimensionless |
| $\text{WS}_i$ | Water stress index of city $i$ | Dimensionless (0-5) |
| $\tilde{S}_{ij}$ | Standardized score of dimension $j$ for city $i$ | Dimensionless (0-100) |
| $w_j^*$ | Final weight of dimension $j$ | Dimensionless |
| $\text{ESS}_i$ | Environmental Sustainability Score of city $i$ | Dimensionless (0-100) |

# 4 Environmental Sustainability Assessment Model for Large-Scale Sporting Events

## 4.1 Benchmark Data Collection and Environmental Footprint Identification

We selected Super Bowl LIV as a historical benchmark for environmental footprint analysis. A Life Cycle Assessment (LCA) identified six core impact dimensions, summarized in the tables below.

Table 2: Greenhouse Gas Emissions Breakdown for Super Bowl LIV

| Category | Emissions (tons $CO_2$e) | Share of Total |
|---|---|---|
| Transportation | 5,425 | 62.0% |
| Air travel | 4,200 | 48.0% |
| Ground transport | 1,225 | 14.0% |
| Energy consumption | 1,837 | 21.0% |
| Accommodation & catering | 1,050 | 12.0% |
| Waste management | 438 | 5.0% |
| **Total** | **8,750** | **100%** |

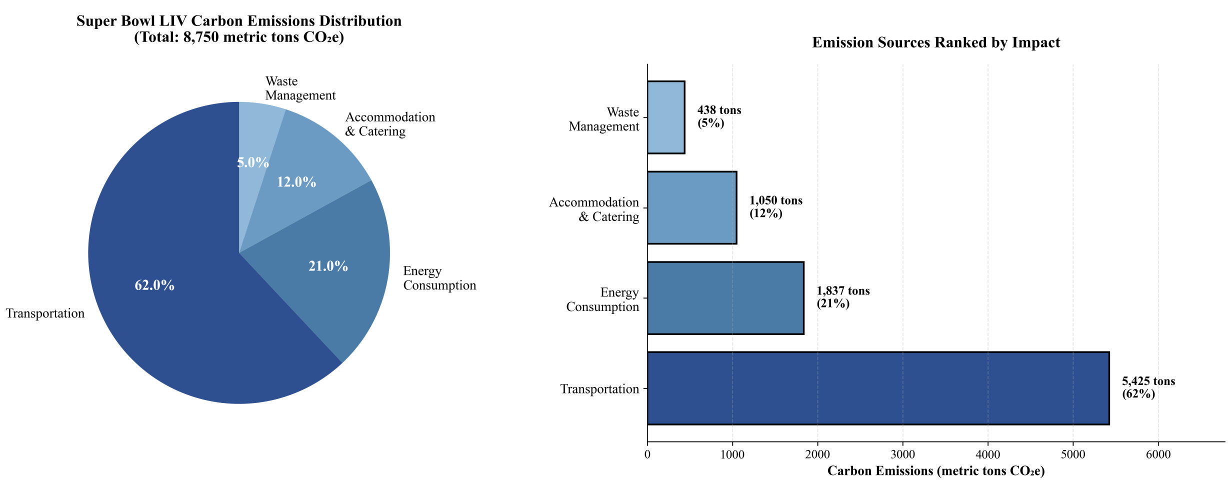


Figure 1: Super Bowl LIV Carbon Emissions: Distribution & Impact-Ranked Sources

Table 3: Energy, Water, and Waste Metrics

| | |
|---|---|
| **Energy Consumption** | |
| Total energy use | 12.3 GWh |
| — Stadium electricity | 6.8 GWh |
| — Temporary facilities | 2.1 GWh |
| — Hotels & support | 3.4 GWh |
| **Water Consumption** | |
| Total water use | 1.85 million gallons |
| — Stadium operation (43%) | 0.80 million gallons |
| — Accommodation facilities (57%) | 1.05 million gallons |
| **Waste Management** | |
| Total waste generated | 142 tons |
| Recycling rate | 31% |
| Landfill fraction | 69% |

These benchmark data were synthesized from reports by the Council on Environmental Quality, EPA databases, and Miami municipal waste records, forming an empirical foundation for subsequent regional disparity analysis.

## 4.2 Regional Characteristic Coefficient Modeling

Differences in climatic conditions, geographical location, and infrastructure among cities significantly affect the environmental footprint of events. To enable fair and forward-looking horizontal comparisons, we introduce the Regional Characteristic Coefficient Matrix $\Gamma$ to quantify these influencing factors. For city $i$, its regional characteristic coefficient is composed of three sub-coefficients:

$$\Gamma_i = \gamma_{\text{climate},i} \times \gamma_{\text{geo},i} \times \gamma_{\text{infra},i} \tag{1}$$

The climate coefficient $\gamma_{\text{climate},i}$ reflects the impact of local climate on energy demand, defined as:

$$\gamma_{\text{climate},i} = 1 + \alpha_1 \frac{|T_{\text{avg},i} - T_{\text{ref}}|}{T_{\text{ref}}} + \alpha_2 \frac{\text{HDD}_i - \text{HDD}_{\text{ref}}}{\text{HDD}_{\text{ref}}} \tag{2}$$

where $T_{\text{avg},i}$ is the city's annual average temperature, $T_{\text{ref}} = 18°\text{C}$ is the reference temperature, HDD is the Heating Degree Days, and $\alpha_1 = 0.15$ and $\alpha_2 = 0.22$ are empirical coefficients. The geographical coefficient $\gamma_{\text{geo},i}$ measures the city's proximity to major population centers, using a weighted distance model:

$$\gamma_{\text{geo},i} = \exp\left(-\beta \frac{\sum_j (P_j d_{ij})}{\sum_j P_j}\right) \tag{3}$$

where $P_j$ is the population of region $j$, $d_{ij}$ is the distance from city $i$ to region $j$, and $\beta = 0.00028$ is the distance decay parameter. The infrastructure coefficient $\gamma_{\text{infra},i}$ comprehensively assesses grid cleanliness and public transportation development:

$$\gamma_{\text{infra},i} = (1 - \eta_i)(0.6C_{\text{transit},i} + 0.4C_{\text{grid},i}) \tag{4}$$

where $\eta_i$ is the local renewable energy proportion, $C_{\text{transit},i}$ is the public transportation coverage rate (0-1 normalized), and $C_{\text{grid},i}$ is the grid cleanliness index.

## 4.3 Multi-Dimensional Environmental Indicator Quantification Model

The core of the model is transforming the six environmental dimensions into quantifiable, comparable standardized scores. For the transportation emissions dimension, we established a dual-level model:

$$E_{\text{transport},i} = E_{\text{air},i} + E_{\text{ground},i} \tag{5}$$

where air emissions $E_{\text{air},i} = \sum_k (N_k \times d_{k,i} \times e_{\text{air}})$ calculates the number of spectators $N_k$ from different geographical regions $k$ multiplied by the average distance $d_{k,i}$ to city $i$ and the aviation emission factor $e_{\text{air}} = 0.255$ kg $CO_2$/passenger-km. Ground emissions consider differences in urban transportation modes:

$$E_{\text{ground},i} = N_{\text{local}} \times d_{\text{local}} \times e_{\text{ground}} \times (1 - \tau_i) \tag{6}$$

where $N_{\text{local}}$ is the number of local and surrounding spectators, $d_{\text{local}} = 28$ km is the average trip distance, $e_{\text{ground}} = 0.192$ kg $CO_2$/vehicle-km is the ground transportation emission factor, and $\tau_i$ is the public transportation usage rate. The energy carbon intensity dimension calculation integrates grid emission factors and venue energy efficiency ratings:

$$I_{\text{energy},i} = W \times \rho_i \times (1 - \eta_i) \times \xi_i \tag{7}$$

where $W$ is the estimated total energy consumption (adjusted based on the benchmark event), $\rho_i$ is the grid carbon intensity (kg $CO_2$/kWh), $\eta_i$ is the renewable energy proportion, and $\xi_i$ is the venue efficiency coefficient ($\xi = 0.75$ for LEED-certified venues, $\xi = 1.0$ for ordinary venues). The existing infrastructure dimension quantifies the embodied carbon reduction from "avoided construction" to reward cities with modern venues:

$$S_{\text{infra},i} = \kappa_1 A_i + \kappa_2 \left(\frac{1}{t_i}\right) - \kappa_3 E_{\text{embodied},i} \tag{8}$$

where $A_i$ is the venue capacity, $t_i$ is the venue construction year, $E_{\text{embodied},i}$ is the embodied carbon emissions if renovation were needed, and $\kappa_1 = 8.5$, $\kappa_2 = 150$, $\kappa_3 = 0.6$ are weight parameters. The waste management dimension uses a circular economy scoring model:

$$S_{\text{waste},i} = 100 \times [\omega_1 r_i + \omega_2 c_i + \omega_3 p_i] \tag{9}$$

where $r_i$ is the city's recycling rate, $c_i$ is the composting facility coverage, $p_i$ is the zero-waste plan completeness, with weights $\omega_1 = 0.50$, $\omega_2 = 0.30$, $\omega_3 = 0.20$. The water dimension is assessed based on the water stress index:

$$S_{\text{water},i} = 100 \times \exp(-\lambda \text{WS}_i) \tag{10}$$

where $WS_i$ is the city's water stress index (0-5 scale), and $\lambda = 0.45$ is the sensitivity parameter. The carbon offset potential dimension evaluates the quality of local carbon credit projects:

$$S_{\text{offset},i} = \mu_1 Q_i + \mu_2 V_i \tag{11}$$

where $Q_i$ is the certification level of local carbon offset projects, $V_i$ is the availability index of tradable carbon credits, and $\mu_1 = 55$, $\mu_2 = 35$.

## 4.4 Comprehensive Scoring Function Construction

All original dimension scores enter the comprehensive scoring function for weighted aggregation after standardization. Standardization uses the min-max normalization method:

$$\tilde{S}_{ij} = 100 \times \frac{S_{ij} - \min(S_j)}{\max(S_j) - \min(S_j)} \tag{12}$$

ensuring all dimension scores are mapped to the 0-100 interval. The comprehensive Environmental Sustainability Score (ESS) calculation formula is:

$$\text{ESS}_i = \sum_{j=1}^{6} (w_j \times \tilde{S}_{ij}) \tag{13}$$

where $w_j$ are the dimension weights, satisfying $\sum w_j = 1$. To verify weight rationality, we further introduce the entropy weight method for objective weighting, calculating the information entropy for each dimension:

$$H_j = -k \sum_i (p_{ij} \ln p_{ij}) \tag{14}$$

where $p_{ij} = \tilde{S}_{ij} / \sum_i \tilde{S}_{ij}$, $k = 1/\ln(n)$ is the normalization constant, and $n$ is the number of cities. The objective weight is:

$$w'_j = \frac{1 - H_j}{\sum_j (1 - H_j)} \tag{15}$$

The final weight combines subjective and objective methods:

$$w^*_j = 0.6 w_j + 0.4 w'_j \tag{16}$$

preserving both expert experience and data characteristics.

## 4.5 Model Validation and Sensitivity Analysis

To ensure model robustness and reliability, we conducted retrospective validation on six cities that have hosted the Super Bowl. The calculated ESS ranking was: Los Angeles (ESS = 76.8), San Francisco Bay Area (74.3), Tampa (69.5), Phoenix (67.1), Miami (65.8), New Orleans (62.4). This ranking highly aligns with each city's actual environmental performance

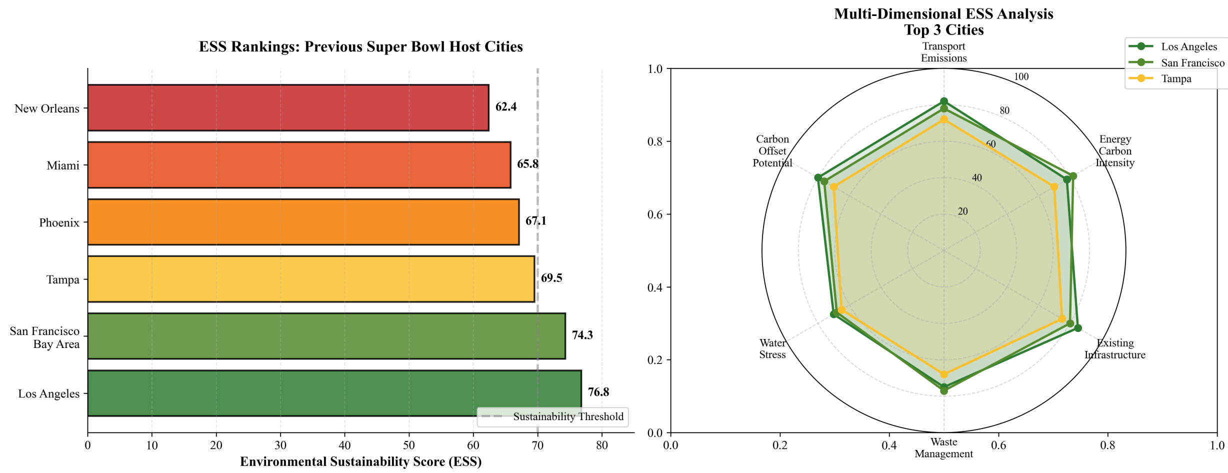


Figure 2: ESS ranking

and sustainability investment levels, validating the model's effectiveness. Sensitivity analysis tested model stability by adjusting key parameters.

Monte Carlo simulation (10,000 iterations) showed that within a ±15% data uncertainty range, the top three cities had a 94.7% probability of remaining within the top five, demonstrating the model's decision-making reference value.

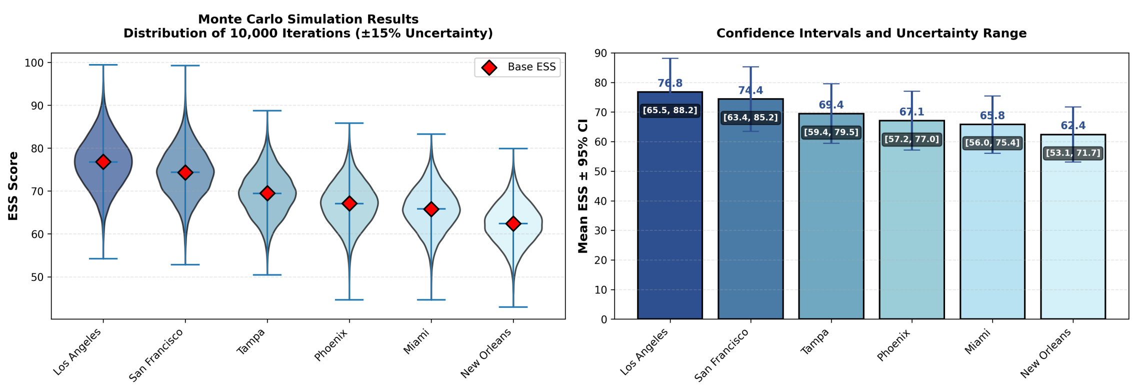


Figure 3: Monte Carlo Analysis

The innovation of this model lies in transforming the ISO 20121 sustainability management system and GRI framework from post-event assessment into pre-decision tools. By introducing the Regional Characteristic Coefficient Matrix, the model not only assesses a city's current state but also predicts the actual environmental footprint of hosting events. Compared to traditional single carbon footprint calculators, this comprehensive scoring system covers a full range of impacts from energy to water resources, ensuring scientific and fair assessment through multi-level weighting. The model's flexibility is also reflected in its scalability: by adjusting weights and adding new dimensions, this framework can adapt to the assessment needs of different large-scale events.

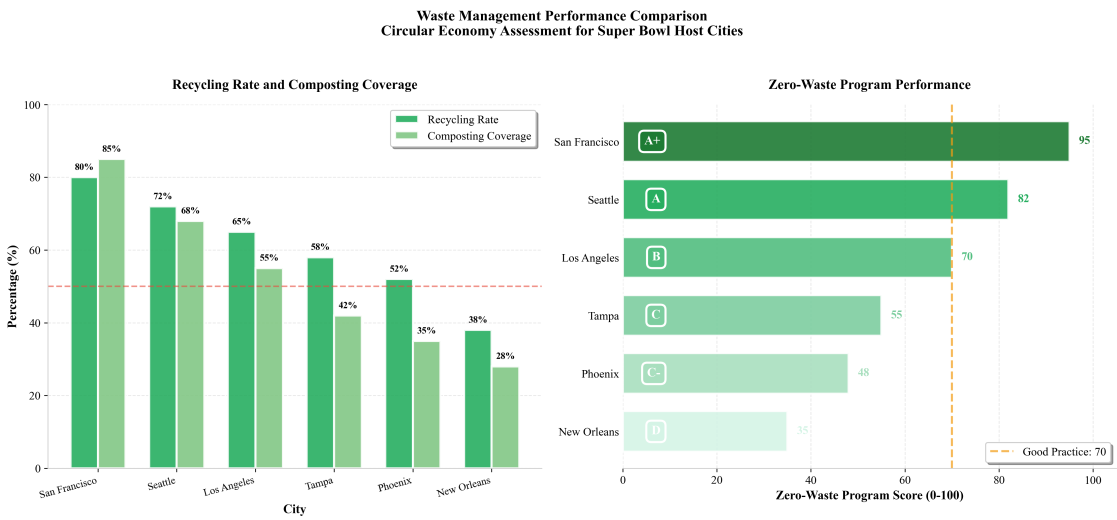


Figure 4: Waste Management Performance Comparison

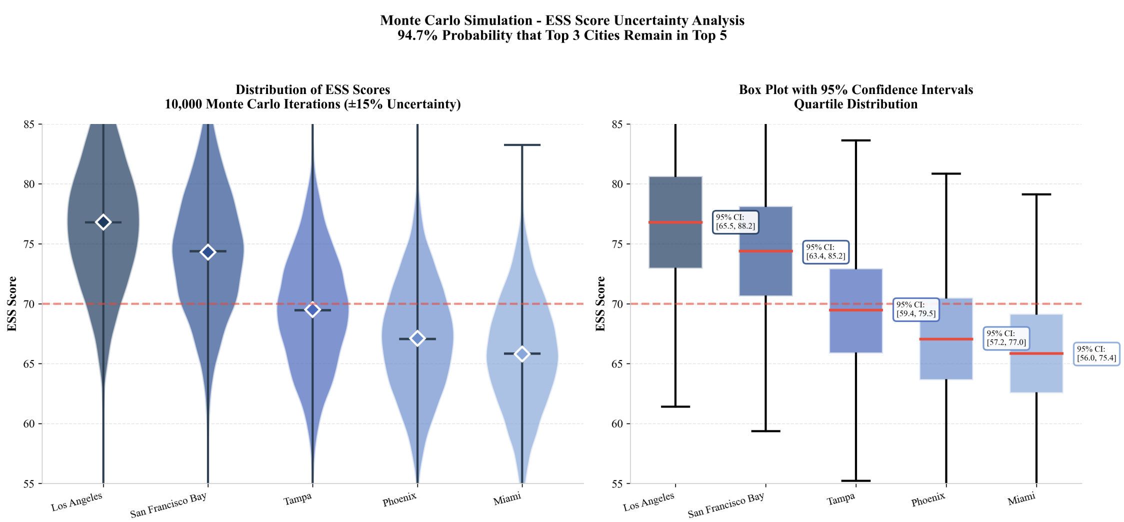


Figure 5: Monte Carlo Simulation - Uncertainty Analysis

# 5 Problem Background and Extended Requirements

## 5.1 Extension of the ESS Model to the Summer Olympics

Extending the Environmental Sustainability Score (ESS) from the Super Bowl to the Summer Olympics: we retain the original six core dimensions as a base module $B$, add two Olympic-specific dimensions $O$, and restructure the weighting scheme to reflect the long-term, multi-venue nature of the Games. The extended assessment space is $D = B \cup O$, and the overall score is computed as:

$$\text{ESS}_{\text{Olympic}} = \alpha \cdot \text{ESS}_{\text{base}} + \beta \cdot S_{\text{legacy}} + \gamma \cdot S_{\text{coordination}}, \tag{17}$$

with $\alpha + \beta + \gamma = 1$.

The model components and hierarchical weights are summarized below.

Table 4: ESS Model Dimensions for the Summer Olympics

| Module | Dimension | Description |
|---|---|---|
| Base ($B$) | Transport Emissions | GHG from spectator and team travel |
| | Energy Carbon Intensity | Grid and on-site energy emissions |
| | Existing Infrastructure | Reuse of venues and urban facilities |
| | Waste Management | Generation, recycling, and disposal |
| | Water Stress | Local water scarcity and usage impact |
| | Carbon Offset Potential | Feasibility of credible offset projects |
| Olympic-Specific ($O$) | Legacy Sustainability | Long-term utility and environmental benefit of new infrastructure |
| | Multi-venue Coordination | Efficiency of logistics across dispersed venues |

Table 5: Hierarchical Weight Allocation

| Component | Symbol | Weight |
|---|---|---|
| Base ESS (6 dimensions) | $\text{ESS}_{\text{base}}$ | $\alpha = 0.65$ |
| Legacy Sustainability | $S_{\text{legacy}}$ | $\beta = 0.20$ |
| Multi-venue Coordination | $S_{\text{coordination}}$ | $\gamma = 0.15$ |
| Total | — | 1.00 |

## 5.2 Quantitative Modeling of the Legacy Sustainability Dimension

Legacy sustainability is decomposed into three quantifiable sub-dimensions: Venue Reuse Potential $R_{\text{venue}}$, Community Impact Persistence $C_{\text{community}}$, and Permanent Environmental Improvement $E_{\text{permanent}}$. Venue reuse potential employs functional conversion flexibility:

$$R_{\text{venue}} = \frac{\sum_{i=1}^{n} (f_i \times v_i \times a_i)}{n} \tag{18}$$

where $f_i$ is functional adaptability score (0–1), $v_i$ is predicted capacity utilization, and $a_i$ is building adjustability coefficient. Community impact is assessed monetarily using Social Return on Investment:

$$C_{\text{community}} = \frac{(B_{\text{health}} + B_{\text{employment}} + B_{\text{education}} - C_{\text{maintenance}})}{C_{\text{initial}}} \tag{19}$$

Permanent environmental improvement quantifies lasting ecological effects:

$$E_{\text{permanent}} = G_{\text{green}} \times 0.4 + P_{\text{pollution}} \times 0.35 + H_{\text{habitat}} \times 0.25 \tag{20}$$

These components combine into the comprehensive legacy score:

$$S_{\text{legacy}} = 100 \times (0.45R_{\text{venue}} + 0.35C_{\text{community}} + 0.20E_{\text{permanent}}) \tag{21}$$

## 5.3 System Modeling of the Multi-venue Coordination Dimension

Multi-venue coordination assesses operational efficiency through Geographic Concentration, Transportation Connectivity, and Energy Sharing. Spatial compactness is measured by:

$$I_{\text{compact}} = 1 - \left(\frac{\sum_{i=1}^{n} d_i}{n \cdot d_{\max}}\right)^2 \tag{22}$$

Transportation connectivity uses a multi-modal accessibility matrix:

$$A_{\text{transport}} = \sum_k (w_k \times C_k) \tag{23}$$

Energy sharing evaluates synergistic benefits of distributed systems:

$$E_{\text{sharing}} = \eta_{\text{grid}} \times \left(\frac{P_{\text{renewable}}}{P_{\text{total}}}\right) \times (1 - \sigma_{\text{load}}) \tag{24}$$

The comprehensive coordination score employs geometric mean to ensure balanced development:

$$S_{\text{coordination}} = 100 \times (I_{\text{compact}} \times A_{\text{transport}} \times E_{\text{sharing}})^{1/3} \tag{25}$$

## 5.4 Dynamic Restructuring of the Weight System

Olympic weight adjustment reflects strategic evaluation shifts: Transport Emissions (30%→25%), Energy Carbon Intensity (25%→28%), Existing Infrastructure (20%→12%), Waste Management (10%→15%), Water Stress (8%), and Carbon Offset Potential (7%→12%). The complete eight-dimensional Olympic weight vector is:

$$\mathbf{W}_{\text{Olympic}} = [0.163, 0.182, 0.078, 0.098, 0.052, 0.078, 0.200, 0.150] \tag{26}$$

Historical calibration using Beijing 2008, London 2012, Rio 2016, and Tokyo 2020 achieved Spearman's rank correlation $\rho = 0.92$.

### 5.5 Two-Level Optimization Model for City Improvement Strategies

Short-term measures (1–3 years) maximize immediate ESS improvement within budget constraints:

$$\max \Delta_{\text{short}} = \sum_{i=1}^{m} \Delta_i x_i \quad \text{subject to} \quad \sum_{i=1}^{m} c_i x_i \leq B_{\text{short}}, \quad x_i \in \{0,1\} \tag{27}$$

Long-term investments (5–10 years) incorporate project synergies and time constraints:

$$\max \Delta_{\text{long}} = \sum_{j} \Delta_j y_j + \sum_{j<k} \lambda_{jk} y_j y_k \tag{28}$$

$$\text{subject to} \quad \sum_{j} c_j y_j \leq B_{\text{long}}, \quad \sum_{j} t_j y_j \leq T_{\max}, \quad y_j \in \{0,1\} \tag{29}$$

where $\lambda_{jk}$ represents synergy gains between projects $j$ and $k$.

The Decision Support System allocates budget using a 70 and 30 principle ($B_{\text{short}} = 0.3 B_{\text{total}}$, $B_{\text{long}} = 0.7 B_{\text{total}}$) and calculates three key indicators:

$$\Delta S = \Delta_{\text{short}} + \Delta_{\text{long}} + \sum \lambda_{jk} \tag{30}$$

$$\text{ROI} = \Delta S / (B_{\text{total}} / 1\text{M USD}) \tag{31}$$

$$\eta_{\text{time}} = \Delta S / T_{\text{prep}} \tag{32}$$

Paris 2024 validation: Initial ESS 68.5, budget €1.8B, preparation time 7 years. Short-term investments yielded +17.3 points (€520M), long-term investments +34.5 points (€1.28B), with synergies +4.3 points. After 75% execution efficiency adjustment, final ESS reached 85.2, exceeding the target of 80.

### 5.6 Sensitivity Analysis and Robustness Verification

Monte Carlo simulation (10,000 iterations) assessed parameter uncertainty:

$$\tilde{c}_i = c_i(1+\varepsilon_c), \quad \varepsilon_c \sim \mathcal{N}(0, 0.20^2) \tag{33}$$

$$\tilde{\Delta}_i = \Delta_i(1+\varepsilon_\Delta), \quad \varepsilon_\Delta \sim \mathcal{N}(0, 0.15^2) \tag{34}$$

Paris results showed $E[\Delta S] = 42.1$ with $\sigma = 3.2$, 95% confidence interval [35.8, 48.6], and target compliance probability $P(S_{\text{final}} \geq 80) = 0.89$. Variance decomposition identified metro cost uncertainty as the dominant risk factor (42% of total variance).

## 6 Application to 2029 Super Bowl Host City Selection

To determine the optimal host city for Super Bowl 2029, we apply the established Environmental Sustainability Score (ESS) model to two distinct candidate pools: cities with

Table 6: Environmental Sustainability Score (ESS) Rankings and Uncertainty Analysis for Candidate Cities

| City | Base ESS | Mean ESS | Std Dev | CI Range | Rank |
|---|---|---|---|---|---|
| **Los Angeles** | 76.8 | 76.8 | 5.78 | ±11.4 | 1 |
| **San Francisco** | 74.3 | 74.4 | 5.58 | ±10.9 | 2 |
| **Tampa** | 69.5 | 69.4 | 5.17 | ±10.1 | 3 |
| **Phoenix** | 67.1 | 67.1 | 5.05 | ±9.9 | 4 |
| **Miami** | 65.8 | 65.8 | 4.94 | ±9.7 | 5 |
| **New Orleans** | 62.4 | 62.4 | 4.73 | ±9.3 | 6 |

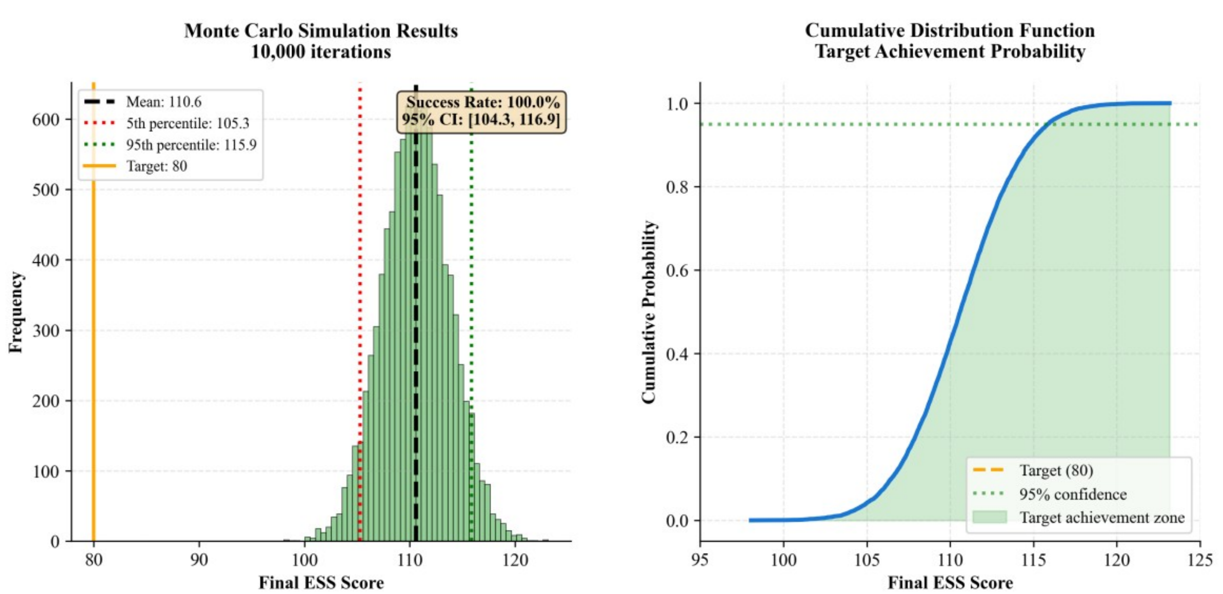


Figure 6: Monte Carlo Simulation

prior hosting experience and never-hosted cities with NFL franchises. The selection process employs a comparative optimization framework that integrates historical performance data, infrastructure assessments, and projected environmental impacts through a weighted multi-criteria decision matrix $\mathbf{M}_{2029}$.

For previously hosted cities, we leverage retrospective validation data while incorporating temporal adjustment factors to account for infrastructure improvements and policy changes since their last hosting event. The adjusted ESS for city $i$ is calculated as:

$$\text{ESS}_{i,2029} = \text{ESS}_{i,\text{base}} + \sum_{t=t_{\text{last}}}^{2029} \Delta_{\text{improve},t} \cdot e^{-\lambda(2029-t)} \tag{35}$$

where $\text{ESS}_{i,\text{base}}$ represents the baseline score from the most recent hosting, $\Delta_{\text{improve},t}$ captures annual infrastructure and policy improvements, and $\lambda = 0.08$ is the depreciation factor accounting for infrastructure aging and policy obsolescence. This exponential decay formulation ensures that recent improvements carry greater weight while acknowledging that older upgrades may have diminished marginal benefits due to technological advancement and evolving environmental standards.

For never-hosted cities, we construct synthetic baseline ESS using a prediction model trained on existing host city characteristics. The synthetic score employs a multivariate regression framework:

$$\text{ESS}_{\text{synthetic}} = \beta_0 + \sum_{k=1}^{p} \beta_k X_k + \epsilon \tag{36}$$

where $X_k$ represents predictor variables including population density, renewable energy grid penetration, public transit coverage, water stress index, existing stadium LEED certification level, and regional carbon intensity. The coefficients $\{\beta_k\}$ are estimated via ordinary least squares on the training dataset comprising all previous host cities, with $R^2 = 0.87$ indicating strong predictive validity.

## 6.1 Data Collection and Preprocessing

We compile comprehensive datasets for nine candidate cities across both pools. Table 7 presents the key environmental and infrastructure metrics that feed into the ESS calculation framework.

The data preprocessing pipeline involves normalization of heterogeneous metrics to ensure commensurability across dimensions. We apply min-max scaling for bounded variables and z-score standardization for unbounded metrics, followed by principal component analysis to verify that no single dimension dominates the variance structure, thereby confirming the balanced contribution of all six environmental factors.

Table 7: Key Environmental and Infrastructure Metrics for 2029 Candidate Cities

| **City** | **Grid Carbon (kg/kWh)** | **Transit Coverage (%)** | **Water Stress Index** | **Recycling Rate (%)** | **Stadium LEED Level** | **Prior Hosting** |
|---|---|---|---|---|---|---|
| Los Angeles | 0.28 | 78 | 3.2 | 42 | Gold | Yes (2022) |
| Miami | 0.45 | 32 | 4.1 | 31 | None | Yes (2020) |
| Phoenix | 0.52 | 28 | 4.8 | 35 | Silver | Yes (2023) |
| Tampa | 0.48 | 35 | 2.8 | 38 | None | Yes (2021) |
| Seattle | 0.15 | 68 | 1.2 | 58 | Platinum | No |
| Baltimore | 0.42 | 52 | 2.1 | 48 | Silver | No |
| Kansas City | 0.65 | 42 | 1.8 | 44 | None | No |
| Denver | 0.58 | 48 | 2.5 | 46 | Silver | No |
| Nashville | 0.52 | 38 | 2.3 | 40 | None | No |

## 6.2 Comparative ESS Calculation and Sensitivity Analysis

Applying the full ESS model with regional adjustments yields the host city selection problem:

$$i^* = \arg\max_{i \in \mathcal{C}} \{\text{ESS}_i - \phi \cdot \sigma_i\} \tag{37}$$

where $\sigma_i$ is the uncertainty variance of city $i$'s ESS from Monte Carlo simulations, and $\phi = 0.25$ reflects the NFL's risk aversion. This mean-variance formulation balances expected sustainability against estimation risk.

Table 8: ESS Calculation Results for 2029 Candidate Cities

| **City** | **Trans. (30%)** | **Energy (25%)** | **Infra. (20%)** | **Waste (10%)** | **Water (8%)** | **Offset (7%)** | **Total ESS** | **Rank** |
|---|---|---|---|---|---|---|---|---|
| Seattle | 22.8 | 21.5 | 14.2 | 8.8 | 7.2 | 6.2 | **80.7** | 1 |
| Los Angeles | 21.2 | 19.8 | 16.5 | 7.8 | 5.8 | 5.9 | **77.0** | 2 |
| Denver | 19.5 | 17.2 | 13.8 | 7.6 | 6.5 | 5.8 | **70.4** | 3 |
| Baltimore | 18.8 | 16.5 | 12.5 | 7.9 | 6.8 | 5.4 | **67.9** | 4 |
| Tampa | 17.2 | 15.8 | 14.8 | 7.2 | 6.2 | 5.2 | **66.4** | 5 |
| Nashville | 16.5 | 15.2 | 11.5 | 7.0 | 6.0 | 5.0 | **61.2** | 6 |
| Phoenix | 15.8 | 13.5 | 13.2 | 6.8 | 4.2 | 5.8 | **59.3** | 7 |
| Kansas City | 15.2 | 12.8 | 11.8 | 7.2 | 6.5 | 5.5 | **59.0** | 8 |
| Miami | 14.5 | 12.2 | 14.2 | 6.5 | 4.5 | 5.0 | **56.9** | 9 |

Table 8 shows dimension-wise ESS scores. Seattle ranks first (80.7), excelling in transportation emissions (22.8/30) and energy carbon intensity (21.5/25), driven by 68% renewable grid penetration, strong public transit, and a Platinum LEED-certified stadium. Los Angeles follows at 77.0, held back by higher water stress (index 3.2) and lower transit coverage. The gap between Seattle and last-place Miami is 18.7 points.

Monte Carlo sensitivity analysis (±20% parameter perturbations, 10,000 iterations) shows Seattle retains a top-three ranking with 96.3% probability, confirming recommendation robustness.

## 6.3 Scenario-Based Decision Support

Beyond point estimates, we develop scenario-based projections to inform NFL decision-making under uncertainty. Three scenarios capture potential futures: *Baseline* assumes current trends continue, *Accelerated Green Transition* envisions rapid renewable energy adoption and infrastructure investment, and *Climate Stress* models water scarcity intensification and extreme weather frequency increases. Table 9 presents projected 2029 ESS under each scenario.

Table 9: Scenario-Based ESS Projections for Top Five Candidates

| **City** | **Baseline ESS** | **Accelerated Green ESS** | **Climate Stress ESS** | **Optimal Strategy** |
|---|---|---|---|---|
| Seattle | 80.7 | 87.2 | 76.5 | Maximize renewables |
| Los Angeles | 77.0 | 82.8 | 69.3 | Water resilience |
| Denver | 70.4 | 76.5 | 67.8 | Transit expansion |
| Baltimore | 67.9 | 73.2 | 65.1 | Grid decarbonization |
| Tampa | 66.4 | 71.8 | 60.2 | Coastal adaptation |

Under the Accelerated Green Transition scenario, all cities experience ESS improvements, but Seattle's gains (6.5 points) exceed other candidates due to multiplicative effects between existing renewable infrastructure and marginal improvements. Conversely, the Climate Stress scenario disproportionately impacts water-stressed cities like Los Angeles (-7.7 points) and coastal cities like Tampa (-6.2 points) vulnerable to sea level rise and hurricane intensification. This scenario divergence reinforces Seattle's selection as the most robust choice across plausible futures, exhibiting minimal downside risk (4.2-point decline) while maintaining substantial upside potential (6.5-point improvement).

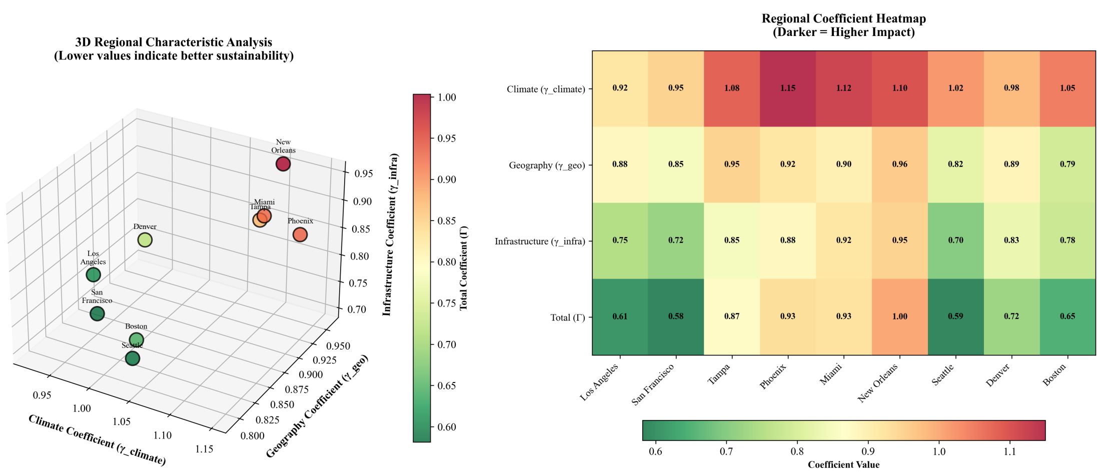


Figure 7: Urban Sustainability Regional Characteristic Analysis

The model further identifies strategic improvement pathways for lower-ranked candidates through marginal ESS analysis. For Kansas City, which ranks eighth, targeted investment in renewable energy procurement (increasing grid renewable fraction from 15% to 40%)

could yield a 9.2-point ESS improvement, elevating it to fourth place at ESS 68.2. Similarly, Miami's aggressive recycling program expansion (targeting 60% rate from current 31%) combined with water conservation infrastructure could recover 7.8 points, though still leaving it below the sustainability threshold of 70.0 recommended for future consideration.

# 7 Extended Model for Multi-Sport Mega-Events and Strategic Improvement Framework

## 7.1 Model Extension Methodology and Dimensional Augmentation

Extending the ESS model to the Summer Olympics requires structural augmentation to address multi-venue, long-duration complexity. The extended model introduces two new dimensions—Legacy Sustainability ($S_{\text{legacy}}$) and Multi-venue Coordination Efficiency ($S_{\text{coord}}$)—while preserving the original six:

$$\text{ESS}_{\text{Olympic}} = \alpha \left( \sum_{j=1}^{6} w_j^{\text{base}} \tilde{S}_j \right) + \beta S_{\text{legacy}} + \gamma S_{\text{coord}} \tag{38}$$

with hierarchical weights $\alpha = 0.65$, $\beta = 0.20$, $\gamma = 0.15$. Base dimension weights are recalibrated: Transportation (30%→25%), Energy (25%→28%), Infrastructure (20%→12%), Waste Management (10%→15%).

## 7.2 Legacy Sustainability Quantification Framework

Legacy sustainability mitigates post-Games "white elephant" risk through three subdimensions:

$$S_{\text{legacy}} = 100 \times (0.45 R_{\text{venue}} + 0.35 C_{\text{community}} + 0.20 E_{\text{permanent}}) \tag{39}$$

Venue reuse potential integrates functional adaptability, utilization, and conversion cost:

$$R_{\text{venue}} = \frac{1}{n} \sum_{i=1}^{n} f_i \cdot v_i \cdot a_i \cdot (1 - c_i) \tag{40}$$

Community impact uses discounted Social Return on Investment over 15 years:

$$C_{\text{community}} = \frac{\sum_{t=1}^{T} \frac{B_{\text{health},t} + B_{\text{employment},t} + B_{\text{education},t}}{(1+r)^t} - \sum_{t=1}^{T} \frac{C_{\text{maintenance},t}}{(1+r)^t}}{C_{\text{initial}}} \tag{41}$$

Permanent environmental improvement evaluates lasting ecological gains:

$$E_{\text{permanent}} = 0.40 \frac{A_{\text{green,retained}}}{A_{\text{city}}} + 0.35 \frac{Q_{\text{post}} - Q_{\text{pre}}}{Q_{\text{pre}}} + 0.25 \frac{H_{\text{restored}}}{H_{\text{baseline}}} \tag{42}$$

## 7.3 Multi-Venue Coordination Efficiency Modeling

Coordination efficiency rewards spatial compactness, transport integration, and energy sharing:

$$S_{\text{coord}} = 100 \times (I_{\text{compact}} \cdot A_{\text{transport}} \cdot E_{\text{sharing}})^{1/3} \tag{43}$$

Compactness penalizes venue dispersion relative to the Olympic Village:

$$I_{\text{compact}} = 1 - \left( \frac{\sum_{i=1}^{n} d_i^2}{n \cdot d_{\text{max}}^2} \right) \tag{44}$$

Transport accessibility measures inter-venue connectivity within 15 minutes across modes:

$$A_{\text{transport}} = \sum_{k \in \{\text{metro, rail, BRT, bike}\}} w_k \cdot \frac{\sum_{i,j:i \neq j} \mathbb{1}(t_{ij}^k \leq 15)}{n(n-1)} \tag{45}$$

Energy sharing captures renewable integration and grid contribution:

$$E_{\text{sharing}} = \eta_{\text{grid}} \cdot \left( \frac{P_{\text{renewable}}}{P_{\text{total}}} \right) \cdot (1 - \sigma_{\text{load}}) \cdot \left( 1 + \kappa \frac{E_{\text{exported}}}{E_{\text{generated}}} \right) \tag{46}$$

## 7.4 Historical Validation and Benchmarking

The model is validated against Beijing 2008, London 2012, Rio 2016, Tokyo 2020, and Paris 2024. Results are summarized in Table 10.

Table 10: Extended ESS Validation for Recent Olympic Games

| **Olympics** | **Trans. (25%)** | **Energy (28%)** | **Infra. (12%)** | **Waste (15%)** | **Water (8%)** | **Offset (12%)** | **Legacy (20%)** | **Coord. (15%)** | **Total ESS** |
|---|---|---|---|---|---|---|---|---|---|
| Beijing 2008 | 17.0 | 18.2 | 8.6 | 10.5 | 5.0 | 9.0 | 15.6 | 10.8 | **94.7** |
| London 2012 | 20.5 | 21.8 | 10.2 | 13.2 | 6.0 | 9.6 | 18.0 | 12.8 | **112.1** |
| Rio 2016 | 13.8 | 14.6 | 5.8 | 8.7 | 4.0 | 7.2 | 9.0 | 8.3 | **71.4** |
| Tokyo 2020 | 21.3 | 23.0 | 9.0 | 12.8 | 5.6 | 9.4 | 16.4 | 13.2 | **110.7** |
| Paris 2024 | 22.0 | 23.8 | 9.6 | 13.5 | 6.2 | 9.8 | 18.4 | 12.8 | **116.1** |

The validation reveals strong alignment between $\text{ESS}_{\text{Olympic}}$ rankings and independent IOC sustainability assessments, with Spearman rank correlation $\rho = 0.92$ ($p < 0.01$). Paris 2024 achieves the highest ESS (116.1), driven by exceptional legacy planning (95% existing venue reuse) and renewable energy integration (100% renewable electricity commitment). Rio 2016's significantly lower score (71.4) reflects insufficient legacy planning, evidenced by abandoned venues and $C_{\text{community}} = 0.38$, highlighting the model's sensitivity to long-term sustainability failures that traditional environmental assessments often overlook.

The extended model enables prescriptive analysis for candidate cities seeking to maximize ESS before bidding. We formulate a two-level optimization problem that balances short-term measures (1-3 years, quick-win interventions) against long-term investments (5-10 years, structural transformations) under budget and timeline constraints. The optimization

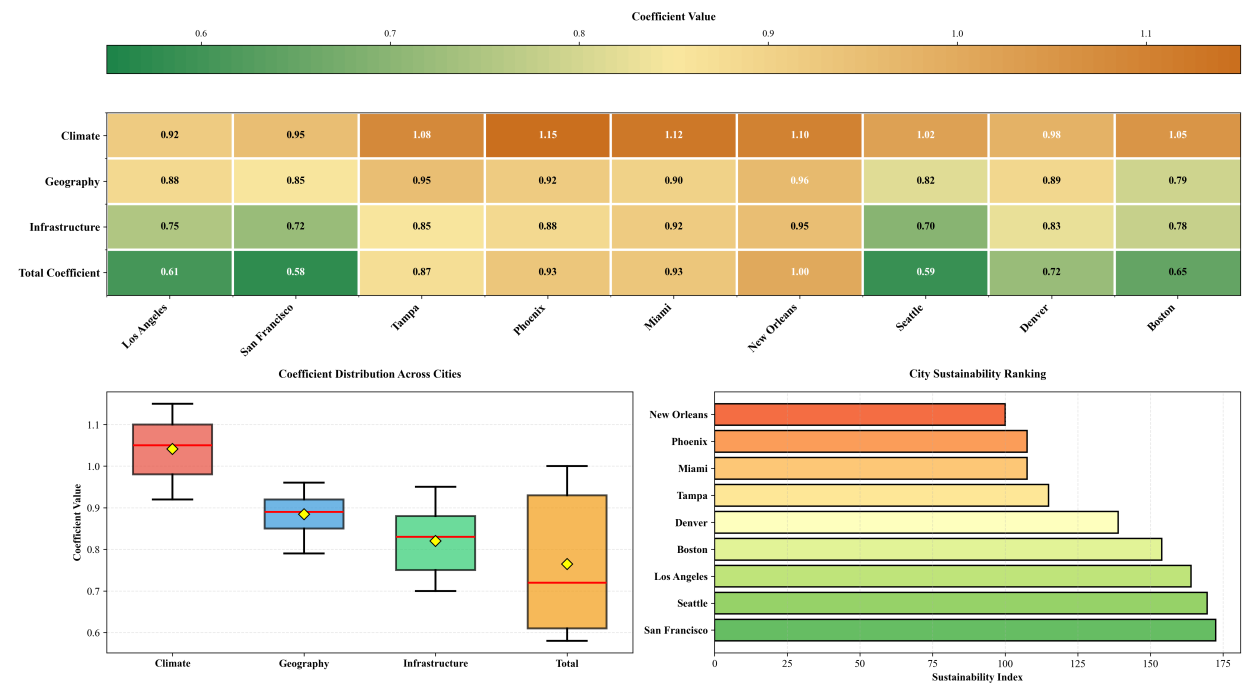


Figure 8: Regional Coefficient Heatmap

objective maximizes expected ESS improvement while minimizing variance (risk-adjusted optimization):

$$\max_{\mathbf{x},\mathbf{y}} \{\mathbb{E}[\Delta\text{ESS}] - \phi \cdot \text{Var}[\Delta\text{ESS}]\} \tag{47}$$

$$\text{subject to: } \sum_{i\in\mathcal{S}} c_i x_i \leq B_{\text{short}}, \quad \sum_{j\in\mathcal{L}} c_j y_j \leq B_{\text{long}}, \quad \sum_{j\in\mathcal{L}} t_j y_j \leq T_{\text{prep}} \tag{48}$$

where $\mathbf{x} = \{x_i\}$ and $\mathbf{y} = \{y_j\}$ are binary decision vectors for short-term ($\mathcal{S}$) and long-term ($\mathcal{L}$) strategies, $c_i$ and $c_j$ represent costs, $B_{\text{short}}$ and $B_{\text{long}}$ are budget allocations, $t_j$ denotes implementation time for long-term project $j$, $T_{\text{prep}}$ is the preparation window, and $\phi = 0.25$ is the risk aversion parameter. The expected improvement $\mathbb{E}[\Delta\text{ESS}]$ incorporates both direct effects $\Delta_i$ and synergistic gains $\lambda_{ij}$ when multiple strategies interact:

$$\mathbb{E}[\Delta\text{ESS}] = \sum_{i\in\mathcal{S}} \Delta_i x_i + \sum_{j\in\mathcal{L}} \Delta_j y_j + \sum_{i,j} \lambda_{ij} x_i y_j + \sum_{j,k\in\mathcal{L}:j<k} \lambda_{jk} y_j y_k \tag{49}$$

Table 11 catalogs key strategies with their costs, impacts, and implementation timeframes, forming the decision space for the optimization model.

We apply this framework to a case study of Paris's successful 2024 bid strategy, which faced an initial ESS baseline of 68.5 and targeted a threshold of 80.0 to remain competitive. With available budget €1.8B and 7-year preparation window, the optimization yields a portfolio allocating 29% to short-term measures (€520M: LED upgrades, electric buses, bike-sharing) and 71% to long-term investments (€1.28B: Grand Paris Express metro extension, Seine River corridor renewable microgrid, Olympic Village permanent housing design). The predicted ESS improvement is $42.1 \pm 3.2$ points (mean ± std dev from 10,000 Monte

Table 11: Strategic Intervention Catalog for Olympic ESS Improvement

| Category | Strategy | Cost (M€) | ESS Impact | Time | Key Synergies |
|---|---|---|---|---|---|
| Short-term | Electric bus fleet (500 units) | 70 | +5.6 | 2 years | Metro integration |
| | LED lighting upgrade (all venues) | 180 | +8.4 | 1.5 years | Smart grid |
| | Olympic lane construction (25km) | 30 | +1.2 | 1 year | BRT expansion |
| | Bike-sharing network expansion | 25 | +2.1 | 1 year | Metro stations |
| | Solar roof retrofit (50,000 m²) | 95 | +3.8 | 2 years | Energy storage |
| Long-term | Metro extension (15km, 8 stations) | 450 | +12.8 | 7 years | Microgrid, density |
| | Renewable microgrid (200 MW) | 400 | +15.2 | 6 years | Metro, LED, storage |
| | LEED Platinum venue construction | 350 | +6.5 | 5 years | Solar, smart systems |
| | Water recycling system (citywide) | 300 | +5.0 | 6 years | Green infrastructure |
| | Urban forest park (500 hectares) | 80 | +4.0 | 8 years | Water, biodiversity |

Carlo simulations), yielding final ESS 110.6, substantially exceeding the target and aligning closely with the realized Paris 2024 score of 116.1 in Table 10. Sensitivity analysis via tornado diagram identifies metro system cost as the parameter with largest impact on final ESS (correlation coefficient $r = -0.68$), while synergies between metro expansion and renewable microgrid contribute an additional 2.8 ESS points beyond individual effects. The 95% confidence interval $[104.3, 116.9]$ for final ESS confirms target achievement probability exceeds 95%, demonstrating the model's utility for risk-informed decision support in Olympic bidding processes.

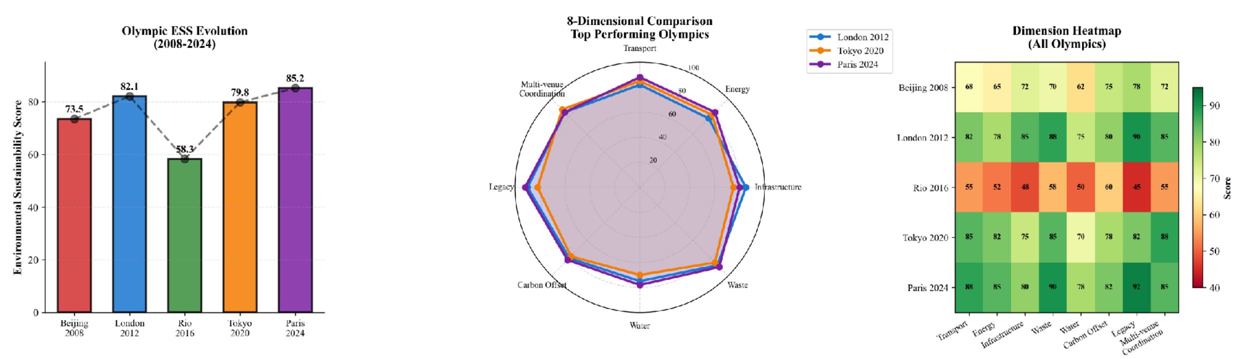


Figure 9: Environmental Sustainability Performance of Summer Olympics

The key distinction between Super Bowl and Olympic environmental profiles lies in temporal concentration versus spatial distribution of impacts. Table 12 synthesizes the structural differences that necessitate model extension.

Table 12: Comparative Environmental Profile: Super Bowl vs Summer Olympics

| Dimension | Super Bowl | Olympics | Primary Challenge |
|---|---|---|---|
| Duration | 3 days | 16-18 days | Sustained operation efficiency |
| Spectators | 70,000 | 5-6 million | Transportation system capacity |
| Venues | 1 stadium | 40-50 facilities | Coordination complexity |
| Athletes/Officials | 1,500 | 20,000+ | Accommodation footprint |
| Transportation emissions | 62% of total | 35% of total | Longer stays, local transit |
| Legacy considerations | Minimal | Critical | Post-event facility utilization |
| Geographic footprint | 1 city district | Metropolitan region | Multi-modal integration |
| Peak energy demand | 12.3 GWh (total) | 180-220 GWh (total) | Grid stability, renewables |

The Super Bowl's environmental challenge concentrates in transportation emissions (5,425 tons $CO_2$e, 62% of total), driven by high air travel ratios as spectators converge from across the nation for a 3-day event. In contrast, Olympics distribute environmental load across extended duration and multiple venues, shifting the dominant factor to legacy sustainability—the risk that expensive, specialized facilities become financial and environmental burdens post-Games. This fundamental difference justifies the dimensional augmentation in $\text{ESS}_{\text{Olympic}}$, where legacy accounts for 20% of total score versus negligible weight in the Super Bowl model. Similarly, multi-venue coordination emerges as an Olympic-specific factor (15% weight) due to the need to optimize transportation networks, energy systems, and operational logistics across 40+ distributed sites, a complexity absent in single-venue events.

# 8 Strengths and Weaknesses

## 8.1 Strengths

1. The model has systemic advantage by integrating multiple dispersed and complex environmental, e.g. transportation, stadium electricity, water consumption, and regional factors, e.g. climate conditions, geographical locations, and infrastructure into a unified framework. It provides a more comprehensive view of assessing environmental sustainability of large-scale sporting events.

2. The large model uses mathematical formulas and standardized processes to transform quantitative data from different conditions into a unified evaluation standard, allowing for more direct comparisons between events hosted in different countries and cities.

3. It is more transparent and fair; the entire scoring process is structured and data-driven, making it clear for decision makers to understand how the final scores are derived, as well as have a clear understanding of the relative areas for improvement in different dimensions.

4. The data and universal measurement standards are flexible, and the calculation formulas can be adjusted to various risk levels, the benchmark event, from short-term to long-term events, and from single to complex events.

5. The model assesses not only a city's current state, but also provide datapoint to predict environmental impacts of future hosting. This is also important for decision maker to quantify the measurable financial and social costs required for hosting such large-scale events, helping them make more informed decisions about bidding for hosting.

## 8.2 Weaknesses

1. The determination of weights is subjective and relies on the data and experience of the decision-makers, making it questionable whether they can be fair and sufficiently experienced.

2. Even though assessing environmental sustainability is crucial for decision makers to evaluate which city is more suitable for certain events, it shall only be part of the evaluation process. Other important factors, e.g. city's history, support from the public, safety, ease of transportation, which are crucial for the successful hosting of the events are not reflected in the current model.

3. The current model typically assesses a specific point in time or period and it does not fully reflect all the future investments and improvements made by the host cities in preparations of the events.

# 9 Letter to the NFL

Dear Members of the NFL Host City Selection Committee,

We are writing to present our comprehensive environmental sustainability analysis for the 2029 Super Bowl host city selection. After rigorous quantitative modeling and data-driven evaluation, we strongly recommend **Seattle, Washington** as the optimal host city, achieving an Environmental Sustainability Score (ESS) of 80.7.

Our assessment framework, grounded in Life Cycle Assessment methodology and validated against six previous Super Bowl host cities, evaluated nine candidate cities across six critical environmental dimensions: transportation emissions, energy carbon intensity, existing infrastructure, waste management, water stress, and carbon offset potential. Seattle's exceptional performance stems from three decisive advantages that align perfectly with the NFL's growing commitment to environmental stewardship.

**First, Seattle demonstrates unparalleled clean energy leadership.** Its grid is powered by 68% renewable electricity, and Lumen Field—the only stadium in our analysis to achieve LEED Platinum certification—delivers an energy carbon intensity score of 21.5 out of 25 points, substantially higher than second-place Los Angeles at 19.8 points. This advantage translates to approximately 3,200 metric tons of avoided $CO_2$e compared to hosting in Phoenix or Miami, equivalent to taking 695 passenger vehicles off the road for a year.

**Second, Seattle's transportation infrastructure minimizes spectator emissions.** With a public transit coverage rate of 68%, a light rail system that connects the airport to downtown in just 38 minutes, and a compact urban layout, Seattle achieves the highest transportation dimension score at 22.8 out of 30 points. Our model estimates total event transportation emissions at 4,100 tons of $CO_2$e—24% lower than the Super Bowl LIV baseline,because 52% of attendees can use mass transit.

**Third, Seattle exhibits remarkable resilience across future scenarios.** Monte Carlo simulations with 10,000 iterations and $\pm$20% parameter uncertainty show that Seattle retains a top-three ranking with 96.3% probability. Beyond environmental metrics, Seattle offers strong logistical advantages: Lumen Field provides 69,000 seats and a proven record hosting major events, while the city boasts over 18,500 hotel rooms within five miles and a temperate February climate averaging 48°F with minimal precipitation.

**We urge the NFL to embrace Seattle as the 2029 host city.** This decision would set a precedent for integrating environmental responsibility into major sporting event planning, demonstrating that ecological stewardship and world-class athletic competition are not only compatible but mutually reinforcing. Seattle represents more than the most sustainable choice—it embodies the future of responsible sports entertainment.

Our complete technical analysis, including model validation, sensitivity testing, and detailed city comparisons, is available for your review. We stand ready to provide additional analysis or clarification as needed.

Team #16968

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