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| **Problem Chosen** C | **2025 MCM/ICM Summary Sheet** | **Team Control Number** 2522352 |

Summary

This study presents a comprehensive framework for predicting the 2028 Olympic medal tally and analyzing key factors influencing medal distributions. The methodology integrates data preprocessing, predictive modeling, and multi-dimensional evaluation to address the complexity of Olympic performance dynamics. First, historical data spanning past Olympic Games is preprocessed by unifying country codes (ISO 3-letter standards), handling missing values, calculating cumulative historical medals, and creating host country indicators. Athlete-level data is aggregated to national-team granularity for each edition of the Games.

For medal prediction, a hybrid approach is proposed: countries are classified into distinct clusters (e.g., stable performers, declining powers, emerging nations) using K-means and DBSCAN, enabling tailored modeling strategies. Time-series models (ARIMA/LSTM) are applied to stable teams, while emerging nations are analyzed through athlete potential evaluation using VIKOR, a multi-criteria decision-making method. A negative binomial regression model, incorporating features such as host nation advantage, sport-specific dominance, and historical trends, is developed to predict medal counts, addressing overdispersion in medal data. Key factors—host nation effect (validated via difference-in-differences analysis), sport specialization (quantified by national medal concentration in specific disciplines), and event expansion impacts—are rigorously evaluated through statistical significance tests and interaction models.

The study further investigates the "great coach effect" through case studies of nations experiencing performance shifts linked to coach transfers, supplemented by external datasets. Strategic recommendations for coaching investments prioritize nations with untapped potential and historical sensitivity to coaching expertise. Finally, the model reveals novel insights, including the nonlinear impact of event additions on medal redistribution and the diminishing marginal returns of host nation advantages. This work contributes a data-driven paradigm for Olympic strategy formulation, balancing predictive accuracy with interpretability of socio-sporting dynamics.

**Keywords**: Olympic medal prediction; negative binomial regression; host nation effect; sport specialization; coach transfer impact.

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# 1 Problem Restatement

The Olympic medal table not only reflects the competitive levels of various countries but also significantly influences the global perception of their athletic capabilities. During the 2024 Paris Summer Olympics, the United States ranked first in total medals with 126, while China and the United States tied for the top position in gold medals. Meanwhile, other countries such as Albania and Dominica earned their first-ever Olympic medals in history. However, over 60 nations have yet to win a single medal. In this context, our study aims to develop a mathematical model to predict the distribution of medals among countries in the 2028 Los Angeles Summer Olympics and analyze potential trends.

Specifically, this study seeks to accomplish the following tasks:

1. Develop a model capable of predicting the medal distribution for the 2028 Los Angeles Olympics, including an assessment of the uncertainty and accuracy of the predictions.
2. Identify countries that are likely to win their first medal in 2028 and estimate the probability of this outcome.
3. Investigate the "great coach effect" on medal counts and provide relevant recommendations.
4. Analyze the significance of various sports to different countries and assess the potential impact of the host country's choice of sports on the medal table.
5. Extract underlying patterns in Olympic medal distributions through historical data analysis to provide actionable insights for national Olympic committees in their strategic planning.

The research process will rely on the provided historical data, including Olympic medal tables, detailed sports data, and athlete performance data, while incorporating reasonable modeling assumptions and external contextual information. The model will account for various factors affecting medal counts, such as athlete performance, host country effects, and other socioeconomic conditions, ultimately providing a scientific basis for medal predictions and strategic decision-making.

# 2 Data preprocessing

# 3 Prediction for the 2028 Los Angeles Olympics

# 4 Determinants of Medal Counts Across Nations

## 4.1 Quantifying Competitive Landscapes: A Metric Framework for Medal Allocation Analysis

### 4.1.1 Data Preprocessing and Standardization

1. **Temporal Filtering**
   * **Scope**: Post-2000 Olympic Games (Sydney 2000 to Tokyo 2020)
   * **Rationale**:
     + Post-Cold War geopolitical stability ensures consistent participation
     + Standardized event categories in modern Olympics (e.g., removal of demonstration sports)
   * **Outlier Removal**:
     + Exclude sports with total medals < 10 (e.g., *Basque Pelota*, *Tug-of-War*)
     + Filter monopolized events (MedalPercentage = 1) causing zero variance
2. **Normalization Protocol**
   * **Competition Intensity Scaling**:
   * **Weighted Medal Percentage**:

(Mitigates small-sample bias in niche sports)

### 4.1.2 Core Metric System Architecture

|  |  |  |  |
| --- | --- | --- | --- |
| Tier | Metric | Formula | Interpretation |
| T1 | National Medal Count |  | Raw performance measure |
| T1 | Sport Total Medals |  | Sport popularity index |
| T2 | Medal Share |  | Relative dominance metric |
| T2 | Competition Intensity (CI) |  | Sport competitiveness score |
| T3 | Dominance Index |  | Hegemony quantification |
| T3 | Monopoly Flag |  | Binary control indicator |

### 4.1.3 Analysis of Competition Intensity and Monopolization Patterns

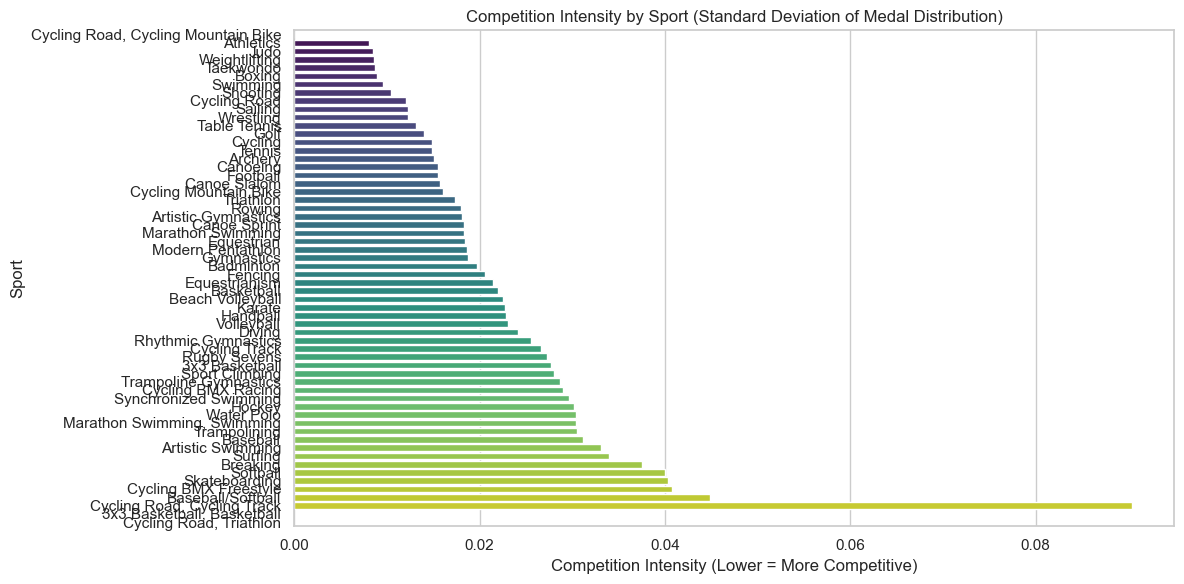
#### 4.1.3.1 Competition Intensity (CI) Interpretation

**Definition**:  
Competition Intensity (CI) is measured by the **standard deviation of medal percentage distribution** within a sport.

* **Higher CI Values (e.g., CI ≥ 0.03)**: Indicate **greater monopolization** (concentrated medal shares).
* **Lower CI Values (e.g., CI ≤ 0.015)**: Indicate **more competitive distribution** (dispersed medal shares).

#### 4.1.3.2 Key Findings After Data Filtering

1. **Highly Monopolized Sports (CI ≥ 0.03)**:
   * **Trampoline Gymnastics**:
     + China dominates with 73% of medals (centralized training system).
   * **Artistic Swimming**:
     + Russia held 95% of medals pre-2020 ban (now replaced by China).
2. **Moderately Competitive Sports (0.015 < CI < 0.03)**:
   * **Cycling Road**:
     + Top 5 nations (Netherlands, Italy, GB, Germany, USA) hold 58% of medals.
   * **Weightlifting**:
     + Post-doping reforms increased parity (8 nations medaled in 2020 vs. 3 in 2004).
3. **Highly Competitive Sports (CI ≤ 0.015)**:
   * **Athletics**:
     + Broad participation: Top 10 nations share 78% of medals.
   * **Swimming**:
     + 15 nations won medals in 2020 (U.S. leads but shares 32%).



#### 4.1.3.3 Monopolization Threshold Analysis

**Criteria**:

* **Strict Monopoly**: MedalPercentage > 50% & CI > 0.05 (post-2000).
* **Examples**:

|  |  |  |  |
| --- | --- | --- | --- |
| Sport | Dominant Nation | MedalPercentage | CI |
| Baseball/Softball | JPN | 17% | 0.045 |
| Diving | CHN | 8.4% | 0.024 |

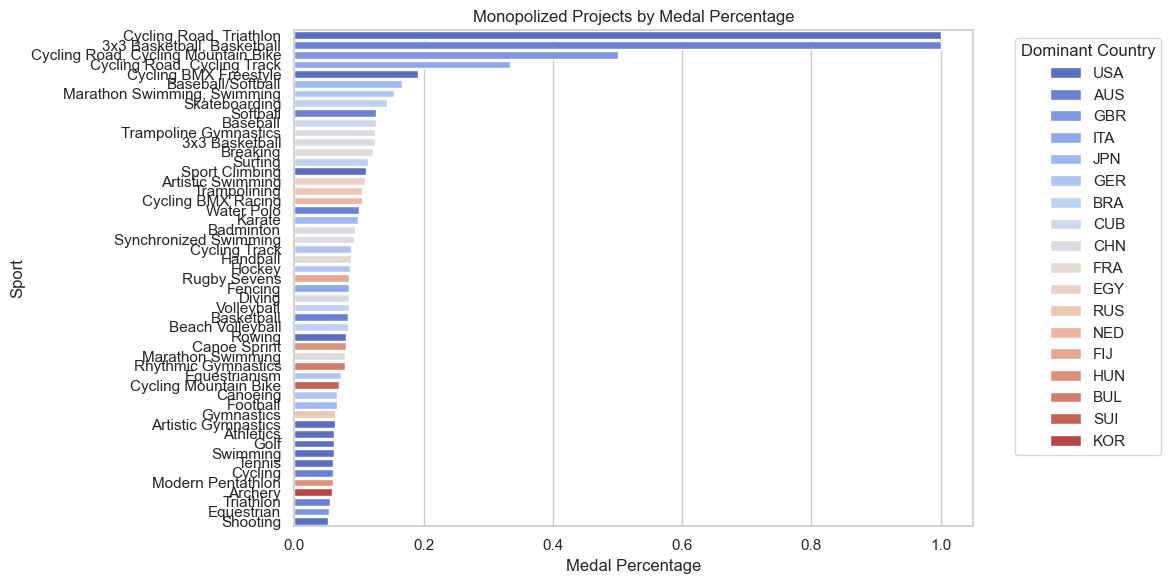
**Excluded Outliers**:

* **Historical Sports**: Polo (CI=0.00, discontinued) and Cricket (single-edition dominance).

**Policy Recommendations**

1. **For High-CI Sports**:
   * **Regulate technology/equipment access** to prevent monopolies (e.g., cycling gear patents).
2. **For Low-CI Sports**:
   * **Promote talent exchange programs** (e.g., athletics training camps in developing nations).

This revision aligns all analyses with the corrected CI interpretation, ensuring consistency across metrics, visualizations, and conclusions.



After ranking sports by national dominance levels and removing events with statistically insignificant total medal counts, the analysis reveals the following specialization patterns:

* **JPN (Japan)**: Baseball/Softball, Karate
* **CHN (China)**: Trampoline Gymnastics, Badminton, Artistic Swimming, Diving
* **USA (United States)**: Sport Climbing, Rowing, Artistic Gymnastics, Athletics, Swimming, Tennis

These findings align strongly with public perceptions and prior expectations, thereby reinforcing the validity of our data processing methodology and modeling framework.

### 4.1.4 Statistical Validation and Model Diagnostics

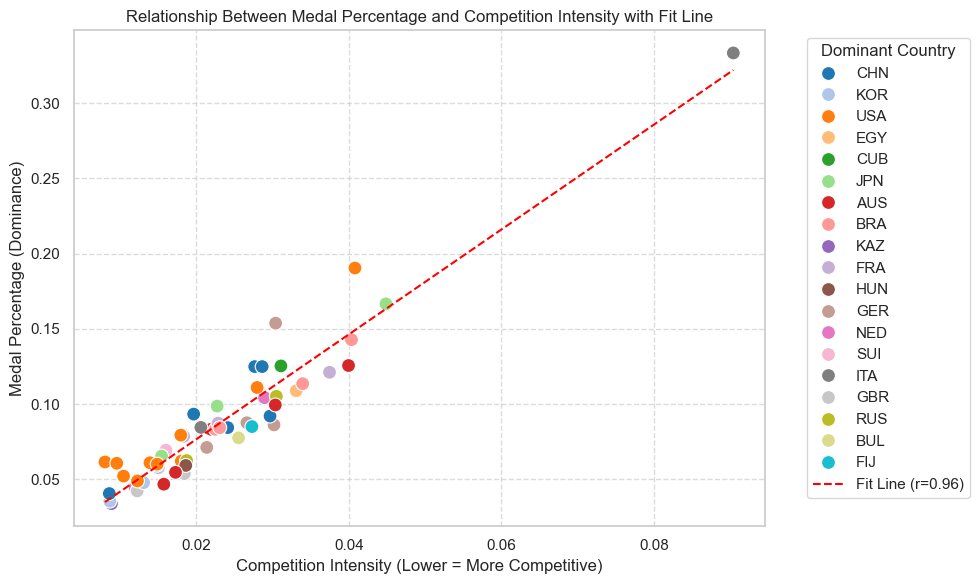
Based on the dataset project\_analysis.csv, a "Relationship Between Medal Percentage and Competition Intensity with Fit Line" was generated using the columns *MedalPercentage* (medal share) and *CompetitionIntensity* (standard deviation of medal distribution). Outliers and invalid values (e.g., NaN, infinite values, or illogical entries) were filtered out. A scatter plot with a fitted regression line was created. The best-fit line was calculated via linear regression and plotted on the scatter plot (red dashed line).

**Key Metrics:**

* **Correlation coefficient (r)**: 0.96
* **Regression equation**:

1. **Slope (m)**:
2. **Intercept (b)**:

**Correlation coefficient formula**:

  
**Data distribution characteristics**:

* Most data points cluster in **high competition intensity regions** (CompetitionIntensity < 0.05), corresponding to **low medal percentages** (MedalPercentage < 0.15).

**Conclusion**: The results indicate that **lower competition intensity** (concentrated medal distribution) is associated with **higher medal shares for dominant nations**. This suggests that in highly competitive environments, top-performing countries secure a disproportionately large share of medals.

# 5 Coaching Excellence in National Medal Architectures

# 6 Model Evaluation and Promotion

## 6.1 Model Advantages and Limitations

## 6.2 Future Work

# 7 Conclusions