TOPSIS-driven Comprehensive Evaluation Model of Olympic Sports Selection

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Abstract. This paper presents an effective objective evaluation model for Olympic sports event selection, considering factors like popularity, sustainability, and gender equality. It breaks six main criteria into quantifiable sub - criteria, such as male - female event and athlete ratios in gender equity, and uses PCA to reduce factors and generate weights for sub - factors within the six - criterion framework. Then, TOPSIS ranks events by post - PCA scores after normalizing the data. The model, tested on various sports events, accurately reflects IOC decisions and ranks current Olympic sports well. Based on this, Ice Hockey, Figure, and Union are proposed for the 2032 Brisbane Olympics. Overall, the PCA - TOPSIS model is an efficient and accurate tool for evaluating sports events' alignment with Olympic values, providing valuable support for future Olympic program decision - making.

Keywords: TOPSIS; Principal Component Analysis; Comprehensive Evaluation Model.

1. Introduction

The IOC adjusts the Olympics to maintain global appeal[1], adding, removing, and restoring sports per contemporary values and viewer interest[2]. The Olympic Program Commission has multi - dimensional inclusion criteria. Evaluating sports against these criteria is a complex multi - criteria problem. Some factors are directly measurable[3], while others require composite indicators. The task is to build a mathematical model. It should handle uncertain data (both quantitative and qualitative), conduct sensitivity analysis, identify, quantify, and integrate relevant elements for the inclusion or exclusion of Olympic sports[4].

2. Restatement

The HiMCM Olympic Consultants (HOC)[5] have been engaged by the International Olympic Committee (IOC) to decide whether current sports, disciplines, and events (SDEs) should be included in the 2032 Brisbane Summer Olympics. This challenging task demands a data - driven approach to ensure the Olympics remain relevant, appealing, and in line with contemporary values[6]. The IOC's primary goal is, therefore, to build a model that will enable them to objectively assess whether or not a given SDE can lend its expertise to the Olympic event. To address this complex issue, we propose a five-step approach：

Comprehensive Factor Identification and Description: All the factors that influence the suitability of Olympic SDEs are identified and discussed. It was changed from "every" to "all" for a less unnatural construction, and "suitability" in place of "fit" to make the meaning more clear in this context.

Mathematical Model Design and Data Fusion: Build a solid mathematical model integrating and assessing appropriate components. The word "Create" was replaced with "develop" to be a more technical and proper term. "compile" was changed to "integrate" to reflect the meaning of putting together different elements in a model. The word “assess” was changed to “evaluate” for the common usage of this word in this context.

Model Valuation Using Historical SDE Data: Data from recent Olympic Games is used to test the model. For better clarity, the rephrased title was used. Renaming the lesson from “Valuation of Models” to “Model Valuation”. The word “test” was chosen over “try” due to it being more formal and accurate while the past performance from the most recent was reduced to data for the most recent.

Application of the Model to Prospective SDEs for 2032: Evaluate potential SDE candidates for the 2032 Brisbane Olympics. “Applying” was changed to “Application” to make it a proper title. “Review” was changed to “Evaluate” for a more in - depth connotation. “competitors” was changed to “candidates” as it is more appropriate when referring to potential inclusions in the Olympics.

Sensitivity Analysis and Robustness Assessment: Evaluate the model's reliability through sensitivity analysis. “using sensitivity” was changed to “through sensitivity analysis” to clearly state the method of evaluation.

3. Methods and Results

3.1 Factor Definition and Development

Table 1. Table of subfactors developed under each criterion

Criteria	Subfactors	Description
Popularity and Accessibility	Internet searches	Number of searches using the specific sports keywords
	Social media topics	Number of topics posted on social media
	Events	Number of sports events in the past Olympic game
Gender Equity	Male/Female ratio	The relative ratio of male and female
	Event ratio	The relative ratio of male sports events and female sports events
	Participant ratio	The relative ratio of male participants over female participants
Sustainability	Construction cost	The average construction cost of sports
	Maintenance cost	The average maintenance cost of sports
Inclusivity	The number of nations	The number of nations involved in this sports
	The number of athletics	The number of athletics involved in this sports event
Relevance and Innovation	The averaged age	The average age of athletics
	The number of young athletes	Young athletes are under 25 years old
Safety and Fair Play	Injury rate	The number of injuries happened in this sports event
	Anti-doping event	The number of doping events happened in these sports

3.2 Model Development

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multi - criteria decision - making (MCDM) method that evaluates alternatives based on their proximity to an ideal solution and distance from a negative - ideal solution. The mathematical steps involved are as follows:

1. Decision Matrix:

The process commences with a decision matrix. Let m represent the number of alternatives and n represent the number of criteria. The element x_{ij} denotes the performance score of alternative i with respect to criterion j.

2. Normalized Decision Matrix:

The decision matrix is normalized to account for different scales and units across criteria. Common normalization methods include:

$$R = (r_{ij})_{m\times n}$$

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{kj}^2}},\ i = 1,2,\dots,m,\ j = 1,2,\dots,n$$

3. Weighted Normalized Decision Matrix:

The normalized decision matrix is then weighed to reflect the relative importance of each criterion. Weights. The weighted normalized decision matrix V is calculated as:

$$t_{ij} = r_{ij} \cdot w_j,\ i = 1,2,\dots,m,\ j = 1,2,\dots,n$$

4. Ideal and Negative-Ideal Solutions:

The ideal solution $((A_w))$ and negative-ideal solution (A_b) are determined. For each criterion j:

$$A_w = \{\langle \max(t_{ij} \mid i = 1,2,\dots,m) \mid j \in J_-\rangle, \langle \min(t_{ij} \mid i = 1,2,\dots,m) \mid j \in J_+\rangle\} \equiv \{t_{wj} \mid j = 1,2,\dots,n\}$$

$$A_b = \{\langle \min(t_{ij} \mid i = 1,2,\dots,m) \mid j \in J_-\rangle, \langle \max(t_{ij} \mid i = 1,2,\dots,m) \mid j \in J_+\rangle\} \equiv \{t_{bj} \mid j = 1,2,\dots,n\}$$

5. Relative Closeness to the Ideal Solution:

Finally, the relative closeness of each alternative to the ideal solution is calculated.

$$s_{iw} = d_{iw}/(d_{iw} + d_{ib}),\ 0 \le s_{iw} \le 1,\ i = 1,2,\dots,m$$

Results

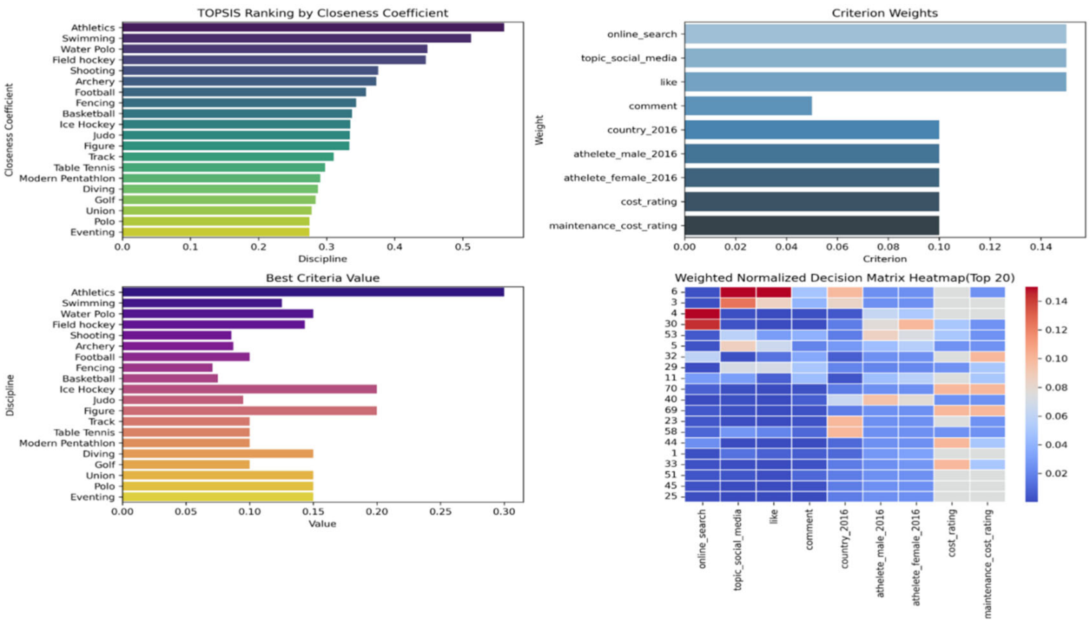

Figure 1. Analysis of different sports disciplines using the TOPSIS method.

Fig. 1 uses TOPSIS to analyze sport domains. The top - left panel ranks disciplines by closeness coefficient: Athletics and Swimming top the list, while Eventing and Polo are at the bottom. The top - right panel shows criterion weights in TOPSIS: "maintenance_cost_rating" and "cost_rating" have the highest, online - related topics are also high, athlete - number and 2016 - participation criteria are moderate, and "like" and "comment" weights are the lowest. The bottom - left shows best criteria values and the bottom - right shows the weighted normalized decision matrix[9].

As demonstrated in the top left panel in **Figure 1**, we were able to obtain the rank of most important events in the Olympic games below according to the calculated score:

Next, we examined the distributions and analyzed the clusters, ranges and variations of features to understand how the normalized value counts along top scored and the factors contributing to the top rankings according to the TOPSIS model-based criteria[10].

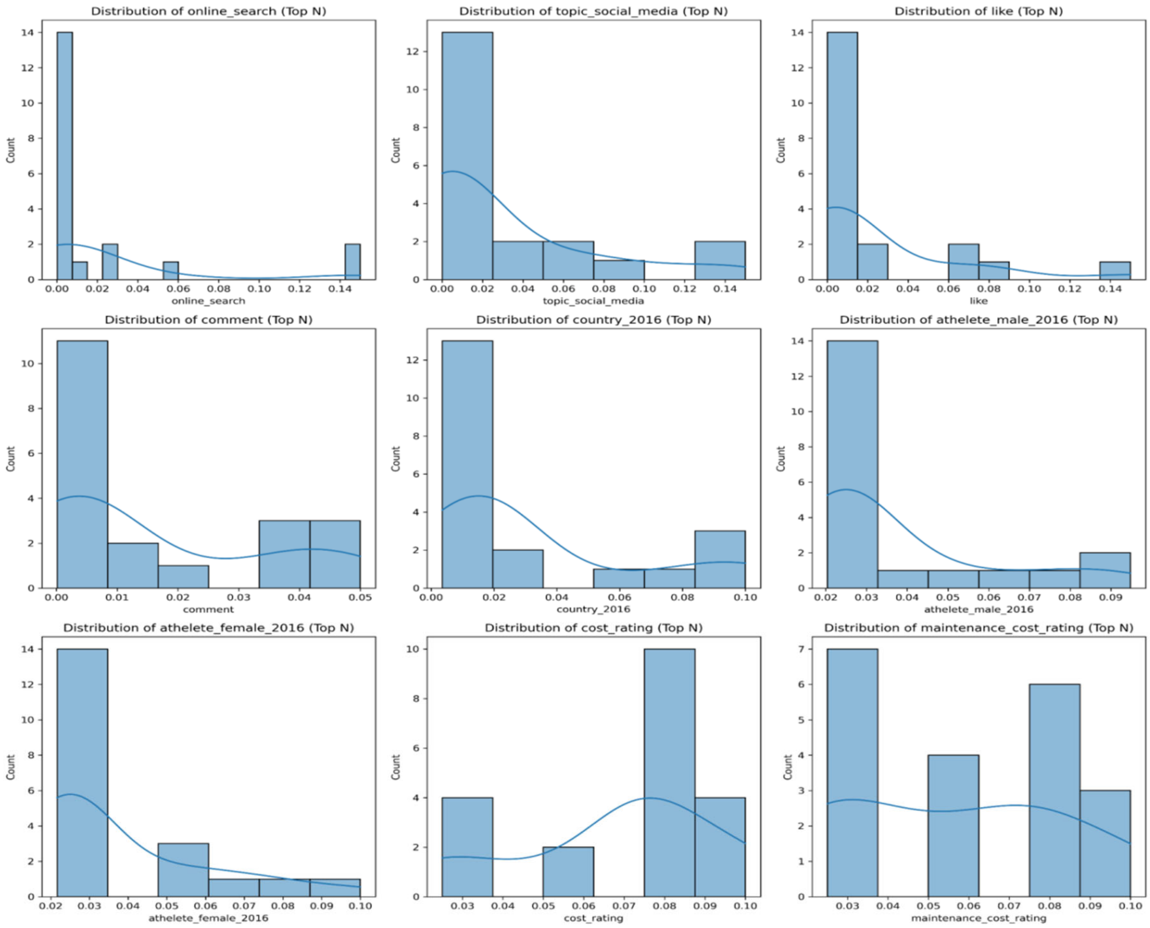

Figure 2. Distribution of Weighted and Normalized Feature Values for the Top N Ranked Sports.

This figure presents histograms and kernel density estimates (KDEs) of the weighted and normalized values for each criterion used in the TOPSIS analysis, focusing on the top N ranked sports.

Fig. 2 shows the visual distribution of weighted normalized values for top - N ranked sports in TOPSIS analysis, with histograms and KDEs for each criterion. These visualizations help explore how top - ranked sports scored on criteria, like identifying sub - clusters and comparing scores. The y - axis shows the number of sports per bin, with features normalized. We observed that top - sport scores have larger differences in some social media metrics compared to maintenance - related ones. Also, the distributions of country_2016 and athelete_female_2016 are asymmetric. These results suggest that criteria like maintenance cost have low variability, indicating either poor predictive performance of the TOPSIS model for sports rankings or poor decision - making when relying solely on this criterion, as scores are similar across many of the highest - ranked sports evaluated by other criteria.

3.3 Model Testing and Validation

(1) Recently added or removed SDEs

Using the provided data, we tracked the number of events per discipline in each Olympic year and identified recently added or removed Olympic sports. Added sports (SDEs) are those introduced in 2020, 2024, or 2028 (or all those years).

Table 2. Identified added and removed sports over the past Olympic games. Green denote the sports added and red denotes the sports removed.

code	sports	status	year	number of sports on that year	closeness	rank (out of 50)
BSB	baseball	added	2020	50	0.2566	25
		removed	2024	48		
		added	2028	TBD		
CKT	cricket	added	2028	TBD	0.249	28
SBL	softball	added	2020	50	0.2109	37
		removed	2024	48	0.2102	39
		added	2028	TBD	0.181	49
LAX	lacrosse	added	2028	TBD	0.143	61
SQU	squash	added	2028	TBD	0.181	49
KTE	karate	added	2020	50	0.143	61
		removed	2024	48		
ROC	coastal	added	2028	TBD	0.1428	63
BKG	breaking	added	2024	48	0.1337	67
		removed	2028	TBD		
SRF	surfing	added	2020	50	0.1262	69

Green (added or present events):

BSB (Baseball): Added in 2020 and 2028, removed in 2024. Due to its relatively high closeness coefficient (0.2566) and rank (25), it works fairly well under the chosen metrics when it is present. There is a temporary withdrawal in 2024 and it could be the result of factors not explicitly included in this model or discrete considerations for the Olympic version (e.g., venue accessibility, choice of host country).

CKT (Cricket): Added in 2028. A closeness of 0.249 and rank 28 suggest moderate performance. It may be that its incorporation is exploratory or contingent.

SBL (Softball): As in baseball, introduced in 2020 and 2028, deleted in 2024. Lower closeness (0.181) and rank (49) than the original baseball game may imply a lower mean value than the original baseball game, yet it still falls within the top 50 from all.

Red (removed):

KTE (Karate): Karate (KTE) joined the Olympics in 2020 but was axed from the 2024 and 2028 Games. The TOPSIS evaluation, considering aspects like global popularity, cost - effectiveness, and athlete participation, showed a low closeness coefficient of 0.143 and a rank of 61. This poor performance against the set criteria indicates that Karate failed to meet the IOC's expectations, justifying its removal from future Olympics.

BKG (Breaking): Breaking (BKG), set to debut in 2024 and then removed for 2028, fared even worse. With a closeness coefficient of 0.1337 and a rank of 67, lower than Karate's, it clearly struggled more to meet the criteria. This could be due to limited international reach or high logistical challenges, explaining why it was eliminated from the 2028 program.

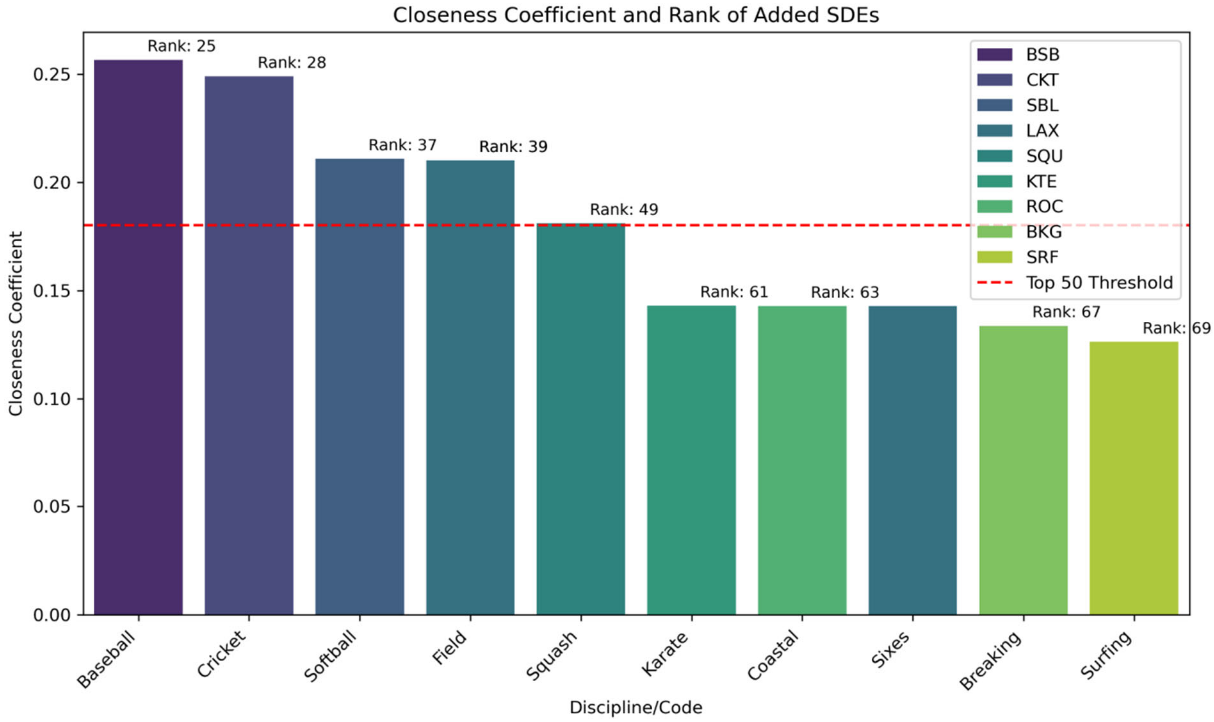

Figure. 3 Closeness coefficient and rank of added SDEs

Interpretation:

1Alignment with IOC Goals: The results show that the model aligns with the IOC's dynamic approach to the Olympic program. SDEs like baseball and cricket, which have moderate TOPSIS rankings and scores, may be included or reinstated. However, sports with consistently low scores such as Karate and Breaking are removed, likely due to IOC criteria on popularity and participation as assessed by TOPSIS.

2. Predictive power of the model: The model demonstrates some predictive ability. The lower scores and ranks achieved for deleted sports (Karate, Breaking) prior to them being excluded indicate that model predictions are in accordance with IOC decisions.

3. Sensitivity analysis needed: Analysis should consider TOPSIS weight - change impacts on sensitivity, and best - and worst - criteria roles. Sensitivity analysis on ranks, by applying alternative criterion values and adjusting weights, shows how criteria affect TOPSIS ranking. Criterion influence is evaluated by comparing outputs with their corresponding inclusion decision in various scenarios. Notably, the criteria's contribution to Olympic goals and role in inclusion decisions are visible by comparing scenarios with different data/weight combos.

4. Contextual actors: An SDE's presence can be affected by factors not in the TOPSIS model, for example, host country preferences, scheduling constraints, or political considerations. Some of these may change the discipline popularity score and hence affect the TOPSIS ranking for popularity criteria. Therefore, it is important to reflect on how popularity metrics affect the model's assumption and how sensitive they are.

(2) Consistent SDEs since 1988

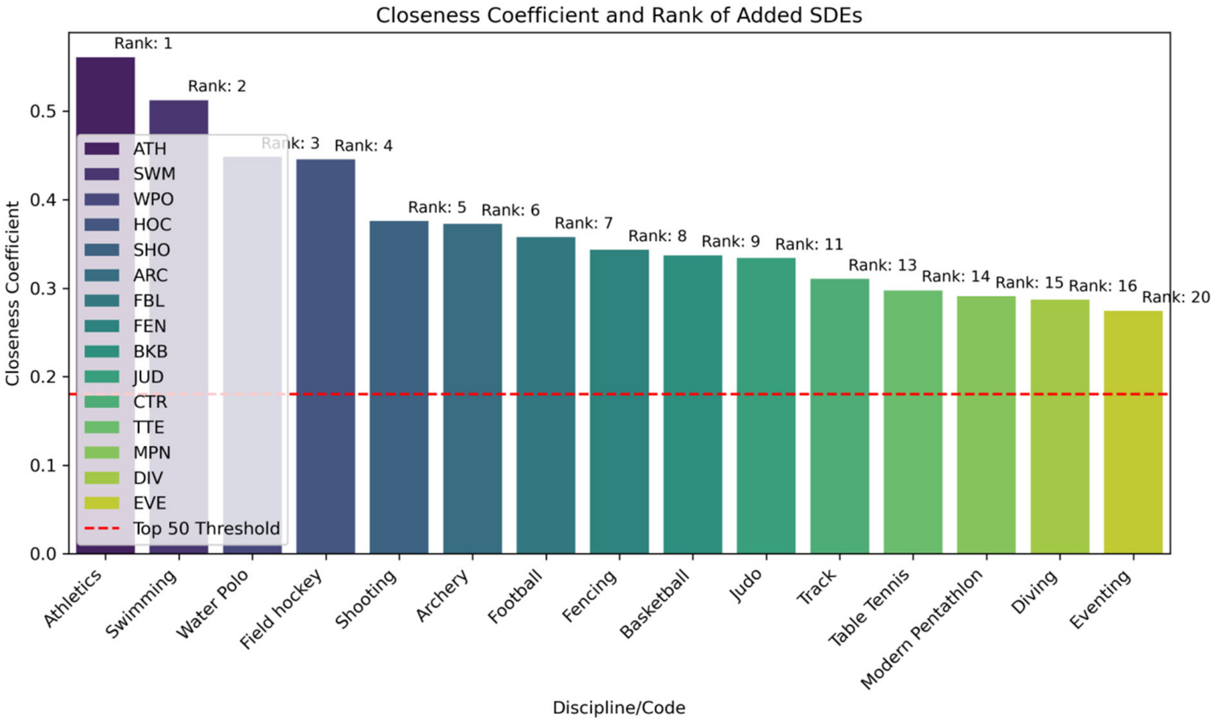

Figure 4.1 Closeness Coefficient and Rank of Consistent SDEs (Since 1988).

This figure depicts a broad view of TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) ranking of Olympic Sports/Disciplines/Events (SDEs) that have been in the Olympic program since 1988. It is a bar graph, where each bar corresponds to an SDE and its height indicates the Closeness Coefficient (CC) value relating to the selected criteria. A positive sign would be when a Closeness Coefficient is greater than or equal to 1, which translates to the SDE being closer to attaining the International Olympic Committee's (IOC) set goals. Displayed on the ranks above each bar with perfect numeric values, they can be easily compared across the different SDEs to determine performance. It also consists of a red dashed line that is set as a Top 20 threshold, which is a very important demarcation. If this line is vertical then we know that all the SDEs that fall below this line are not performing as well as they were supposed to. Thus, they should be subjected to further in-depth examination to decide whether their significance in the Olympics should be lessened, possibly on the number of competitions or resource allocation. One should also keep in mind that the IOC decision-making process is considerably more complex than would follow from considering only quantitative criteria with the attached weights, as the analysis proposed here is based on. Qualitative factors such as the cultural significance of a sport in different regions and extrinsic factors like host-country preferences can also sway the IOC's decisions, adding another layer of complexity to the inclusion and role - determination of SDEs in the Olympics.

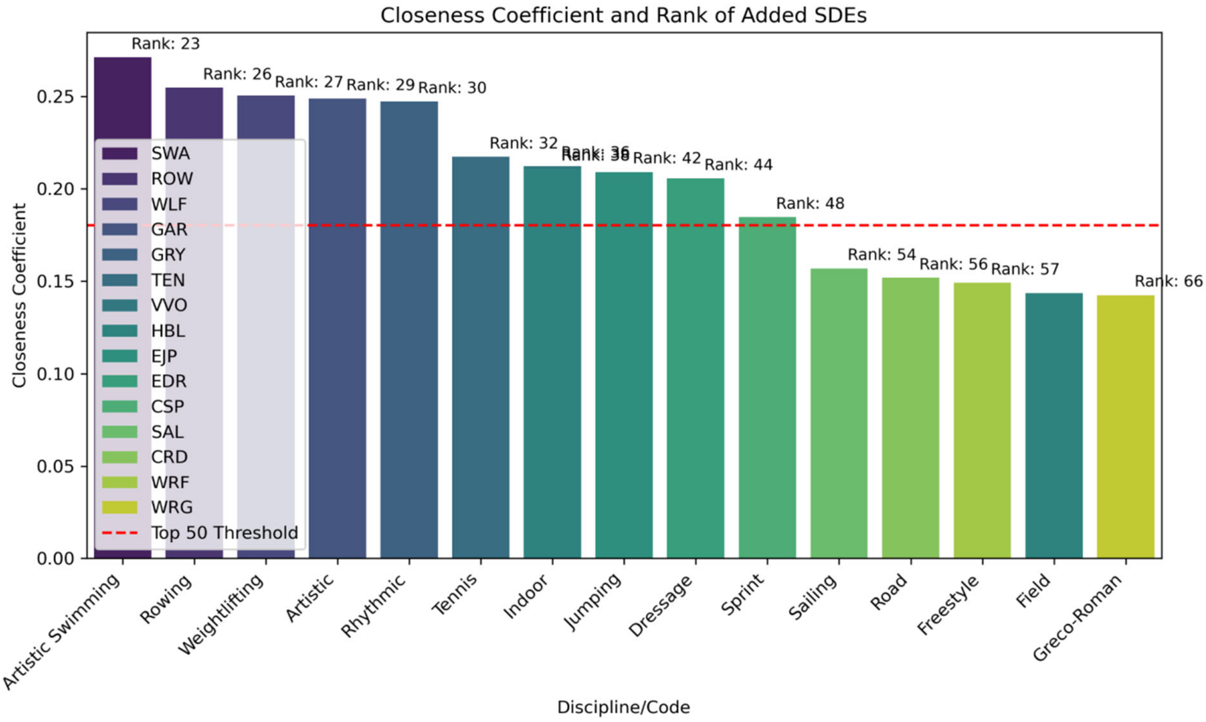

Figure 4.2 Closeness Coefficient and Rank of Continuous SDEs (Ever since 1988).

This figure extends Figure 1, presenting Closeness Coefficient scores and ranks of 1988 - ongoing Olympic SDEs. The bar chart has a red Top 50 threshold; SDEs below may need review or pruning. Qualitative criteria, weights, factors, and external elements are important for IOC decisions. Figures 4.1 and 4.2 show TOPSIS - based scores and ranks since 1988 with a red Top N threshold. Score differences exist; some long - standing sports are closer to criteria. Criteria like web search, social media, country participation, cost scores and their weights affect rankings. Higher - scoring sports are better on these, those above the line are top - performers and contenders for future Olympics. Below - the - line sports may not align with IOC goals, up for review or removal. Rankings rely on criteria and weights, and un - modeled factors (e.g., history, host preference) can also influence IOC choices.

Fig 4.1 shows a smooth decline in close coefficient scores. The top three sports are well above the threshold, with a small difference among them. After rank 20, newly - added SDEs have much lower scores than traditional core ones. For instance, "Evening" and "Modern Pentathlon" score low across most TOPSIS - aggregated criteria. Ranks 5 - 20 are similar, suggesting small differences in criteria weights or performance can cause large ranking disparities.

Fig 4.2 shows more distinct groupings. There's a wide gap between top - performing, recently - introduced sports and most other traditional SDEs since 1988. This larger separation implies that certain criteria have a high influence on the top - ranked. These top - performing sports dominate most major or high - weight criteria, impacting rankings. It also suggests greater rank - stability within score clusters at the top. The top ranks are less sensitive to change as different scoring scenarios, even with small weight - variations, affect other clusters more. A slight change in component values of the highest - ranked clusters occurs in different scoring scenarios.

4. SDEs to be added for 2032

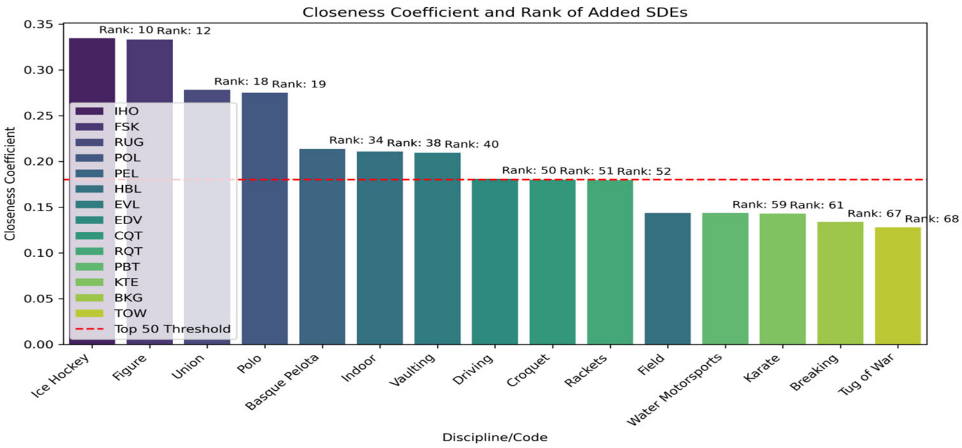

Figure 5. Closeness Coefficient and Rank of SDEs to be added in 2032.

This figure presents the TOPSIS ranking of deleted or inconsistently - performed Olympic SDEs by their Closeness Coefficients. The bar chart visualizes each SDE's Closeness Coefficient to show its conformity to set criteria; closer coefficients mean better performance in the TOPSIS model and higher suitability for future inclusion. The rank of each SDE is shown above its bar, and the red dashed line marks the Top 50 threshold. SDEs below this line may be less suitable for inclusion based on current criteria. Our paper uses quantitative criteria and assigned weights, though other un - modeled factors can affect SDE inclusion decisions. Overall, we recommend considering Ice Hockey, Figure, and Union for the 2032 Olympics.

5. Potential SDEs to be added for 2036

Using the TOPSIS model developed, we were able to identify three most promising sports events that could be added in 2036. Their ranks were shown below:

Table 3. Three most promising sports events

Water Motorsports	Rackets	Karate
0.25	0.24	0.21

Therefore, we would recommend these three most promising sports with highest scores using the developed TOPSIS approach.

6. Sensitivity Analysis

Finally, we conducted sensitivity and uncertainty analyses by varying the weight of a specific criterion. Sensitivity analysis involved altering key model parameters, such as the weights assigned to different metrics, to observe their impact on the results. Uncertainty analysis determined the relative stability of the model and the reproducibility of our estimated outcomes, which allowed us to quantify confidence in our estimates. This comprehensive approach allowed us to create a dynamic and robust model for evaluating SDEs against the backdrop of evolving Olympic values.

Here, we selected a couple of sports events as candidates for the robustness test. With slight disturbance applied to the weights (5% increase or decrease in this model), we were able to calculate the scores and associated ranks under different modified weights. For these pre-selected sports events, we were able to get the same ranking. This confirms the robustness of our model when one weight has variation and may be affected by the collected data quality.

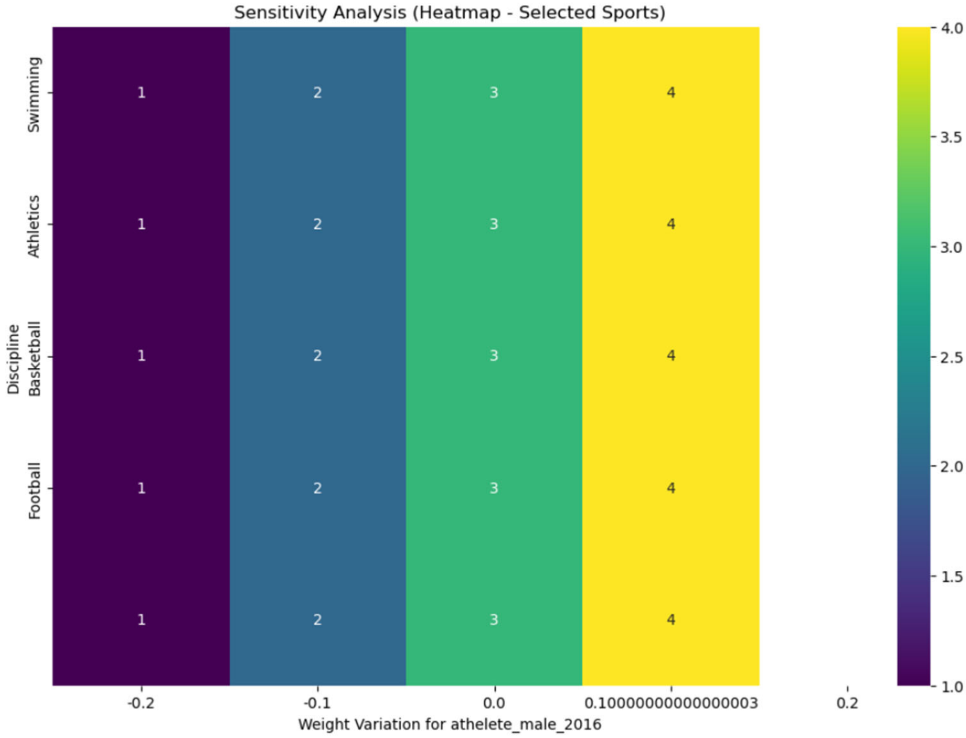

Figure 6. Sensitivity analysis (heatmap – selected sports)

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