Application of the TOPSIS method and gray correlation model in the competitiveness evaluation of basketball teams

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Abstract

The technique for order preference by similarity to an ideal solution (TOPSIS) method is frequently used in multi-factor selection, whereas the gray correlation analysis method is used to study uncertain systems. Thus, a comprehensive model is constructed for 12 teams that are participating in the 2012 London Olympic Games, and the competitiveness of each team is evaluated through these two methods. Results show that the American team is strong enough to win. Furthermore, the evaluation results of the other teams were fundamentally similar to the final results, although they also differed. This model can also reflect the strength of each team objectively in terms of offense, defense, and a combination of both pass and exclude subjective interferences. Therefore, this model feasibly assesses multi-factor competition events in the field of sports.

Keywords: TOPSIS, Gray correlation, Evaluation, Competitiveness, Basketball team

1 Introduction

The technique for order preference by similarity to an ideal solution (TOPSIS) method is commonly used in multi-factor selection [1]. It first confirms the optimal and the inferior solutions and then filters out the distance between the study object with the optimal and the inferior solutions. This method is often used in management decision-making. However, in practical life, many phenomena cannot be determined in practical applications, and the relations among each element cannot be determined [2]. Thus, the gray correlation analysis method should be utilized. This method mainly explores the correlations and interactions of each element in a multi-system. The model combines the TOPSIS and gray correlation analysis methods to accurately solve for the correlation among the evaluation elements and the sequencing problem of the study object [3]. This method is significant in actual research. Gong Jianhua et al. apply the TOPSIS and gray correlation analysis methods to comprehensively assess the operation risks of power grid enterprises, obtain the correlation and relative appropriateness degree between actual and ideal samples, and establish risk management mechanisms [3]. Peng Shaoxiong et al. generated a model using the TOPSIS and gray correlation analysis methods for the third party logistics of the armed forces and present a feasible method for the operational decision-making related to these logistics [2]. Xu Tingxue et al. studied through a similar method and guaranteed a tactical missile [4]. They also set up an evaluation system preliminarily [5]. This method is simple, highly applicable, and reliable.

Since basketball was invented in 1891 in Massachusetts, USA, it has developed rapidly [6]. With the development of sports, the competitiveness of each country in basketball causes such nations to gradually catch up with America in this respect. Xiao Feng et al. analyze the strength of the men's basketball teams in the London Olympic Games through video observation, consultation interviews, and mathematical statistics [7]. They conclude that America remains strong in basketball. However, Spain and Argentina are comparable with America in this regard. Thus, these three teams are included in the first group. The teams that are slightly weak are classified into the second and the third groups. The strengths of the other teams differ slightly, with the exception of the first group [8]. Yan Haibo et al. evaluate and analyze the men's basketball competition in the London Olympic Games, and report that the basketball development levels of various regions are unbalanced [7]. Specifically, the development level in America is high and the overall level in Europe is quite favorable [9]. However, those of Asia and Africa are low. They obtain the relationship between the scores and the integrals of each team through the model. However, the research results vary slightly from the actual ones [10]. At present, sports competition is evaluated by qualitative analysis in China. Many subjective methods of qualitative judgment have been developed, but objective evaluation methods are lacking.

The TOPSIS and gray correlation analysis methods are independent of each other, and each presents its own advantages and disadvantages. Nonetheless, they are often merged during sample analysis because the results obtained from this combination approaches the actual value more than the use of only one method does, and the degree of closeness can meet evaluation requirements although the findings still differ in certain ways. Common methods for comprehensive assessment also include a simple weighting method and an analytic hierarchy process. These methods are frequently used in specific model research, but they are seldom used in sports competition models. Therefore, a model was constructed for 12 men's basketball teams in the 2012 London Olympic Games using the TOPSIS and gray correlation analysis methods to analyze the competitiveness

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of each team. Investigating the application effects of these methods on the competitiveness of basketball teams facilitates the development of a feasible and scientific scheme for evaluating modern competitive sports.

2 Multi-attribute analysis principles of the TOPSIS and gray correlation analysis methods

2.1 PRINCIPLE OF THE TOPSIS METHOD

The problem objectives in actual research often involve complex systems. The total objective of the system should be evaluated, spotted, and optimized. The TOPSIS method can combine data with the subjective experience of evaluators during assessment to address the lack of subjective judgment in the data analysis process. However, the method is limited by the fact that the optimal and inferior value distances of the study object may be equal in the sporting process. As a result judgment is difficult for the decision-maker. Figure 1 presents the implementation process.

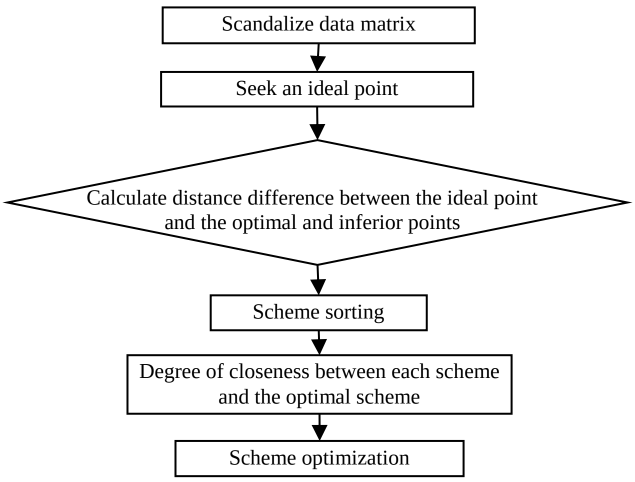

FIGURE 1 Implementation flow chart of the TOPSIS method

2.2 PRINCIPLE OF GRAY CORRELATION ANALYSIS

Gray correlation analysis is often used to study uncertain systems, and the process of theoretical research on the system is historical. The probability theory was first used to study uncertain systems, followed by Later, fuzzy mathematics and the gray correlation analysis method. Fuzzy mathematics is typically used to study problems with unclear extensions and clear connotations, whereas the gray correlation analysis method is used to study problems with clear extensions and unclear connotations. For example, American Teal outplays their opponents by scores of 15—20, wherein the scores between 15 and 20 are a gray concept. The degree of correlation between each element and its actual values can be calculated. Reliability can be evaluated further with respect to the occurrence possibility of each factor in the system. Given that the Chinese statistics level remains in the development stage, the coverage of data and information is insufficient. The gray correlation analysis method can solve this problem rationally; thus, this theory has progressed significantly. However, it is limited in the following ways: The obtained results are based on statistical data. If data reliability is low, then the results differ significantly from the actual value. A visual mathematical explanation of the theory is therefore presented as:

Assuming that the following sequences exist:

$$\vec{a}^{(0)}, \vec{a}^{(1)}, \vec{a}^{(2)}, \vec{a}^{(3)} \quad (1)$$

$$\vec{a}^{(0)} = \left(\vec{a}_1^{(0)}, \vec{a}_2^{(0)}, \vec{a}_3^{(0)}, \cdots, \vec{a}_n^{(0)}\right) \quad (2)$$

$$\vec{a}^{(1)} = \left(\vec{a}_1^{(1)}, \vec{a}_2^{(1)}, \vec{a}_3^{(1)}, \cdots, \vec{a}_n^{(1)}\right) \quad (3)$$

$$\vec{a}^{(2)} = \left(\vec{a}_1^{(2)}, \vec{a}_2^{(2)}, \vec{a}_3^{(2)}, \cdots, \vec{a}_n^{(2)}\right) \quad (4)$$

$$\vec{a}^{(3)} = \left(\vec{a}_1^{(3)}, \vec{a}_2^{(3)}, \vec{a}_3^{(3)}, \cdots, \vec{a}_n^{(3)}\right) \quad (5)$$

$\vec{a}^{(0)}$ is a data series used for reference, whereas $\vec{a}^{(1)}$, $\vec{a}^{(2)}$, and $\vec{a}^{(3)}$ are data series for comparison. Given the relationship among the data series, the following schematic diagram can be made constructed:

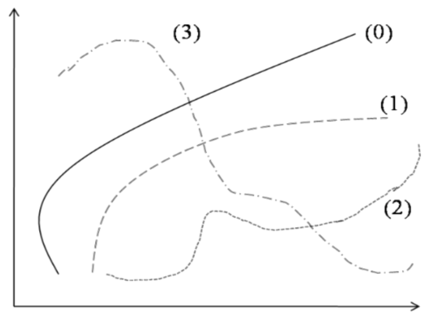

FIGURE 2 2D geometrical association diagram of gray correlation analysis

The analysis object of the gray correlation analysis method is the time series. Figure 2 visually reflects the rule that two objects of similar shapes have a close time series. Thus, the time series of (0) and (1) are the closest, whereas the time series of (0) and (3) are the farthest.

2.3 ANALYSIS METHODS AND STEPS BASED ON TOPSIS AND GRAY CORRELATION

With the ideal scheme of each element, the TOPSIS method is used to analyze distance, whereas the grey correlation analysis is used to examine correlations. This study combines both methods to evaluate the strength of each team. The scheme is ideal for the team perfect in each aspect. The specific handling methods are as follows:

Assuming that $A = \{A_1, A_2, \cdots A_m\}$ is a set of each team (i.e., the scheme set in the decision) and that $F = \{f_1, f_2, \cdots, f_n\}$ is the strength evaluation index of each team (i.e., the attribute set in the evaluation scheme). The evaluation matrix is $X = \left(x_{ij}\right)_{m*n}$ and the weight vector is expressed as $\omega = \left(\omega_1, \omega_2, \cdots, \omega_n\right)^T$. The following relationships are observed: $\sum_{j=1}^{n}\omega_j = 1$。 $i = 1,2,\cdots m$, $j = 1,2,\cdots n$. The specific analysis steps are as follows:

(1) Standardization of evaluation decision-making matrix, i.e.,

$$X = \left(x_{ij}\right)_{m*n} \rightarrow Y = \left(y_{ij}\right)_{m*n} \tag{6}$$

The benefit and cost attributes undergo the following corresponding changes:

$$y_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} \tag{7}$$

$$y_{ij} = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} \tag{8}$$

Formulas (7) and (8) are the benefit and cost attributes and $i = 1,2,\cdots m$, $j = 1,2,\cdots n$.

(2) Calculation of the decision matrix $Z = \left(z_{ij}\right)_{m*n}$, where the weight is considered and $z_{ij} = \omega_j y_{ij}$. On this basis, the positive (optimal strength) and negative (poorest strength) distance solutions (Z^+ and Z^-, respectively) are calculated. These values are selected after conducting a common trend process for the existing data. The positive ideal solution in the optimal data and the negative ideal solution in the most limited data are determined.

$$Z^+ = (z_1^+, z_2^+, \cdots, z_n^+) = \omega \tag{9}$$

$$Z^- = (z_1^-, z_2^-, \cdots, z_n^-) = 0 \tag{10}$$

(3) The distance between the strength of each team and the positive and negative ideal solutions (d_i^+ and d_i^-, respectively) are computed. According to the results, the strength of each team can be determined quantitatively.

$$d_i^+ = \left\| z_i - A^+ \right\| = \sqrt{\sum_{j=1}^{n}\left(z_{ij} - z_j^+\right)^2} \tag{11}$$

$$d_i^- = \left\| z_i - A^- \right\| = \sqrt{\sum_{j=1}^{n}\left(z_{ij} - z_j^-\right)^2} \tag{12}$$

(4) As per the last step, the gray correlation coefficient matrix and the degree of correlation of each team are calculated and a non-dimensionalization treatment conducted. The result derived from the last step is merely a probability value rather than an absolute value. A certain discrepancy is observed between these values and the actual ones. The reliability of data time should be determined by computing the degree of correlation.

The gray correlation coefficient matrix can be written as:

$$R^+ = \left(r_{ij}^+\right)_{m*n}, \tag{13}$$

where

$$r_{ij}^+ = \frac{\min_i \min_j \left|z_j^+ - z_{ij}\right| + \varepsilon \max_i \max_j \left|z_j^+ - z_{ij}\right|}{\left|z_j^+ - z_{ij}\right| + \varepsilon \max_i \max_j \left|z_j^+ - z_{ij}\right|} = \frac{\varepsilon\omega_j}{\omega_j - z_{ij} + \varepsilon\omega_j}$$

$$R^- = \left(r_{ij}^-\right)_{m*n}, \tag{14}$$

where $\varepsilon \in (0,1)$, and the value is generally 0.5. It is also known as the resolution ratio.

The correlation degree of positive distance is expressed as:

$$r_i^+ = \frac{1}{n}\sum_{j=i}^{n} r_{ij}^+ \tag{15}$$

The correlation degree of negative distance is written as:

$$r_i^- = \frac{1}{n}\sum_{j=i}^{n} r_{ij}^- \tag{16}$$

The non-dimensionalization treatment is expressed as:

$$D_i^+ = \frac{d_i^+}{\max_i d_i^+}, D_i^- = \frac{d_i^-}{\max_i d_i^-}.$$

$$R_i^+ = \frac{r_i^+}{\max_i r_i^+}, R_i^- = \frac{r_i^-}{\max_i r_i^-}, \tag{17}$$

where $i = 1,2,\cdots m$.

(5) The degree of closeness and sport is calculated according to the computed results.

Relative degree of closeness:

$$T_i^+ = \frac{D_i^-}{D_i^+ + D_i^-}, \quad S_i^+ = \frac{R_i^-}{R_i^+ + R_i^-} \tag{18}$$

If the values of T_i^+ and S_i^+ are large, then the strength of the team approaches the ideal optimum strength.

$$Q_i^+ = v_1 T_i^+ + v_2 S_i^+, \tag{19}$$

where $v_1 + v_2 = 1$. It reflects subjective preference of calculators. Moreover, $v_1 = v_2 = \frac{1}{2}$.

The final Q_i^+ value is computed according to Formula (19). Each team is then sorted, and the gray correlation analysis method is introduced based on the traditional TOPSIS method. It considers both the degree of deviation from the ideal strength and the similarity. When the calculation results are similar, the S and T values should be modified according to the preference degree of the calculator.

3 Empirical study based on the TOPSIS and gray correlation analysis methods

3.1 OBJECT OF STUDY

The selected study objects are 12 men's basketball teams in the 2012 London Olympic Games. The data are collected from the competition videos and records; thus, they are highly reliable. Research attributes include offense, defense, and combination passing, as well as basketball skills such as number of attempts or hits, steals, offense and defense in relation to defensive rebounds, blocks, and errors.

3.2 DATA HANDLING AND RESULT ANALYSIS

The data of each team are treated in a uniform manner. Table 1 and Table 2 depict the results obtained after normalization.

TABLE 1 Results of common trend treatment of each index of each team (Offense Factors)

Team	Offense				
	Two-point shot	Three-point shot	Penalty shot	Total attempts	Total hit rate
America	0.4589	0.4933	0.5547	0.4688	0.4577
Argentina	0.4212	0.4021	0.5101	0.4514	0.4156
France	0.3845	0.3689	0.4989	0.4055	0.4114
Lithuania	0.4016	0.3554	0.5012	0.4123	0.4061
Tunisia	0.2978	0.3645	0.4154	0.3417	0.3447
Nigeria	0.3569	0.2987	0.4121	0.3714	0.3564
Britain	0.2846	0.3025	0.3078	0.2966	0.3367
Spain	0.4311	0.4877	0.5141	0.4764	0.4457
Russia	0.4432	0.4654	0.4987	0.4089	0.4347
Brazil	0.3978	0.3314	0.3254	0.3364	0.3964
Australia	0.3544	0.3278	0.5031	0.3978	0.3989
China	0.2678	0.3012	0.4512	0.3814	0.3638

TABLE 2 Results of common trend treatment of each index of each team (Defense Factors)

Team		Defense				Combination pass	
		Rebound	Steal	Block		Assist	Error
America		0.3514	0.3391	0.2914		0.2614	0.1578
Argentina		0.3313	0.2918	0.2814		0.2462	0.2065
France		0.3012	0.2789	0.2131		0.2301	0.1687
Lithuania		0.3112	0.2654	0.3074		0.2346	0.2266
Tunisia		0.3011	0.2147	0.2314		0.2047	0.2114
Nigeria		0.2978	0.2358	0.2136		0.2163	0.2212
Britain		0.2257	0.2136	0.1934		0.1978	0.2631
Spain		0.3412	0.3014	0.3124		0.2214	0.1515
Russia		0.3514	0.2678	0.2945		0.2368	0.1869
Brazil		0.2978	0.2314	0.2364		0.2113	0.2141
Australia		0.3312	0.2014	0.2417		0.2465	0.1889
China		0.2879	0.2113	0.2689		0.2264	0.2079

3.2.1 Determination of the vectors of the optimal and inferior solutions

We must calculate the vectors of the optimal and inferior solutions according to the standardized matrix, i.e., the positive and negative distance solutions. In terms of offense, A^+ = (0.4577, 0.4457, 0.4347), A^- = (0.3447, 0.3564, 0.3367). In relation to defense, A^+ = (0.3514, 0.3412, 0.3312), A^- = (0.3447, 0.3564, 0.3367). With regard to combination passing, A^+ = (0.2614, 0.2462, 0.2368), A^- = (0.1978, 0.2047, 0.2113). Based on the statistics above, good teams such as America and Spain are dominant, whereas poorly performing teams such as China and Tunisia are inferior in all indices. The data of each team are obtained from records of competition against Tunisia and are highly persuasive. America is superior over the other teams in eight indexes and deserves the top title of in the basketball field.

3.2.2 Solution, analysis, and evaluation of the optimal and inferior distances

Using Formula (17), we solve the optimal and inferior distances D_i^+ and D_i^- and the gray correlation degrees R_i^+ and R_i^-, shown as in Table 3.

TABLE 3 Overall competitiveness of each team

Team		Overall competitiveness			
		D_i^+	D_i^-	R_i^+	R_i^-
America		0.7856	0.0175	0.6678	0.4496
Argentina		0.5678	0.1476	0.5478	0.5478
France		0.3645	0.4575	0.4369	0.5345
Lithuania		0.2077	0.5347	0.3987	0.6087
Tunisia		0.0621	0.7758	0.2247	0.6781
Nigeria		0.0778	0.7898	0.2174	0.6987
Britain		0.2410	0.6475	0.3045	0.5967
Spain		0.7789	0.0689	0.6589	0.4501
Russia		0.7645	0.0747	0.6478	0.4568
Brazil		0.1978	0.4978	0.4578	0.5340
Australia		0.2147	0.5748	0.3579	0.5014
China		0.0861	0.7989	0.2069	0.6678

Using Formula (19), we calculate Q_i^+ and sort the strength of each team according to the obtained value. The teams are ranked as follows in terms of offense: America > Spain > Russia > Argentina > France. The ranking in relation to defense is: America > Russia > Spain > Australia > Argentina. That with respect to combination passing is: America > Argentina > Russia > Spain > Lithuania. After synthesizing the three indices above, the final ranking is as follows: America > Spain > Russia > Argentina > France > Lithuania > Brazil > Britain > Australia > Nigeria > Tunisia > China. In the actual competition, the top eight teams included America, Spain, Russia, Argentina, Brazil, France, Australia, and Lithuania. The American team defeated the Spanish team to capture the gold medal for men's basketball in the London Olympic Games.

The model calculation results may resemble the actual results, but both sets of findings differ. The discrepancy may be attributed to the following reasons: (1) the model analyzes only technical indices that can be quantified. However, other unquantifiable indices (e.g., the competition and health statuses of athletes) can influence the competition results as well. Such indices cannot be judged by on-site changes and decision-maker experience alone; thus, they are uncontrollable; (2) in basketball competitions, the on-site commands and tactical changes made by the team coach also influence competition performance significantly. The teaching styles of coaches strongly affect the playing techniques of a team; (3) Teams encounter numerous uncertain factors in various sports competitions that are usually ascribed to fortune.

The TOPSIS and gray correlation analysis models examine digital statistics, and the obtained results are relatively objective. However, the models cannot generate objective findings under certain special circumstances. Nonetheless, the produced results are close to the final results. The results can be sufficiently defined for such analysis by simplified treatment. Hence, this method is operable, and scientific, and reliably predicts and analyzes multi-factor sports competitions.

4 Conclusion

This study applied TOPSIS and gray correlation analysis models to 12 men's basketball teams in the 2012 London Olympic Games. The strengths of each team in terms of offense, defense, and combination passing competitiveness are visually detailed based on these model. Based on existing data, the teams are ranked as follows with regard to competitiveness: America > Spain > Russia > Argentina > France > Lithuania > Brazil > Britain > Australia > Nigeria > Tunisia > China. However, the final competition results disagree slightly with this conclusion. In addition, the values of other aspects also approach the actual ones; in particular, the top and bottom four teams display high degrees of conformity. The difference in the middle four teams may attributed to the slight difference in the strength levels of the four teams and the detection of errors in the calculation process. In general, this method is simple to operate, with clear concepts and high reference value. Thus, this method evaluates the strength of each team in an accurate, highly reliable, and objective manner for sports competition, with the exception of the effects of the main deviation factors. Moreover, it is feasible for use in the analysis of multi-factor complex systems in sports competitions.

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