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Comparing The Performance of Women's National Volleyball Teams at the 2024 Paris Olympics Using Rams, Raps and Other Multi-Criteria Decision Making Methods

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Abstract

Multi-criteria decision-making techniques (MCDM) have been used extensively in ranking studiesdue to their ease of application and interpretation. While there are many MCDM methods, new methods are also being developed and added to the literature. In this study, RAPS and RAMS methods, which have been developed recently, were used to rank the teams in the women's volleyball category of the 2024 Paris Olympics by using the statistics announced by the Olympic Committee. The rankings obtained are compared and interpreted with both the rankings obtained from other MCDM methods and the actual rankings obtained according to the Olympic results.

Keywords: Multi-criteria decision making, RAMS, RAPS, volleyball

Introduction

The most important step for the execution of a process is the decision making step. Multi-criteria decision-making methods (MCDM), which have been widely used in recent years, provide decision makers with the opportunity to manage processes better and in a shorter time compared to the use of other methods. MCDM refers to a group of methods used to rank, compare and select multiple factors or alternatives (Zare, et al., 2016). Multivariate data analysis methods can be used to analyze different variables, but it would be appropriate to use multi-criteria decision making methods to find the best option among the available alternatives (Ananda Murugan & Nataraj, 2024). In these methods, weights that are objective or subjective depending on the criteria and express the relative importance of the criteria in terms of alternatives are used (Alao, Ayodele, Ogunjuyigbe, & Popoola, 2020).

In the literature, there are many studies in the field of sports based on multi-criteria decision making methods. Some of these studies are directly aimed at sports teams and some of these studies are aimed at the improvement of sports fields and their environments.

In this study, it is aimed to determine the rankings of the teams participating in the women's volleyball competitions

in the 2024 Paris Olympics according to the Olympic statistics and to compare them with their actual rankings. For this purpose, team statistics announced at the end of the Olympics on August 10, 2024 were used. Different multi-criteria decision-making techniques were applied by maximizing or minimizing some of the variables, consisting of 7 variables related to the teams of 12 countries participating in the Olympics. In the study, mainly two relatively new methods are explained in detail. One of these methods, RAPS (ranking alternatives by perimeter similarity) uses the concept of perimeter similarity in ranking alternatives, while the other method, RAMS (ranking alternatives by median similarity) uses median similarity in ranking alternatives. The weighting values used in all methods are based on the information obtained from five experts in volleyball. Also ELECTRE, PROMETHEE, TOPSIS and VIKOR methods, which are frequently used in the literature, were also applied in the study and rankings were obtained and all ranking findings were compared with the actual ranking obtained according to the Olympic results.

Literature Review

Multi-criteria decision-making techniques, which are more preferred than many other statistical methods in terms of their advantages in the application and interpretation process, have been used to make different measurements in the field of sports. In these studies, the effects of sports inareas such as economy, logistics, tourism and technology have been tried to be measured.

Karaköprü and Kabadurmuş (2019) revealed the best transportation alternative for a Turkish volleyball sports club to competitions by using the Analytic Hierarchy Process (AHP) in the weighting process and applying the ELECTRE method. For this purpose, they determined cost, comfort level, time and prestige variables as criteria (Karaköprü & Kabadurmuş, 2019).

In their study, Özel and Türkmen (2023) found that the Turkish Bocce Bowling and Darts Federation's 42 coaches and analyzed the criteria that are thought to affect talent in the relevant Bocce branch with the Analytic Hierarchy Process. As a result of the study, cognitive characteristics, psycho-social characteristics, motoric characteristics, anthropometric and physical characteristics were determined as variables that may be important in talent selection and talent development in Bocce (Özel & Türkmen, 2023).

Xu et al. (2024), based on the DPSIR model proposed by the OECD, examined the socioeconomic variables that they thought could affect the development of sport in 31 cities in China andevaluated the development of competitive sport using Entropy and TOPSIS methods. With the help of the findings, they also presented strategies to be promoted at the end of their study (Xu, Lin, & Qiu, 2024).

In their study, Nikša et al. (2021) calculated the relative importance coefficients of the serve- volley playing style for 18 performance evaluation criteria, taking into account the opinions of 7 tennis experts. For this, they used the Analytic Hierarchy Process (Nikša, Mladen, & Ljubica, 2021).

Nasiri et al. (2018) used the fuzzy analytic network process method to evaluate the importance of different performance criteria for each position on the field in the formation process of a football team. The scores obtained by different players for each position were calculated using the PROMETHEE II method. Finally, they used data envelopment analysis to identify the most efficient Pareto solution that determines the status of each player. In their study, transfer situationsfor 60 players were determined for a real soccer team, taking into account their positions on the field (Nasiri, Ranjbar, Tavana, Santos Arteaga, & Yazdanparast, 2019).

In addition, Urosevic et al. compared multi-criteria decision making methods and listed the advantages and disadvantages of the methods compared to each other in order to facilitate applications. The relevant table is simplified and presented as follows only on the basis of the MCDM methods that will be used in this study (Uroševic, Gligoric, Miljanovic, Beljic, & Gligoric, 2021)

Table 1. Comparison of the methods used in the study

Method	Advantages	Disadvantages	Year
ELECTRE	Takes uncertainty and vagueness into account. No need for independence of attributes. Very poor performance on a single criterion may eliminate an alternative from consideration.	Relatively complex algorithm. A complete ranking of the alternatives may not be achieved.	1966
VIKOR	Usable for problems with difficulties in expressing preferences. Stability analysis included.	Quantitative information is necessary. Needs initial weights. The ranking needs can be performed with different values of variables' weights.	1980
TOPSIS	Works with a fundamental ranking. Complete use of allocated information. • Simple computation process.	Not considering correlation of attributes. A strong deviation of an indicator from the ideal solution strongly influences the results. Suitable when the indicators of alternatives do not vary very strongly.	1981
PROMETHEE	Useful with alternatives that are difficult to harmonize. Using both qualitative and quantitative information. Potential for inclusion of uncertain and fuzzy data.	No clear method for assigning criteria weights. Moderately complex computation process.	1986

Source: (Uroševic, Gligoric, Miljanovic, Beljic, & Gligoric, 2021)

Methodology

There are a large number of CRM methods used in the literature. In this section, the application processes of RAPS and RAMS methods used in this study are explained in detail.

RAPS Method

In the RAPS method, which is one of the multi-criteria decision making methods, unlike other methods, each alternative is considered as the perimeter of a shape and the score of an alternative is obtained by dividing the perimeter of that shape by the perimeter of the optimal alternative. Perhaps due to this difference, the RAPS method has recently become one of the most preferred methods (Van Thien, Tien Dung, & Trung , 2024).

The implementation steps of the RAPS method are given below:

Step 1: Creating the decision matrix

A decision matrix is created where alternatives and criteria are shown together.

$$D = [x_{ij}]_{mxn} = \begin{bmatrix} A/C & C_1 & C_2 & \dots & C_n \\ A_1 & x_{11} & x_{12} & \dots & x_{1n} \\ A_2 & x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_m & x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (1)$$

$A=[A_1, A_2, \dots, A_m]$, denotes m alternatives and, $C=[C_1, C_2, \dots, C_n]$ denotes n criteria. At this stage, the criteria to be maximized and minimized are determined.

Step 2: Normalization of the decision matrix

Equation (2) is used for the criteria that are decided to be maximized in the first step.

$$r_{ij} = \frac{x_{ij}}{max_i(x_{ij})}, \qquad \forall i \epsilon [1,2,..,m] \wedge j \epsilon S_{max} \tag{2}$$

Equation (3) is used for the criteria that are decided to be minimized in the first step.

$$r_{ij} = \frac{min_i(x_{ij})}{x_{ij}}, \qquad \forall i \epsilon [1,2,..,m] \wedge j \epsilon S_{min} \tag{3}$$

S_{max} indicates the set of criteria to be maximized and ve S_{min} indicates the set of criteria to beminimized. As a result of the normalization process, the matrix is formed as follows.

$$R = [r_{ij}]_{mxn} = \begin{bmatrix} A/C & C_1 & C_2 & \dots & C_n \\ A_1 & r_{11} & r_{12} & \dots & r_{1n} \\ A_2 & r_{21} & r_{22} & \dots & r_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_m & r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix} \tag{4}$$

Step 3: Constructing the weighted normalized decision matrix

The weight matrix is determined by using one of the multi-criteria decision-making methods such as expert judgment or AHP. Whichever method is preferred, the values that make up the weight matrix, sum must be equal to 1 ($\sum_{j=1}^{n} w_j = 1$).

Based on this, weighted normalized values are calculated by equation (5).

$$u_{ij} = w_j r_{ij}, \forall i \in [1,2,\dots,m], \forall j \in [1,2,\dots,n] \tag{5}$$

Thus, the weighted normalized decision matrix is shown as follows.

$$U = [u_{ij}]_{mxn} = \begin{bmatrix} A/C & C_1 & C_2 & \dots & C_n \\ A_1 & u_{11} & u_{12} & \dots & u_{1n} \\ A_2 & u_{21} & u_{22} & \dots & u_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_m & u_{m1} & u_{m2} & \dots & u_{mn} \end{bmatrix} \tag{6}$$

Step 4: Identifying the best alternative

The following equation is used for each component in determining the best alternative.

$$q_i = \max(u_{ij} | 1 \le j \le n) \, \forall i \epsilon [1,2,\dots,m] \tag{7}$$

Based on this, the best alternative set is created as shown below.

$$Q = \{q_1, q_2, \dots, q_j\}, \; j = 1,2,\dots,n \tag{8}$$

Step 5: Decomposition of the best alternative

In this step, the best alternative in two clusters or two combinations is separated.

$$Q = Q^{max} \cup Q^{min} \tag{9}$$

$$Q = \{q_1, q_2, \dots, q_k\} \cup \{q_1, q_2, \dots, q_h\}\,;\;\; k + h = j \tag{10}$$

Where k is the total number of criteria to be maximized and h is the total number of criteria to be minimized.

Step 6: Decomposition of each alternative

Similar to the previous step, each alternative is parsed.

$$U_i = U_i^{max} \cup U_i^{min}\,,\;\; \forall i \epsilon [1,2, \dots m] \tag{11}$$

$$U_i = \{u_{i1}, u_{i2}, \dots, u_{ik}\} \cup \{u_{i1}, u_{i2}, \dots, u_{ih}\};\;\; \forall i \epsilon [1,2, \dots m] \tag{12}$$

Step 7: Calculating the magnitudes of the components of the alternatives

The magnitudes for each component of the best alternative are calculated as follows.

$$Q_k = \sqrt{q_1^2 + q_2^2 + \cdots + q_k^2} \tag{13}$$

$$Q_h = \sqrt{q_1^2 + q_2^2 + \cdots + q_h^2} \tag{14}$$

Similarly, the same method is applied for all other alternatives.

$$U_{ik} = \sqrt{u_{i1}^2 + u_{i2}^2 + \cdots + u_{ik}^2}\,,\quad \forall i = [1,2, \dots, m] \tag{15}$$

$$U_{ih} = \sqrt{u_{i1}^2 + u_{i2}^2 + \cdots + u_{ih}^2}\,,\quad \forall i = [1,2, \dots, m] \tag{16}$$

Step 8-a: Ranking alternatives by perimeter similarity (RAPS)

The perimeter of the optimal alternative is expressed as the perimeter of a right-angled triangle. The components Q_k and Q_h denote the base and the right side of this triangle, respectively.

$$\mathrm{P} = Q_k + Q_h + \sqrt{Q_k^2 + Q_h^2} \tag{17}$$

The perimeter value for each alternative is calculated in the same way.

$$P_i = U_{ik} + U_{ih} + \sqrt{U_{ik}^2 + U_{ih}^2} \quad (18)$$

Perimeter similarity is calculated as the ratio between each alternative perimeter and theoptimal alternative perimeter.

$$PS_i = \frac{P_i}{P}, \quad \forall i = [1,2,\dots,m] \quad (19)$$

According to the descending order of PS_i, the best alternative is determined as the alternative with the highest PS_i value (Turanlı, Özden, & Gerçeker, 2024), (Uroševic, Gligoric, Miljanovic, Beljic, & Gligoric, 2021), (Abdulaal & Bafail, 2022).

RAMS Method

The RAPS method used perimeter similarity. In the RAMS method, which is proposed as an alternative to this method, it is proposed to use median similarity instead of perimeter similarity (Abdulaal & Bafail, 2022). In the RAMS method, where the same process as the RAPS method is applied until the eighth step, median values are used in the eighth step and the following calculations are made.

Step 8-b: Ranking alternatives by median similarity (RAMS)

The median of the best alternative is expressed as the median of the right angle used for the RAPS technique.

$$M = \frac{\sqrt{Q_k^2 + Q_h^2}}{2} \quad (20)$$

The median for each alternative is calculated in the same way.

$$M_i = \frac{\sqrt{U_{ik}^2 + U_{ih}^2}}{2} \quad (21)$$

Median similarity is calculated as the ratio of the median value calculated for each alternative to themedian value of the optimal alternative.

$$MS_i = \frac{M_i}{M}, \quad \forall i = [1,2,\dots,m] \quad (22)$$

According to the descending order of MS_i, the best alternative is determined as the alternative with the highest MS_i value (Abdulaal & Bafail, 2022).

2024 Olympic Games Women Volleyball Category Rankings with RAPS and RAMS

In the Olympic Games, which are held every four years, competitions are organized in different branches in sports and Olympic champions are announced for the relevant branches. In this study, women's volleyball is analyzed for the Olympics held in Paris in 2024.

According to their world rankings and success in preliminary tournaments, 12 women's national volleyball teams competed in the Olympics in 2024. The countries represented by these teams are shown in Table 3. In the fixture formed in 4 groups, the first two teams of each group advanced to the quarterfinals and the Olympic champion was determined as a result of the ongoing competitions. In 2024, Italy was the country that won the Olympic championship in the women's national volleyball branch.

In this study, the statistics taken from the official website of the 2024 Paris Olympics (Olympics, 2024) and given on the basis of countries were used. The criteria used for comparing the teams in the study are shown in Table 2.

While creating the data set, averages were used by calculating the values per match for the variables due to the different number of matches played by the teams during the tournament. Out of the countries listed in Table 3, France, Japan, Kenya and the Netherlands, who were eliminated in the group matches, played 3 matches during the tournament; China, Dominican Republic, Poland and Serbia, who completed the first round, played 4 matches; Brazil, Italy, who played in the quarterfinals, semifinals and finals, Turkey and the United States played 6 matches and averages are calculated based on the number of matches.

Table 2. Criteria

C1	C2	C3	C4	C5	C6	C7
Attack errors	Blockfailures	Block points	Service failures	Service numbers	Successful reception(no points)	Attack score

The aim of the study is to determine how the national team rankings of the countries should be at the end of the tournament, considering the criteria given in Table 2. For this purpose, some of the multi-criteria decision making techniques will be used and the results obtained will be compared. In the application phase of the study, details of RAPS and RAMS methods are presented, which are also detailed in the methodology section.

Table 3. Alternatives

Alternative No	Country	Alternative No	Country
A1	Brazil	A7	Kenya
A2	China	A8	Netherlands
A3	Dominican Republic	A9	Poland
A4	France	A10	Serbia
A5	Italy	A11	Turkey
A6	Japan	A12	America

The results of the first step of multi-criteria decision-making methods, the construction of the decision matrix, are shown in Table 4.

Table 4. Decision matrix and weights

Criteria	C1	C2	C3	C4	C5	C6	C7
Alternatives	**MIN**	**MIN**	**MAX**	**MIN**	**MAX**	**MAX**	**MAX**
A1	16,00	18,00	13,17	7,50	4,17	36,67	50,00
A2	15,25	21,50	12,00	4,75	4,00	41,00	60,25
A3	23,00	16,50	8,25	9,50	3,50	36,00	47,00
A4	20,00	10,33	6,67	8,33	2,00	31,00	37,00
A5	11,50	17,00	9,00	7,50	4,67	31,83	46,50
A6	17,33	16,00	4,00	7,67	3,33	42,33	48,33
A7	20,33	12,00	3,33	4,67	1,67	22,00	30,00
A8	18,67	23,33	9,33	9,33	4,33	47,67	50,00
A9	12,50	23,75	11,25	7,75	3,50	38,75	43,00
A10	21,75	16,75	9,75	9,75	5,50	42,50	51,25
A11	21,83	20,50	9,00	8,83	4,50	39,67	55,00
A12	22,17	22,83	10,83	6,17	4,67	41,17	54,00
Weights	0,130	0,130	0,153	0,130	0,153	0,153	0,153

Five experts were consulted on the necessity of minimizing or maximizing the criteria to be used in the study in accordance with the purpose, as well as determining the weights of the relevant criteria, and the relevant values are shown in Table 4.

Table 5. Weighted Normalized Decision matrix

Criteria	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
Alternatives	**MIN**	**MIN**	**MAX**	**MIN**	**MAX**	**MAX**	**MAX**
A1	0,09344	0,07463	0,15250	0,08089	0,11553	0,11731	0,12656
A2	0,09803	0,06248	0,13899	0,12772	0,11091	0,13117	0,15250
A3	0,06500	0,08141	0,09555	0,06386	0,09705	0,11517	0,11896
A4	0,07475	0,13000	0,07722	0,07280	0,05545	0,09918	0,09365
A5	0,13000	0,07902	0,10424	0,08089	0,12939	0,10184	0,11770
A6	0,08625	0,08396	0,04633	0,07913	0,09242	0,13544	0,12234
A7	0,07352	0,11194	0,03861	0,13000	0,04621	0,07038	0,07593
A8	0,08009	0,05757	0,10810	0,06500	0,12015	0,15250	0,12656
A9	0,11960	0,05656	0,13030	0,07828	0,09705	0,12397	0,10884
A10	0,06874	0,08020	0,11293	0,06222	0,15250	0,13597	0,12972
A11	0,06847	0,06553	0,10424	0,06868	0,12477	0,12691	0,13921
A12	0,06744	0,05883	0,12547	0,09838	0,12939	0,13170	0,13668

Table 5 shows the weighted normalized decision matrix, which should be created in most of the multi-criteria decision making methods.

The calculations related to the methods used in the study were carried out with Excel (21st version) in Microsoft 365.

The findings and rankings obtained for the RAPS method according to the criteria examined for the 12 women national teams in the volleyball branch in the 2024 Olympics are shown collectively in Table 6.

Table 6. Ranking of Alternatives according to RAPS Method

Alternatives	Max Q_k 0,30500 U_{ik}	Min Q_h 0,22517 U_{ih}	Perimeter P 0,90928 P_i	Perimeter Similarity	Rank
A1	0,25765	0,14437	0,69735	0,76693	2
A2	0,26848	0,17270	0,76041	0,83628	1
A3	0,21440	0,12219	0,58336	0,64157	10
A4	0,16627	0,16670	0,56840	0,62511	11
A5	0,22767	0,17230	0,68549	0,75388	4
A6	0,20976	0,14405	0,60826	0,66895	9
A7	0,11977	0,18665	0,52820	0,58090	12
A8	0,25572	0,11813	0,65554	0,72095	7
A9	0,23154	0,15372	0,66319	0,72936	6
A10	0,26707	0,12259	0,68351	0,75171	5
A11	0,24884	0,11704	0,64087	0,70481	8
A12	0,26175	0,13300	0,68835	0,75703	3

With the application of the RAPS method that takes into account the similarity of perimeter, it was concluded that China (A2), Brazil (A1) and the United States (A3) women's national teams should share the first 3 places in the Olympic Games, while the Netherlands (A8), France (A4)and Kenya (A7) should share the last 3 places. In the next stage of the study, the findings of the RAMS method based on median similarity are presented collectively in Table 7.

Table 7. Ranking of Alternatives according to RAMS Method

Alternatives	Max	Min	Median	Median Similarity	Rank
	Q_k	Q_h	M		
	0,30500	0,22517	0,18956		
	U_{ik}	U_{ih}			
A1	0,25765	0,14437	0,14767	0,77903	2
A2	0,26848	0,17270	0,15961	0,84205	1
A3	0,21440	0,12219	0,12339	0,65093	10
A4	0,16627	0,16670	0,11772	0,62103	11
A5	0,22767	0,17230	0,14276	0,75313	5
A6	0,20976	0,14405	0,12723	0,67119	9
A7	0,11977	0,18665	0,11089	0,58498	12
A8	0,25572	0,11813	0,14084	0,74303	6
A9	0,23154	0,15372	0,13896	0,73310	7
A10	0,26707	0,12259	0,14693	0,77512	3
A11	0,24884	0,11704	0,13749	0,72535	8
A12	0,26175	0,13300	0,14680	0,77445	4

According to the findings obtained from Table 7, the first two ranked teams in the women's volleyball branch of the Olympic Games were China (A2) and Brazil (A1), similar to the RAPS method, while the third ranked team was Serbia (A19). In the last three places, DominicanRepublic (A3) was ranked differently from the RAPS method, followed by France (A4) andKenya (A7), which were similar to the RAPS method.

In order to understand whether the rankings obtained with RAPS and RAMS methods are appropriate or not, other MCDM methods were also used. The rankings obtained with the help of other methods and the actual rankings according to the Olympic results are presented in Table 8. It was determined that very similar results were obtained with other methods except ELECTRE method.

Table 8. Ranking Results of Different Multi-Criteria Decision Making Methods

Alternatives	Original	RAPS	RAMS	ELECTRE	PROMETHEE	TOPSIS	VIKOR
A1	3	2	2	5	2	2	3
A2	5	1	1	1	1	1	1
A3	8	10	10	12	12	10	10
A4	11	11	11	10	9	11	11
A5	1	4	5	2	5	5	7
A6	9	9	9	8	7	9	8
A7	12	12	12	6	6	12	12
A8	10	7	6	7	8	6	2
A9	6	6	7	9	10	8	9
A10	7	5	3	3	4	4	4
A11	4	8	8	11	11	7	6
A12	2	3	4	4	3	3	5

In order to show the correlation with the actual ranking, the correlation between the rankings obtained by RAPS and RAMS method and the rankings obtained from the actual and other methods were examined with the help of Spearman rank correlation coefficients and the results obtained and the Spearman correlation heat map are shown in Figure 1.

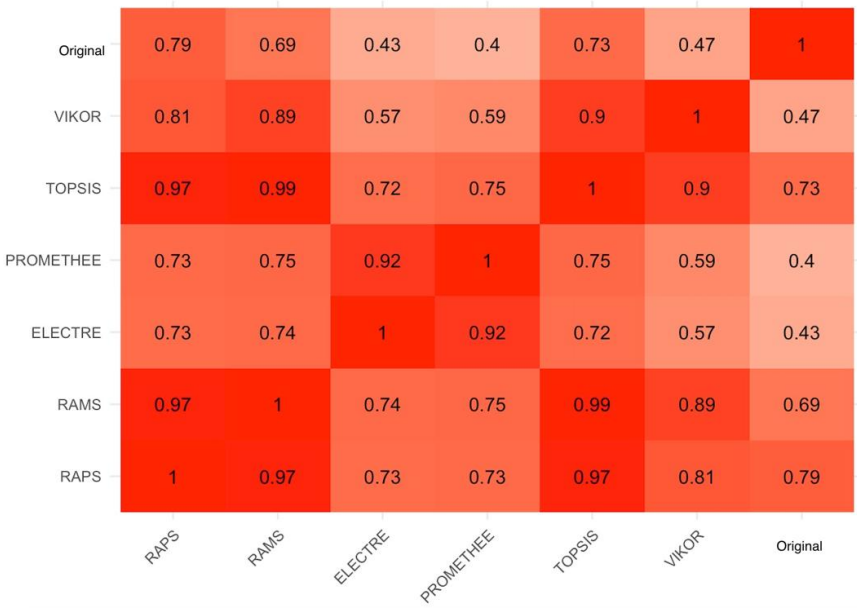


Figure 1. Spearman Correlation Heat Map for Methods

When the Spearman rank correlation coefficients are analyzed, it is seen that the rankings obtained from RAPS, RAMS and TOPSIS methods are highly similar. However, it can be saidthat the RAPS method has the highest similarity to the actual ranking. When all methods are analyzed, it is determined that only RAPS, RAMS and TOPSIS methods have a significantrelationship with the actual values.

Conclusion

As in many fields, different statistical methods can be used to create rankings in different branchesof sports. Multi-criteria decision-making techniques are highly preferred for their ease of application and easier interpretation.

The aim of this study is to determine the final rankings of the teams in the women's national volleyball category of the 2024 Paris Olympics with the help of the statistics obtained during the Olympics. Mainly, RAPS and RAMS methods, which are quite up-to-date, are applied and the results are compared with other multi-criteria methods and real rankings. The weights used in the study are based on the feedback of experts in the field.

When the Olympic results are analyzed, Italy, the United States of America and Brazil took the first three places respectively. However, when their performances during the Olympics were taken into consideration with the help of the statistics obtained, multi-criteria decision-making methods were applied, considering that the ranking would be different. According to the RAPS method, which gives the most similar results to the actual ranking, China, Brazil and the United States took the first three places respectively. Similarly, China ranks first in all ranking methods. While China's high defensive and offensive statistics allowed China to be ranked high in the study, their high team error rates in general caused them to be ranked lower in the actual ranking. If the rankings at the end of the Olympics were based on performance-based statistics, the Olympic rankings in women's volleyball would be much different.

Multi-criteria decision-making methods are widely used in both comparison and decision-making stages due to the development of the field of use. In this study, with the help of the rankings made with different methods, it was determined that the teams have superiorities and weaknesses compared to each other. It may be useful to conduct comprehensive examinations on the basis of variables on which variables these weaknesses or superiorities are based, in which areas the teams should improve in order to strengthen themselves, and which

positions they should pay attention toin the tactical determination phase before the competitions to be held against each other, using different methods.

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