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The research of shuttlecock comprehensive evaluation model based on data envelopment

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ABSTRACT

Data envelopment is mainly used for the evaluation on the relative effectiveness study of decision making units with multiple inputs, especially multiple outputs. This article starts from the social, oneself and psychological three aspects to establish teaching evaluation system and evaluation model; in combination with shuttlecock movement characteristics, it starts from the education quality and teaching quality to set up quality comprehensive evaluation model of fuzzy analytic hierarchy process, and uses this two models to make a scientific, objective and accurate evaluation on shuttlecock sport. According to this model, we get the evaluation results that the state of teaching and learning is medium, which lay a foundation for future research.

KEYWORDS

AHP;
Data envelopment analysis;
Evaluation model.

INTRODUCTION

Currently, the shuttlecock as a traditional physical fitness sport, many schools have introduced it, carried out comprehensively and achieved some results. But most schools have taken the traditional sports teaching methods, which are different with the features of shuttlecock sport itself. Similarly, as a measure of physical education the evaluation system will be accompanied by the arising of many defects and problems. The traditional evaluation system mainly used a single evaluation system, which can not scientifically reflect the objectives and requirements of modern teaching.

Data envelopment analysis is the evaluation on the relative effectiveness of decision making units with multiple inputs, especially multiple outputs using mathematical programming (including linear programming, multi-objective programming) model. It has the advantage of objective accuracy of the data, but in real life it is difficult to find data with accurate index factor, so it has ambiguity.

The traditional evaluation system takes the athletes achievements as the main criteria and the evaluation on shuttlecock sport is much difficult than other sports evaluation. Therefore, this article starts from the social, oneself and psychological three aspects to establish mathematical evaluation system and evaluation model. It starts from the education quality and teaching quality to set up physical education evaluation model to meet the needs of modernization.

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ESTABLISH A COMPREHENSIVE EVALUATION MODEL OF DATA ENVELOPMENT ANALYSIS

Conduct complementation on the accuracy of data envelopment analysis and fuzziness of fuzzy comprehensive evaluation to obtain fuzzy comprehensive evaluation model of data envelopment analysis, which is divided into three steps: the first step, fuzzy computing non-quantified index weight; second, using data envelopment analysis, accurately calculate quantified indicators weights and fuzzify the calculation results; third, conduct fuzzy comprehensive evaluation on the above results and obtain the final evaluation results.

If there is m evaluation units, $(c + d)$ evaluation indicators, c quantified indicators, d non-quantified indicators in a model.

Fuzzy operation of non-quantified weights

If $C = (c_1, c_2, \ldots, c_q)$ is the factor set, $V = (v_0, v_1, \ldots, v_{p-1})$ is the comment set, then the comprehensive evaluation matrix is:

$$\mathbf{R_j}=\begin{bmatrix} \mathbf{r_{j10}} & \mathbf{r_{j11}} & \cdots & \mathbf{r_{j1(p-1)}} \\ \mathbf{r_{j20}} & \mathbf{r_{j21}} & \cdots & \mathbf{r_{j2(p-1)}} \\ \cdots & \cdots & \cdots & \cdots \\ \mathbf{r_{jq0}} & \mathbf{r_{jq1}} & \cdots & \mathbf{r_{jq(p-1)}} \end{bmatrix}, \mathbf{j = 1,2, \ldots, m,}$$

$A_j = (a_{j1}, a_{j2}, \ldots, a_{jq})$ is the weight matrix. So, the fuzzy operation non-quantified indicator weight of the j–th decision-making unit is:

$$\mathbf{B_j = A_j R_j = (a_{j1}, a_{j2}, \cdots, a_{jq})}\begin{bmatrix} \mathbf{r_{j10}} & \mathbf{r_{j11}} & \cdots & \mathbf{r_{j1(p-1)}} \\ \mathbf{r_{j20}} & \mathbf{r_{j21}} & \cdots & \mathbf{r_{j2(p-1)}} \\ \cdots & \cdots & \cdots & \cdots \\ \mathbf{r_{jq0}} & \mathbf{r_{jq1}} & \cdots & \mathbf{r_{jq(p-1)}} \end{bmatrix} = \mathbf{(b_{j1}, b_{j2}, \cdots, b_{jp})}.$$

Data envelopment calculation of quantified weights

Assuming that $X_j = (x_{1j}, x_{2j}, \ldots, x_{nj})^T$ and $Y_j = (y_{1j}, y_{2j}, \ldots, y_{sj})^T$ are the input and output vectors of $DMU_i(1 \le i \le m)$ for the i-th assessment unit, wherein $j = 1,2, \ldots, m$; coordinates of each vector are positive. Use the following to represent the input and output vectors.

$\mathbf{v = (v_1, v_2, \ldots, v_n)^T, u = (u_1, u_2, \ldots, u_s)^T}$

Linear programming model can be obtained using the Charnes-Cooper transform:

$$\begin{cases} \max \boldsymbol{\mu}^T \mathbf{Y_{j0}} \\ \text{s.t.} \quad \boldsymbol{\omega}^T \mathbf{X_j} - \boldsymbol{\mu}^T \mathbf{Y_j} \ge 0, \mathbf{j = 1,2, \cdots, m} \\ \boldsymbol{\omega}^T \mathbf{X_{j0}} = 1 \\ \boldsymbol{\omega} \ge 0, \boldsymbol{\mu} \ge 0 \end{cases}.$$

Put data into the model, the optimal solution $\mathbf{B_j'}$ obtained is quantified indicators weights with accurate calculation.

Although the data obtained by data envelopment analysis are more objective and more persuasive, but they do not have the "excellent, good, normal, poor" such emotional awareness and the membership form of fuzzy comprehensive evaluation. Therefore, this paper uses the membership function to fuzzify the results.

Data envelopment analysis result the operation can be considered the degree of membership separately for the comment set $V = (v_0, v_1, \ldots, v_{p-1})$; assuming that $r = (r_0, r_1, \ldots, r_{p-1})$ is the membership degree, then:

$$\mathbf{r_j} = \begin{cases} \dfrac{\mathbf{x-(j-1)\dfrac{1}{p-1}}}{\dfrac{\mathbf{1}}{\mathbf{p-1}}} & \mathbf{,(j-1)\dfrac{1}{p-1} \le x < j\dfrac{1}{p-1}} \\ \dfrac{\mathbf{(j+1)\dfrac{1}{p-1}-x}}{\dfrac{\mathbf{1}}{\mathbf{p-1}}} & \mathbf{,j\dfrac{1}{p-1} \le x < (j+1)\dfrac{1}{p-1}} \\ \mathbf{0} & \end{cases} \mathbf{, rj \in [0,1],}$$

$\mathbf{j = 0,1, \ldots, p\text{-}1.}$

Substitute $\mathbf{B_j'}$ into the formula above to get membership degree $B_j = (b_{j1}, b_{j2}, \ldots, b_{jp})$.

The establishment of comprehensive evaluation mathematical model

Conduct comprehensive evaluation of the above results, and comprehensive evaluation matrix is

$\mathbf{R_j} = \begin{bmatrix} \mathbf{B_{j1}} \\ \mathbf{B_{j2}} \\ \cdots \\ \mathbf{B_{jk}} \end{bmatrix}, \mathbf{j = 1,2, \cdots, m}$, where k is number of items for all indicators (non-quantified and quantified). Assuming

$A_j = (a_{j1}, a_{j2}, \ldots, a_{jk})$ $j = 1,2, \ldots, m$ are the weights, there is $B = A$ and:

$$\mathbf{R \Rightarrow B_j = (a_{j1}, a_{j2}, \cdots, a_{jk}) \begin{bmatrix} B_{j1} \\ B_{j2} \\ \cdots \\ B_{jk} \end{bmatrix} = (b_{j1}, b_{j2}, \cdots, b_{jp}), j = 1,2, \cdots, m}$$

Using the principle of maximum membership degree, the final result after comprehensive evaluation is the v_i in $(v_0, v_1, \ldots, v_{p-1})$ corresponding to the maximum value b_{ji} in $B_j = (b_{j1}, b_{j2}, \ldots, b_{jp})$.

The application of comprehensive evaluation mathematical model in shuttlecock sport

Suppose $U = \{U_A, A_B, U_C\}$ means the evaluation set, where $U_A = \{U_{A1}, U_{A2}, U_{A3}, U_{A4}\}$ = {Shuttlecock knowledge, physical fitness, ability, technique} represents their own factors, $U_B = \{U_{B1}, U_{B2}, U_{B3}, U_{B4}\}$ = {intelligence, endurance, self-control ability, perception ability} represents the psychological factor, $U_C = \{U_{C1}, U_{C2}, U_{C3}, U_{C4}\}$ = {shuttlecock cognition, hobby level, adaptive ability, shuttlecock quality} represents the social factors. The first level indexes have three kinds, and the secondary level indexes have sixteen kinds.

Suppose $m = \{m_A, m_B, m_C\}$ means the weight distribution set, wherein $m_A = \{m_{A1}, m_{A2}, m_{A3}, m_{A4}\}$ = {0.3, 0.2, 0.2, 0.1}, $m_B = \{m_{B1}, m_{B2}, m_{B3}, m_{B4}\}$ = {0.4, 0.3, 0.2, 0.3}, $m_C = \{m_{C1}, m_{C2}, m_{C3}, m_{C4}\}$ = {0.3, 0.2, 0.3, 0.2}, V = {Excellent, good, normal, poor, worse} is the evaluation level.

If we evaluate an athlete's psychological factors; the four secondary level evaluation indicators: intelligence, endurance, self-control ability, perception ability respectively are {0.2, 0.3, 0.3, 0.15, 0.05}, {0.15, 0.4, 0.3, 0.15, 0}, {0.3, 0.35, 0.3, 0.05, 0} and {0.25, 0.3, 0.2, 0.15, 0.1}, then we get the evaluation matrix:

$$\mathbf{R} = \begin{pmatrix} 0.2 & 0.3 & 0.15 & 0.3 & 0.05 \\ 0.15 & 0.4 & 0.15 & 0.3 & 0 \\ 0.3 & 0.35 & 0.05 & 0.3 & 0 \\ 0.25 & 0.3 & 0.15 & 0.2 & 0.1 \end{pmatrix}$$

Based on the set weight distribution, we get the fuzzy matrix:

$$\mathbf{R = (0.3,0.3,0.2,0.2)} \begin{pmatrix} 0.2 & 0.3 & 0.15 & 0.3 & 0.05 \\ 0.15 & 0.4 & 0.15 & 0.3 & 0 \\ 0.3 & 0.35 & 0.05 & 0.3 & 0 \\ 0.25 & 0.3 & 0.15 & 0.2 & 0.1 \end{pmatrix} \mathbf{= (0.2, 0.3, 0.3, 0.15, 0.1)}$$

Through normalization, we obtain R = (0.19, 0.29, 0.28, 0.15, 0.09). This indicates that 19% of the people believe that the comprehensive evaluation of his psychological factors is excellent, 29% consider good, 28% consider normal, 15% consider poor, 9% consider worse.

Then we assign scores for each evaluation grade: excellent is 95 points, good is 85 points, normal is 75 points, poor is 60 points and worse is 50 points. In this way, we get the scores of comprehensive evaluation:

$$\mathbf{W = (0.19,0.29,0.28,0.15,0.09)} \begin{pmatrix} 95 \\ 85 \\ 75 \\ 60 \\ 50 \end{pmatrix} \mathbf{= 77.2}$$

Finally, according to the distribution of weights recalculate W, we get his psychological factor score of 7.72s. Similarly, other factor score can also be got, so we get the total score of the athletes.

TEACHING QUALITY COMPREHENSIVE EVALUATION MODEL OF FUZZY AHP

The teaching quality assessment of Shuttlecock cause means the accurate judgments by all influencing factors in the teaching process based on the teaching objectives and their combined results, including teacher's teaching evaluation and athlete's learning evaluation. The teacher's teaching evaluation takes their teaching methods and teaching effectiveness as the evaluation object. Athlete's learning evaluation takes their final grade as the evaluation object. Conventional teaching quality evaluation is only evaluation in aspects of the teaching methods and the final transcript. It does not embody the inherent dialectical relationship between teaching and learning. Therefore, based on the past evaluation system, this paper introduces the teaching efficiency, improves the deficiencies of the old system, and establishes a new comprehensive evaluation system.

The model combines the qualitative description and quantitative description, mainly includes three aspects: athletes evaluate teachers, teachers evaluate athletes and teaching efficiency.

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First, this paper first establishes questionnaire of teachers by athletes, and then randomly selects 100 athletes to conduct a regional survey. On this basis, we get athletes evaluation form on the teachers. Evaluation form contains six kinds of first-level evaluation index and fourteen kinds of secondary level evaluation index, as shown in TABLE 1.

This paper sets five kinds of evaluation rank: excellent, good, normal, poor and worse. Using the analytic hierarchy process, we determine the index weight and grade of evaluation level, as shown in TABLE 2.

Using fuzzy comprehensive evaluation method, set W_i is the synthesis weights, V_j is the evaluation level, we first obtain the membership degree distribution $\mathbf{B}_j = \sum \mathbf{W}_i \mathbf{R}_{ij}$, where $\sum \mathbf{W}_i = 1$ and R_{ij} are the membership; Then get athletes evaluation value $\mathbf{G}_T = \sum \mathbf{B}_j \mathbf{V}_j^T$ on the teacher, where $\mathbf{V}_j^T$ is the transposed matrix of evaluation rating score. Substituting the data of TABLE 2 into fuzzy comprehensive evaluation method, we get B_j = (0.146, 0.509, 0.31, 0.02, 0.01) and G_T = 0.764.

Secondly, calculate the teacher's evaluation scores on athletes. This paper firstly determines the composition of athletes' final grade, and then creates the thirteen evaluation levels of the results shown in TABLE 3.

Using the formula $\mathbf{G}_s = \sum \mathbf{R}_j \mathbf{V}_j^T$, the paper gets the teacher evaluation scores G_S = 0.682 of athletes, where $\mathbf{V}_j^T$ is the transposed matrix of the thirteen evaluation levels and R_j is the people number ratio of the thirteen evaluation levels.

Finally, establish the teaching efficient model. Teaching efficient measures the level quality of two aspects: teaching and learning activities, and reflects the functional relationship of the activity quality of teaching and learning. Suppose $H_{(T)}$ means the teaching efficiency of the teachers, if $-2 < G_T < 2$, then we have

$$\mathbf{H}_{(T)} = \ln\left(1 + \frac{\mathbf{G}_s\sqrt{(2-\mathbf{G}_T)(2-\mathbf{G}_s)}}{(2-\mathbf{G}_T)^2}\right).$$

TABLE 1 : Evaluation index

First-class index	Secondary index
Teaching plan	Moderate teaching hours
	Explicit teaching plan
Teaching content	Reasonable structure
	Ability training
	Moderate exercise
Teaching ability	Affect students
	Skilled technical action
Tutoring after class	Reasonable manner
	Careful guidance
Teaching Achievement	Raise the teaching level
	Improve self-learning ability
Teaching methods	Enrich teaching methods
	Orderly teaching processes
	Expand teaching

TABLE 2 : Evaluation table

Secondary index	Evaluation level					Combining weight
	Excellent	Good	Normal	Poor	Worse	
Moderate teaching hours	0.2	0.7	0.1	0	0	0.07
Explicit teaching plan	0.1	0.6	0.2	0.1	0	0.06
Reasonable structure	0.1	0.8	0.1	0	0	0.1
Ability training	0.2	0.3	0.4	0.1	0	0.09
Moderate exercise	0.1	0.5	0.3	0	0.1	0.08
Affect students	0.2	0.2	0.1	0.1	0	0.09
Skilled technical action	0.2	0.7	0.1	0	0	0.12
Reasonable manner	0.1	0.5	0.2	0.1	0.1	0.05
Careful guidance	0.4	0.3	0.1	0.2	0	0.08
Raise the teaching level	0.3	0.4	0.2	0.1	0	0.09
Improve self-learning ability	0	0.3	0.5	0.1	0.1	0.02
Enrich teaching methods	0.1	0.3	0.4	0.2	0	0.03
Orderly teaching processes	0.2	0.5	0.3	0	0	0.11
Expand teaching	0.2	0.3	0.4	0.1	0	0.09

TABLE 3 : Distribution of the final performance

grades	>95	>89	>83	>77	>71	>65	>59	>53	>47	>41	>35	>29	<29
rank	2.00	1.65	1.34	1.00	0.66	0.32	0.01	-0.32	-0.66	-1	-1.3	-1.65	-2
ratio of people number	0.03	0.06	0.11	0.20	0.22	0.26	0.10	0.02	0.02	0	0.03	0.01	0

If $G_S < 0$ we have

$$\mathbf{H_{(T)} = \ln\left(1+\frac{G_s\sqrt{(2-G_T)(2-G_s)}}{(2-G_s)^2}\right)}.$$

From the above two equations, we get that when $G_T = 2$ the athlete's evaluation of the teacher is full mark; when $G_T = -2$ the athlete's evaluation of the teacher is zero. Meanwhile, we find $H_{(T)}$ using these two formulas, in TABLE 4.

By TABLE 4, we know that athlete's quality of learning G_S, the teacher's lectures quality G_T and teaching efficiency $H_{(T)}$ are not a simple linear relationship, but are interrelated and interactional relation function. Then, we set five kinds of evaluation criteria $H_{(T)}$: $H_{(T)} < 0$ means the lectures state is worse; $H_{(T)} = 0$ means the lectures state is poor; $0 < H_{(T)} \le 0.6$ means the lectures state is normal; $0.6 < H_{(T)} \le 1$ means the lectures state is good; $H_{(T)} > 1$ means the lectures state is excellent.

TABLE 4 : Teaching efficiency

$H_{(T)}$	-1	0	0.2	0.4	0.6	0.8	1	1.2	1.4	1.5	1.6	1.8	1.9
-1	-0.4	0	0.05	0.1	0.13	0.16	0.18	0.19	0.19	0.18	0.17	0.14	0.1
0	-0.31	0	0.09	0.16	0.22	0.27	0.3	0.31	0.32	0.32	0.3	0.25	0.2
0.2	-0.28	0	0.11	0.19	0.26	0.31	0.35	0.37	0.45	0.36	0.35	0.29	0.22
0.4	-0.27	0	0.12	0.22	0.3	0.36	0.4	0.41	0.43	0.42	0.41	0.33	0.3
0.6	-0.25	0	0.16	0.27	0.36	0.42	0.47	0.5	0.51	0.49	0.48	0.4	0.31
0.8	-0.23	0	0.18	0.33	0.43	0.51	0.57	0.6	0.61	0.59	0.57	0.48	0.38
1	-0.2	0	0.24	0.41	0.54	0.63	0.69	0.73	0.72	0.73	0.7	0.59	0.47
1.2	-0.18	0	0.32	0.53	0.69	0.8	0.87	0.92	0.92	0.91	0.88	0.75	0.61
1.4	-0.16	0	0.45	0.74	0.93	1.06	1.15	1.2	1.2	1.19	1.16	0.99	0.81
1.5	-0.14	0	0.56	0.89	1.1	1.25	1.34	1.38	1.41	1.38	1.35	1.19	0.98
1.6	-0.12	0	0.72	1.9	1.34	1.5	1.59	1.67	1.65	1.64	1.61	1.43	1.22
1.8	-0.08	0	1.39	1.9	2.2	2.4	2.45	2.56	2.57	2.55	2.51	2.3	2.05
1.9	-0.05	0	2.25	2.8	3.2	3.6	3.48	3.5	3.56	3.54	3.5	3.25	2.96

Using the previous result $G_T = 0.764$ and $G_S = 0.682$, and combining with $\mathbf{H_{(T)} = \ln\left(1+\frac{G_s\sqrt{(2-G_T)(2-G_s)}}{(2-G_T)^2}\right)}$, we obtain $H_{(T)} = 0.45$. Therefore, according to the mathematical model, the evaluation result obtained is the state of a medium between the teaching and learning.

CONCLUSION

With Shuttlecock deeply entering into the campus, the traditional Physical Education pattern is not entirely suitable for course teaching of Shuttlecock. This paper, on the basis of modern physical education, studied modern shuttlecock education mode. Further, based on the study of the mode, this paper established a mathematical comprehensive evaluation system. Meanwhile, starting from the quality of teaching and the quality of education, it established two comprehensive evaluation mathematical models: the education quality comprehensive evaluation model of data envelopment analysis and teaching quality comprehensive evaluation model of fuzzy AHP, and used these two models to make a scientific, objective and accurate evaluation.

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