

Entropy Coefficient Method to Evaluate the Level of Sustainable Development of China's Sports

Wei Liu¹, Jin Cui²

¹ Physical education college of Hunan University Science and Technology

² Physical education college of Central South University of Forestry and Technology

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Abstract. According to the Statistical Yearbook of China's sports undertakings and the related Statistical Yearbook, as well as related indicators Construction principles, the sustainable development evaluation index system of China's sports is constructed. This essay uses entropy coefficient method to research on the weight of every subsystem and indicator in the Sports sustainable development and find the top fives were: National Sports input on the level of 0.108, a mass movement participation rate of 0.083, the state sports input level of 0.076, the state sports input-output index 0.062, 0.061 coaches guidance level. The essay also adopts weighting function method to conduct the level index of Chinese sports' sustainable development from 1991 to 2005, and find out the unsustainable development state of China's sports for 1991-1998, the critical development state for the 1999-2001 and the sustainable development state for 2002 – 2005, in accordance with the sustainable development of China's sports determination criteria.

Keywords: Entropy coefficient method, sports, sustainable development

1. Entropy coefficient method Introduction^[1]

In System science, entropy is the measure of the disorder degree of the system, and it can also measure the effective information provided by the data. Therefore, the entropy can be used to determine the weights. When the evaluated objects have quite a large difference between each other on a particular indicator, the entropy is smaller, which shows that when the indicators provide more effective information, the weight of the indicators should be larger; on the contrary, the smaller the difference, the larger the entropy, which shows that the smaller the amount of information provided by indicators, the smaller the index weights. When the value of every evaluated object reaches the same one, the entropy reaches the maximum, which means that this indicator failed to provide any useful information to the making of the decision, so we can consider the removal of it from the evaluation index system. Therefore, the entropy coefficient method is an objective empowering method. To determine the weight by calculating the entropy is just the way of determining the weights of each indicator based on the evaluation of the discrepancy degree of every evaluation indicator value.

Supposing there are m evaluation indicators and n evaluation objects, the original data matrix $X = (x_{ij})_{m \times n}$ is formed, and as to an indicator i , the greater the difference of the index value x_{ij} , the greater the role played by the indicator in the comprehensive assessment. If the indicator values of an indicator are all the same, then the indicator plays little role in the Comprehensive Assessment. The main steps of using entropy coefficient method to determine the weights are as follows:

① Standardization of the original data matrix

Supposing there are m evaluation indicators and n evaluation objects, the original data matrix is as follows:

To standardize the matrix, the result is:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}$$

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

R_{ij} is the standard value of the j -th evaluation object on the i -th evaluation indicator, $r_{ij} \in [0, 1]$. Of which:

The indicator playing the positive role: $X'_{ij} = (X_{ij} - \min X_j) / (\max X_j - \min X_j)$

The indicator playing the negative role: $X'_{ij} = (\max X_j - X_{ij}) / (\max X_j - \min X_j)$

② Define entropy

During the assessment where there are m evaluation indicators and n evaluation objects, the definition of the entropy of the i -th indicator is:

$$H_i = -k \sum_{j=1}^n f_{ij} \ln f_{ij}, \quad i = 1, 2, \dots, m$$

$$f_{ij} = r_{ij} / \sum_{j=1}^n r_{ij}, \quad k = 1 / \ln n, \quad \text{when } f_{ij} = 0, \text{ so } f_{ij} \ln f_{ij} = 0$$

③ Define entropy weight

After the entropy of the i -th indicator is defined, the definition of the entropy weight of the i -th indicator is:

$$w_i = (1 - H_i) / \left(m - \sum_{i=1}^m H_i \right), \quad 0 \leq w_i \leq 1, \quad \sum_{i=1}^m w_i = 1$$

2. The definition of the sustainable development of China's sports system

The sustainable development system of China's sports, referring to the goal of sustainable development of China's sports, is an open complex giant system conducted by the population of sports, sports economy, sports culture and sports science and technology subsystems, and its external environment is composed by the state Politics, economy, culture, science and technology and the resource environment, which is the macro-layer of the sustainable development of China's sports system. The micro-system layer refers to the subsystems of China's athletics and the masses sports, and this is also the core-layer of the system. The highest goal the system pursued is: all-round human development.

3. The Construction of the Evaluation Index System of the Sports Sustainable Development System

3.1. The construction principles

① Simple scientific principles

Index system should be a true reflection of the relationship between the subsystems and the indicators; the indicators concept must be clear, have scientific connotation, and can objectively and truthfully reflect and measure the structure, the present function, the development trend, the development potential and the objective realization extent of the Sports system.

② System integrity principle

The construction of the evaluation system of the sports sustainable development System is a complex system engineering, and indicator system should both fully reflect the basic characteristics of each subsystem, and also reflect the coordination between subsystems. All indicators must be independent of each other, interrelated and jointly form an organic entity.

③ Operational and comparable principle

The setup of the index system should take the quantization of the indicators and the difficulty Level of the access of the indicators data into consideration. The setup of the indicators should make the fullest possible use of existing statistical information, the data should be accessible, and has measurability and comparability, and the evaluation scope calibers should be coherent. At the same time results of the evaluation index system should reach the state that there must be comparability between the status quo and the past in time, and among the different regions in space.

④Dynamic guiding principle

Sports sustainable development is a dynamic process, the evaluation standard should also be a relative and developing concept. Therefore, the chosen evaluation index system must be able to reflect the history, current situation the potential and the evolution trends of the sports development, reveals its intrinsic development rule. Index system should be able to embody the unity of static and dynamic state, have the sensitivity with the changes in time and space, and therefore guide the formulation, adjustment and implementation of the sustainable development policies.

3.2. The determination of the index system of sports sustainable development

According to the indicators Construction principles as well as the relevant statistics ^[2-6] in China Statistical Yearbook, and the collection of the original statistical data from 1991 to 2005, the author adopts indicators standardization, independent analysis and effective treatment to determine the evaluation system of the sustainable development of China's sports.

3.3. To solve the weight of each indicator and subsystem by entropy coefficient method

This study takes the sports population subsystem as an example to demonstrate the process of determining the weight by the entropy coefficient method, and then gives the weight assignment of all the indicators of each indicator and subsystem in the sustainable development of China's reports by the same principle. The weight evaluation and results of the sports population subsystem are as follows:

For sports population subsystem, there are nine evaluation indicators C_1-C_9 , 15 evaluated objects (from 1991 to 2005), to standardize the numerical values of the 15 evaluated objects, and then construct a matrix for the standardizations, we can get the following table:

matrix $R = (R_{ij})_{15 \times 9}$ and $f_{ij} = R_{ij} / \sum_{i=1}^{15} R_{ij}$ are as follows:

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
1991	0.23	0.69	0.05	0.76	0.00	0.40	0.00	0.00	0.00
1992	0.10	0.76	0.10	0.67	0.04	0.65	0.04	0.32	0.01
1993	0.41	1.00	0.00	0.02	0.01	0.75	0.08	0.32	0.06
1994	0.24	0.62	0.10	0.00	0.07	0.95	0.13	0.38	0.05
1995	1.00	0.25	0.10	0.09	0.09	0.75	0.15	0.35	0.09
1996	0.00	0.32	0.10	0.18	0.11	0.60	0.17	0.60	0.07
1997	0.26	0.64	0.14	0.22	0.15	1.00	0.16	0.72	0.07
1998	0.17	0.62	0.29	0.29	0.24	0.90	0.18	0.87	0.09
1999	0.41	0.25	0.33	0.38	0.31	0.80	0.19	0.88	0.09
2000	0.23	0.17	0.38	0.53	0.38	0.80	0.19	1.00	0.06
2001	0.32	0.01	0.48	0.76	0.49	0.75	0.24	0.63	0.06
2002	0.34	0.25	0.71	1.00	0.77	0.00	0.72	0.94	0.26
2003	0.15	0.04	0.62	0.62	0.62	0.15	0.55	0.79	0.37
2004	0.57	0.00	0.90	0.91	0.88	0.30	0.66	0.55	0.28
2005	0.50	0.16	1.00	0.89	1.00	0.15	1.00	0.47	1.00

	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9
1991	0.046	0.120	0.009	0.103	0.000	0.045	0.000	0.000	0.000
1992	0.019	0.132	0.018	0.091	0.007	0.073	0.008	0.036	0.002
1993	0.083	0.173	0.000	0.003	0.002	0.084	0.017	0.037	0.023
1994	0.048	0.108	0.018	0.000	0.014	0.106	0.028	0.043	0.021
1995	0.203	0.044	0.018	0.012	0.017	0.084	0.033	0.039	0.033
1996	0.000	0.056	0.018	0.024	0.021	0.067	0.038	0.068	0.029
1997	0.052	0.111	0.027	0.030	0.030	0.112	0.037	0.082	0.028
1998	0.035	0.108	0.054	0.040	0.047	0.101	0.040	0.099	0.034
1999	0.084	0.042	0.063	0.052	0.059	0.089	0.042	0.100	0.036
2000	0.047	0.029	0.072	0.073	0.073	0.089	0.043	0.114	0.025
2001	0.065	0.002	0.090	0.103	0.094	0.084	0.054	0.071	0.023
2002	0.069	0.044	0.135	0.137	0.149	0.000	0.162	0.107	0.101
2003	0.031	0.006	0.117	0.085	0.121	0.017	0.124	0.090	0.143
2004	0.115	0.000	0.171	0.125	0.171	0.034	0.149	0.062	0.111
2005	0.101	0.027	0.189	0.122	0.194	0.017	0.225	0.053	0.391

According to the definition of the entropy $H_i = -k \sum_{i=1}^{15} f_{ij} \ln f_{ij} = -\frac{1}{\ln 15} \sum_{i=1}^{15} f_{ij} \ln f_{ij}$ the matrix of the entropies of the 9 individual indicators is:

$H_i = [0.912 \ 0.871 \ 0.852 \ 0.895 \ 0.830 \ 0.934 \ 0.848 \ 0.949 \ 0.750]$, and then according to the entropies of

the 9 individual indicators and the evaluation formula $w_i = (1 - H_i) / \left(9 - \sum_{i=1}^9 H_i \right)$, the matrix of the entropies of the 9 individual indicators is:

$$w_i = [0.076 \quad 0.111 \quad 0.128 \quad 0.090 \quad 0.147 \quad 0.057 \quad 0.131 \quad 0.044 \quad 0.216]$$

And then the weights of nine individual indicators C_1 to C_9 are the corresponding values in the matrix, that is, World Championship-winning level C_1 of 0.076, the level to create a world record C_2 of 0.111, the mass movement ability level C_3 of 0.128, Sports service level C_4 of 0.090, coaches' guidance level C_5 of 0.147, sports staff workers' index C_6 of 0.057, the stadiums-using level C_7 of 0.131, national physical training standards fulfillment rate C_8 of 0.044, mass movement participation rate C_9 of 0.216.

3.4. Subsystems of the sustainable development of China's sports and their index weight results

Similarly according to the corresponding methods and steps we can calculate the weights of the individual indicators in sports economy subsystems, sports culture subsystems and Sports Science and Technology subsystems. As to the weights of sports population subsystems, sports economy subsystems, sports cultural subsystems and sports Science and Technology subsystems, then sum up the individual indicators of the four subsystems respectively (in which X_i is the standardized values of the individual indicators and W_i is the weight of the individual indicators) according to $\sum_{i=1}^n X_i W_i$, and then get the development index of the four subsystems, under which calculate the weights of the four subsystems according to the calculating steps of the entropy.

Right now the weights of the sports subsystems and the weight results of the individual indicators of the sports subsystems calculated by entropy coefficient method are listed in Table 1.

Table 1 The weights of the sports subsystems and the weight results of the individual indicators

system (B)	Subsystem weight	B	Index (C)	weight
B ₁ sports population subsystem	0.385	C1 World Championship-winning level(a/ten thousand)		0.076
		C2 the level to create a world record (a/ten thousand)		0.111
		C3 the mass movement ability level (a/ten thousand)		0.128
		C4 Sports service level (man/tims)		0.090
		C5 coaches' guidance level		0.147
		C6 sports staff workers' index (a/ten thousand)		0.057
		C7 the stadiums-using level (times/ten thousand)		0.131
		C8 national physical training standards fulfillment rate (%)		0.044
		C9 mass movement participation rate (%)		0.216
B ₂ Sports economic subsystem	0.483	C10 GDP		0.126
		C11 Engel coefficient (%)		0.140
		C12 the state athletics input level (%)		0.224
		C13 national sports input-output index		0.128
		C14 athletics input distribute index (%)		0.037
		C15 State Sports input level (%)		0.157
		C16 sports industry contributor rate (%)		0.086
		C17 the city family culture and sports consume proportion (%)		0.062
		C18 the rural family culture and sports consume proportion (%)		0.039
B ₃ sports cultural subsystems	0.093	C19 the index of Pedagogy graduates (%)		0.145
		C20 education of sports output index (%)		0.100
		C21 the gym teacher in the sum population proportion(a/ten thousand)		0.076
		C22 the student in the sum population proportion (%)		0.077
		C23 the student of sports school in the sum student proportion (%)		0.084
		C24 coaches' professional title level (%)		0.132
		C25 athletes literacy level (%)		0.241
		C26 the sports group exchange visits rate (ten thousand times)		0.047
		C27 society guides of sports proportion in national physical training standards fulfillment (a/ten thousand)		0.047
B ₄ Sports Science and Technology Subsystem	0.039	C28 juvenile sports school send top school students proportion in total (%)		0.050
		C29 national investment in science and technology level (%)		0.158
		C30 the accepting amount of annual patent applications (ten thousand)		0.266
		C31 the sports paper published in the sum paper published proportion (%)		0.095
		C32 the graduste student of physical education proportion in the sum (%)		0.127
		C33 devote sports science financial proportion in the total (%)		0.104
		C34 the sports science and technology proportion in the total(a/ten thousand)		0.094
		C35 management manpower index of sports system (%)		0.155

From the table we can see that in the sustainable development system of China's sports the weights of each subsystem can be arranged by weight as follows: Sports economic subsystem 0.483, sports population subsystem 0.385, sports cultural subsystems 0.093, Sports Science and Technology Subsystem 0.039, in which sports economy and sports Cultural subsystems as a whole accounted for 87.8%, from which we can see that these two subsystems play an important role in the sustainable development of China's sports.

the top three in order of the weights of Sports economic subsystem are: the state athletics input level C_{12}

of 20.224, State Sports input level C_{15} of 0.157, Engel coefficient C_{11} of 0.140; the top three in order of the weights of Sports population subsystem are: mass movement participation rate C_9 of 0.216, coaches guidance level C_5 of 0.147, sports stadium- using level C_7 of 0.131 ; the top three in order of the weights of Sports cultural subsystem are: athletes literacy level C_{25} 0.241, the index of Pedagogy graduates C_{19} of 0.145, coaches' professional title level C_{24} of 0.132; the top three in order of the weights of Sports Science and Technology subsystem are: the accepting amount of annual patent applications C_{30} of 0.266, national investment in science and technology level C_{29} of 0.158, management manpower index of sports system C_{35} of 0.155.

The top five of the indicators and weights which affect the sustainable development system of China's sports are: The national athletics input level 0.108; mass movement participation rate of 0.083; national sports input 0.076; national sports input-output index 0.062; coaches' guidance level of 0.061.

4. The test results and evaluation of the Sustainable development system level of China's sports

Through entropy coefficient method the weights of each subsystem and indicator has been obtained above, the next is to use these weights and the standardized value of each indicator these weight and the value of indicators to synthesize to solve the sustainable development level of each subsystem and the whole system in the years 1991-2005.

4.1. The integrated synthesis methods of the indicator System of Sports sustainable development

Because of the systematicness and complexity of the sports sustainable development issues, every indicator of the sustainable development indicator System can only reflect the sustainable development of sports from a certain perspective.

To get a comprehensive reflection of the overall level of sports sustainable development, this study defined sports sustainable development level by the Sustainable development index of sports (SDIS), and the method is to weighting the individual indicators by the way of weighting function:

$$SDIS = \sum_{i=1}^4 \left(\sum_{j=1}^n X_j W_j \right) R_i$$

X_j is the standardized value of the j -th individual indicator which the i -th sports subsystem belongs to; W_j is the weight corresponding to the j -th individual indicator which the i -th sports subsystem belongs to; R_i is the weight of the i -th sports subsystem; $\sum_{j=1}^n X_j W_j$ stands for the Comprehensive Assessment value of each sports subsystem (that is, the development index of each sports subsystem), in order to reflect the development degree of each sports subsystem.

4.2. The discrimination of the sports sustainable development degree

According to the evaluation index system and evaluation model of the sports sustainable development, the comprehensive index of the sports sustainable development is achieved. Reference geography, resources and the environment for sustainable development in the science of the extent of the level of the standard^[7], The author designs a 5-grade-evaluation criteria of the sports sustainable development level referring to the evaluation criteria of the sustainable development level in Geography and Resources environmentology to judge synthetically the sports sustainable development level (see table 2).

Table 2 The sustainable development of sports discretion standard

level	[0, 0.25]	(0.25, 0.45)	[0.45, 0.55]	(0.55, 0.75)	[0.75, 1.00]
state	Extreme development	unsustainable development	critical development	Sustainable development	Extreme sustainable development

4.3. The indicators composing results and evaluation of China's Sports sustainable system

The development level results of China's sports sustainable development system after the synthetical formation through weighting in Table 3

As can be seen from the table-3, China's Sports has been showing a good state of development from 1991 to 2005, and its composite index of 0.20 in 1991 steadily reaches 0.67 in 2005, an increase of 0.47, rising as much as 235%, with an average annual growth of 15.67%;

According to the discrimination criteria to the sports sustainable development degree, the sustainable development state of China's sports in the past 15 years can be divided into three phases: the unsustainable development state for 1991-1998; the critical development state for 1999-2001; the sustainable development state for 2002-2005.

① 1991-1998, during which the composite index of the sports sustainable development system is in the block(0.25,0.45), is the unsustainable development state of the sustainable development of sports. The reasons are: China is at the food and clothing stage, the people's standard of living is very low, in this stage the nation's main task is to solve the problem of feeding the people, people's main focus is to solve the food and clothing problem, and sports exists mainly as a leisure and entertainment activity, therefore it is difficult to see a big improvement of the sports .

Table 3 The development level results of the sustainable development system and subsystems of China's sports for 1991-2005

year	PSIS	SEIS	SCIS	STIS	SDIS
1991	0.19	0.19	0.22	0.41	0.20
1992	0.23	0.21	0.30	0.39	0.23
1993	0.23	0.31	0.47	0.39	0.30
1994	0.21	0.11	0.36	0.47	0.19
1995	0.24	0.18	0.40	0.34	0.23
1996	0.18	0.31	0.41	0.39	0.27
1997	0.28	0.21	0.38	0.50	0.26
1998	0.31	0.49	0.42	0.51	0.41
1999	0.31	0.56	0.35	0.43	0.44
2000	0.32	0.64	0.35	0.37	0.48
2001	0.34	0.69	0.37	0.43	0.52
2002	0.54	0.64	0.57	0.50	0.59
2003	0.44	0.61	0.56	0.46	0.53
2004	0.56	0.60	0.42	0.43	0.56
2005	0.79	0.62	0.48	0.59	0.67
weight	0.385	0.483	0.093	0.039	—

* PSIS - Sports population subsystem development index, the SEIS - Sports economic subsystem development index, SCIS – sports cultural subsystem development index STIS - Sports Science Subsystem development index, SDIS - Sports Sustainable Development System development Index.

② 1999-2001, during which the composite index of the sports sustainable development system is in the block(0.45, 0.55), is the critical development state of the sustainable development of sports. The reasons are: the state's GDP is in steady growth, per capita GDP is close to the level of middle-income countries, the Engel coefficient declined steadily, and the people's life has just begun to achieve a well-off level, enabling the transitional transition of the country and the people's input into and consumption of the sports

③2002-2005, the composite index of the sports sustainable development system is in the block (0.55, 0.75). The first reason is that the forces of the subsystems of both the sports economy and the sports population have reached a higher level. For example, the per capita GDP broke through 1,000 US dollars since 2001 and reached the level of middle-income countries; Engel coefficient declined up to 40.95 at the same year, the people's living standards get a high improvement and people's lives reach the well-to-do level, which ensure that people have leisure time and disposable funds to spend on sport and physical consumption. in 2001 the State Sports funds reached 11.91 billion yuan, 7.5 times of that in 1991, providing a strong economic power for our countries' sports cause; with China's success in bidding for the Olympic Games in 2001, people hold a high spirit on the sports and the number of people who participate in sports meetings above the county level reached 119091000 in 2002, which is 12.5 times of that in 1991; at the same year the National Physical Training Standards figure reached 11.98%, 1.66 times of that in 1991; the number of people who get the world champion reached 123, which is 37 more than that of 1991, and 1.4 times of that in 1991; the performance is that on the summation of the composite index of the two subsystems they reach 0.47,0.52,0.45,0.46,0.47 respectively, which is 2.6,2.9,2.5,2.6,2.6 times of those respectively in 1991, which indicate that the value has reached a high level. Second, during this period the two subsystems sports cultural and sports science and technology system maintained a relatively stable level, and thus makes the overall system maintain a high state of development, that is, the sustainable development state.

5. Conclusion

5.1 1991-2005, the country's sports has been showing a good momentum of development, and its development index of 0.20 in 1991 has steadily increased up to 0.67 in 2005, an increase of 0.47, rising as much as 235%, with an average annual growth of 15.67 percent.

5.2 The sustainable development state of China's sports in the past 15 years is : the unsustainable development state for 1991-1998; the critical development state for 1999-2001;the sustainable development state for 2002-2005.

5.3 in the sustainable development system of China's sports the weights of each subsystem can be arranged by size as follows: Sports economic subsystem 0.483, sports population subsystem 0.385, sports cultural subsystems 0.093, Sports Science Subsystem 0.039.

5.4 The top five of the indicators and weights which affect the sustainable development system of China's sports are: national athletics sports input 0.108; mass movement participation rate of 0.083; national sports input 0.076; national sports input-output index 0.062; coaches' guidance level of 0.061

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