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## Analytic hierarchy process-based national competitive sports value comparative research

Dezhong Li

Department of Physical Education, Harbin University of Science and Technology,  
Harbin 150080, Heilongjiang, (CHINA)

### ABSTRACT

Nowadays, world globalization becomes more and more heated; all countries in the world mutual cooperate while they also have intense competition. Today's competition has become not only economic competition but also soft power contests. And meanwhile, competitive sports value also plays important roles. The paper takes China, America, Russia and Japan four countries as research objects, utilizes analytic hierarchy process, establishes hierarchical structure chart of exploring country of highest competitive sports value. By reference lots of literatures, it is clear that competitive sports values influence factors are spiritual value, economic value, cultural value and political value. Comprehensive consider these four factors, establish paired factors comparison matrix. By relative software calculating, and then get conclusion, among the four countries, China is a country with highest competitive sports value.

### KEYWORDS

Analytic hierarchy process; Competitive sports value; Mathematical model; Consistency test.



## INTRODUCTION

Nowadays, competitive sports have become an indispensable event in daily life and sports field. To people at work and in learning, competitive sports is a kind of way to relax. To professional athletes, competitive sports is a form to reflect their works values.

In 2007, Kang Dong in the article “Competitive sports value orientation changes and impacts on building harmonious society”, analyzed sports value problem from value composition, value type and sports composition three perspectives. The author took competitive sports value orientation and its changes as research objects, started researching from competitive sports value orientation theoretical level, found benefits that competitive sports brought into building socialism harmonious society, and then implemented the purpose of combining theory with practice.

In 2013, Jiang Xing-Hua in the article “Competitive sports education value interpretation”, took Ivy school as research object, firstly introduced sports and competitive sports connotations, and then made preliminary analysis of Ivy school competitive sports status, and made profound summary of the school reflected education value. The article pointed out that Chinese universities should make research on Ivy school sports culture, system construction and other aspects.

In 2012, Duan Lian in the article “Competitive sports ethical education value study”, comprehensive applied experts interview, logic analysis and others multiple research methods, explained Chinese competitive sports development important significances after Beijing Olympic Games in 2008. The article synoptically pointed out competitive sports ethical value and education value existence had practical significances. At the same time, the author put forward ways that could reflect sports value ethical value to the maximum extent.

In 2010, Shu Sheng-Fang in the article “Great power competitive sports rising and their strategic value study”, from the perspective of competitive sports rising, rising motivations, rising strategy generation and strategic value four perspectives, made research and analysis of China, Russia, Japan and America four great powers. Analysis result showed each country ways in upgrading strategic value were different, Japan mainly relied on competitive sports strength, America relied on powerful society sports organization, China relies on national force and cohesive force.

Today competitive sports play huge values with its unique ways. Competitive sports have different classification ways, the paper divides competitive sports values into four types they are respectively cultural value, political value, economic value and spiritual value, integrates the four type factors, it makes comprehensive evaluation on optimal country in competitive sports value.

## ANALYTIC HIERARCHY PROCESS MODEL ESTABLISHMENTS

The paper selects four countries they are respectively Japan, Russia, America and China. In the evaluation process, it needs to consider factors as cultural value, political value, economic value and spiritual value.

*AHP* can solve relative tedious and vague problems’ decision-making problems. Use the method to construct model, it roughly needs four steps :

- Establish hierarchical structure scheme;
- Construct every layer that fully used in judgment matrix;
- Hierarchical single arrangement and consistency test;
- Hierarchical total arrangement and consistency test;

In the following, it respectively states each step detailed process.

### Hierarchical structure

*AHP* solved problems are required to be hierarchic, orderly and logic. Only then it can construct hierarchical scheme. Let tedious problems’ elements to form into multiple hierarchies according to its

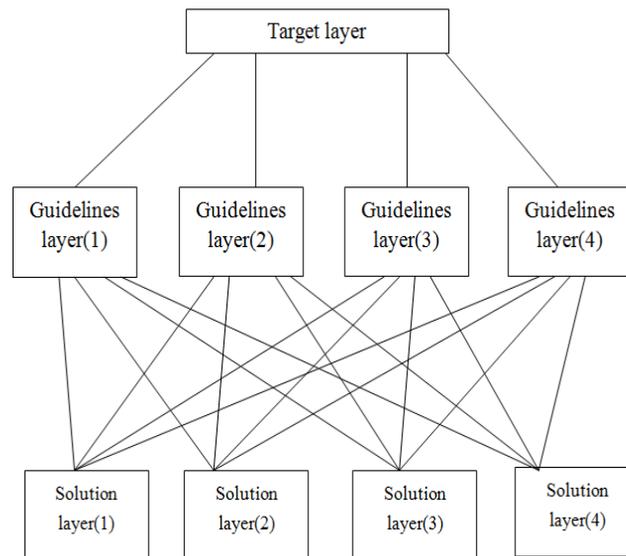
attributes, membership and its relations. Last hierarchical element plays a dominate role in next hierarchical relative elements. In general, these hierarchies can be divided into 3 types:

(1) Top layer: Only one element in this hierarchy, it normally is final target of analytic problems. The layer is also called target layer.

(2) Middle hierarchy: In this hierarchy, it includes intermediate links that get involved to fulfill targets, which can be composed of some hierarchies that include multiple and multilayer criterions that required to consider. It can also be called guidelines layer.

(3) The bottom hierarchy: This hierarchy includes optional each method and way to fulfill targets. It can also be called measure layer or solution layer.

Hierarchy numbers in hierarchical structure have something to do with problem's complicated degree as well as analysis detailed requirements, normally the hierarchy numbers are not limited, each element in every hierarchy governs less than 9 elements. Hierarchical structure is as Figure 1.



**Figure 1 : Hierarchical structure chart**

In Figure 1, layer 1 is target layer that is the purpose which is required to finally fulfill for researching problems, layer 2 is guidelines layer that is the medium process that researching problems go through, layer 3 is solution layer that is each kind of referencing solutions. In general, layer one is one factor, layer two and layer three have multiple factors and quantity is not fixed.

### Judgment matrix construction

Each layer structure can show factors relationships, but in middle layer, each factor occupied proportion in target evaluation basically will not be fully the same, in the heart of evaluators, each factor has certain proportions.

When define each factor proportion that is to compare  $n$  pieces of factors  $X = \{x_1, \dots, x_n\}$  to factor  $Z$  impacts. Saaty etc. proposed to carry out paired comparison among factors, and constructed comparison matrix method. That is to say, it selects two factors  $x_i$  and  $x_j$  every time, uses  $a_{ij}$  to express  $x_i$  and  $x_j$  to  $Z$  impacts ratios, all comparison is using matrix  $A = (a_{ij})_{n \times n}$  to express,  $A$  has become judgment matrix between  $Z - X$ . From matrix, it is clear that if  $x_i$  and  $x_j$  to  $Z$  impact ratio is  $a_{ij}$ , then  $x_j$  and  $x_i$  to  $Z$  impact ratio is  $a_{ji} = \frac{1}{a_{ij}}$ .

According to linear algebra theoretical knowledge, if matrix  $A = (a_{ij})_{n \times n}$  meets  $a_{ij} > 0$  and  $a_{ji} = \frac{1}{a_{ij}}$  ( $i, j = 1, 2, \dots, n$ ), then matrix  $A$  is positive reciprocal matrix.

$a_{ij}$  Value determination can accord scale table, contents are as following TABLE 1.

TABLE 1 : Scale table

Scale	Definition
1	Indicates two factors have equal importance by comparing
3	Indicates the former is slightly more important than the later by comparing two factors
5	Indicates the former is obviously more important than the later by comparing two factors
7	Indicates the former is intensely more important than the later by comparing two factors
9	Indicates the former is extremely more important than the later by comparing two factors
2, 4, 6, 8	Indicates middle level of above judgment
Reciprocal	If importance ratio between $i$ and $j$ is $a_{ij}$ , then importance ratio between $j$ and $i$ is $a_{ji} = \frac{1}{a_{ij}}$ .

**Consistency test**

Matrix  $A$  corresponding maximum feature value  $\lambda_{max}$  feature vector  $W$ , it is the priority weight of same hierarchy corresponding elements relative importance to last hierarchy some element through normalization, the process is called hierarchical single arrangement. Though the process can reduce other factors interference, it is hard to avoid appearing inconsistency to some extent when integrate all comparison results. If comparison results are consistent, then  $A$  factor should also meet:

$$a_{ij}a_{jk} = a_{ik}, \forall i, j, k = 1, 2, \dots, n \tag{1}$$

The positive reciprocal matrix that meets above formula is called consistent matrix. To easy define  $A$  can be accepted or not, it should test  $A$  inconsistency is very serious or not.

If  $A$  is consistent matrix, then

- (1)  $A$  surely is positive reciprocal matrix.
- (2) Transposed matrix  $A^T$  is consistent matrix.
- (3)  $A$  matrix any two lines are in proportions, and factors are above 0, therefore  $rank(A) = 1$ , so is the column.
- (4) In  $A$ ,  $\lambda_{max} = n$ ,  $n$  is  $A$  matrix order number. Other features roots of  $A$  is 0.

(5)  $\lambda_{max}$  corresponding feature vector  $W = (w_1, \dots, w_n)^T$ , then  $a_{ij} = \frac{w_i}{w_j}, \forall i, j = 1, 2, \dots, n$ , so:

$$A = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \dots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \dots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \dots & \frac{w_n}{w_n} \end{bmatrix} \tag{2}$$

$A$  is  $n$  order positive reciprocal matrix, when it is consistent matrix, when and only when  $\lambda_{\max} = n$  as well as when  $A$  is inconsistent, it surely has  $\lambda_{\max} > n$ . Thereupon, use  $\lambda_{\max}$  and  $n$  relationship to test whether  $A$  is consistent matrix or not.

$A$  consistency test steps:

Calculate consistency indicator  $CI$ ,

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (3)$$

Consult corresponding average random consistency indicator  $RI$ . *Saaty* researched  $RI$  value,  $RI$  value could refer to TABLE 2.

TABLE 2 :  $RI$  value

n	1	2	3	4	5	6	7	8	9
$RI$	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

$RI$  Value is got in this way that randomly constructs 500 sample matrixes. Random select numbers from 1 to 9 as well as its reciprocals to construct positive reciprocal matrix, and determine average value of maximum feature root  $\lambda'_{\max}$ , and define

$$RI = \frac{\lambda'_{\max} - n}{n - 1} \quad (4)$$

Solve consistency ratio  $CR$

$$CR = \frac{CI}{RI} \quad (5)$$

When  $CR < 0.10$ , it is thought that  $A$  consistency is acceptable, otherwise it should make proper correction.

In the process, it also includes hierarchical total arrangement and consistency test, due to article lengths are limited, no theoretical statements here, directly apply it in the following.

### CONSTRUCT SPORTS VALUE OPTIMAL COUNTRY MODEL

The purpose of the model establishment is to look for competitive value highest country from the four countries. Therefore, target layer is value of competitive sports optimal country. Considering competitive sports include four aspects, therefore, guidelines layer includes four elements that are respectively cultural value, political value, economic value and spiritual value. The model solution layer includes Japan, Russia, America and China four countries. Hierarchical structure is as Figure 2.

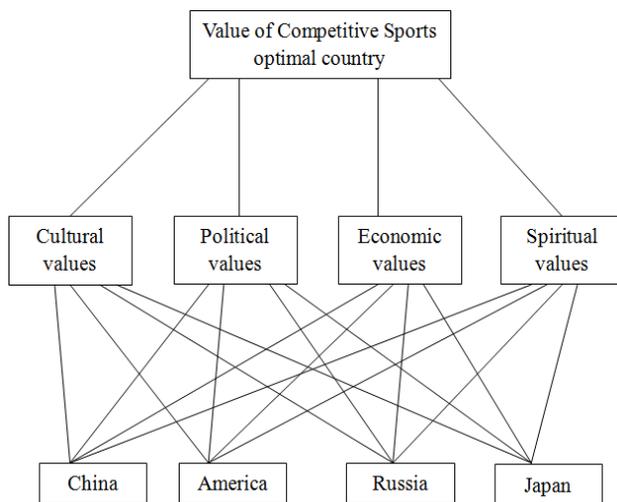


Figure 2 : The hierarchy chart of sports optimal value of country

**Judgment matrix construction**

Construct judgment matrix firstly needs to define guidelines layer four factors importance comparison result. Considering different occupations have different opinions on problems, we adopt hierarchical sampling questionnaire survey form to define their importance, respectively random selects ten teachers, ten university students, ten athletes and ten white-collar workers, subsequently we handle with investigation result, it can get data as TABLE 3.

TABLE 3 : Four values importance comparison

	Percentage (%)	Rank
Spiritual value	45.3	1
Economic value	29.4	2
Cultural value	19.6	3
Political value	5.7	4

According to TABLE 3 data, we establish target layer paired comparison matrix, as TABLE 4 show.

TABLE 4 : Target layer paired comparison matrix

A	B <sub>1</sub>	B <sub>2</sub>	B <sub>3</sub>	B <sub>4</sub>
B <sub>1</sub>	1	1/2	1/3	1/5
B <sub>2</sub>	2	1	1/2	1/3
B <sub>3</sub>	3	2	1	1/2
B <sub>4</sub>	5	3	2	1

And then, establish guidelines layer paired matrix, data contents are as TABLE 5-8.

TABLE 5 : Guidelines layer paired matrix one

B <sub>1</sub>	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>4</sub>
P <sub>1</sub>	1	1/2	1/3	1/4
P <sub>2</sub>	2	1	1/2	1/3
P <sub>3</sub>	3	2	1	1/2
P <sub>4</sub>	4	3	2	1

TABLE 6 : Guidelines layer paired matrix two

<b>B<sub>2</sub></b>	<b>P<sub>1</sub></b>	<b>P<sub>2</sub></b>	<b>P<sub>3</sub></b>	<b>P<sub>4</sub></b>
<i>P<sub>1</sub></i>	1	2	1/2	1/3
<i>P<sub>2</sub></i>	1/2	1	1/3	1/4
<i>P<sub>3</sub></i>	2	3	1	1/2
<i>P<sub>4</sub></i>	3	4	2	1

TABLE 7 : Guidelines layer paired matrix three

<b>B<sub>3</sub></b>	<b>P<sub>1</sub></b>	<b>P<sub>2</sub></b>	<b>P<sub>3</sub></b>	<b>P<sub>4</sub></b>
<i>P<sub>1</sub></i>	1	1/2	1/3	1/4
<i>P<sub>2</sub></i>	2	1	1/2	1/3
<i>P<sub>3</sub></i>	3	2	1	1/2
<i>P<sub>4</sub></i>	4	3	2	1

TABLE 8 : Guidelines layer paired matrix four

<b>B<sub>4</sub></b>	<b>P<sub>1</sub></b>	<b>P<sub>2</sub></b>	<b>P<sub>3</sub></b>	<b>P<sub>4</sub></b>
<i>P<sub>1</sub></i>	1	2	3	5
<i>P<sub>2</sub></i>	1/2	1	2	3
<i>P<sub>3</sub></i>	1/3	1/2	1	2
<i>P<sub>4</sub></i>	1/5	1/3	1/2	1

TABLE 5 data shows each country comparative status about spiritual value.

### Computed result

The model involved algorithm can implement by *Matlab* software programming, therefore it can get computed result as TABLE 9.

TABLE 9 : Hierarchical total arrangement

<b>Guidelines</b>		<b>Spiritual value</b>	<b>Economic value</b>	<b>Cultural value</b>	<b>Political value</b>	<b>Total arrangement weight</b>
Guidelines layer weight		0.0083	0.0178	0.0178	0.0178	
Solution layer single arrangement	China	0.4829	0.1601	0.1601	0.0954	0.016964
	America	0.2720	0.0954	0.0954	0.1601	0.013361
	Russia	0.1570	0.2772	0.2772	0.2772	0.013361
	Japan	0.0882	0.4673	0.4673	0.4673	0.13360

From TABLE 9 data, it is clear competitive sports value highest one is China, secondly are America and Russia, the worst is Japan, in order to more intuitional express analysis result, draw pie chart, as Figure 3.

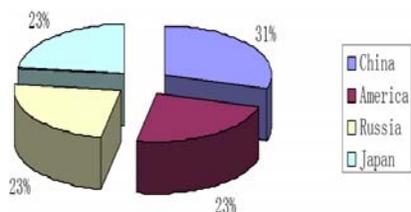


Figure 3 : The figure of evaluation results

By Figure 3, we can more intuitional see that China is the country with highest competitive sports value. The model compares four stronger sports countries in the world, in order to more intuitional compare four countries internal factors, draw broken line figure as Figure 4 shows.

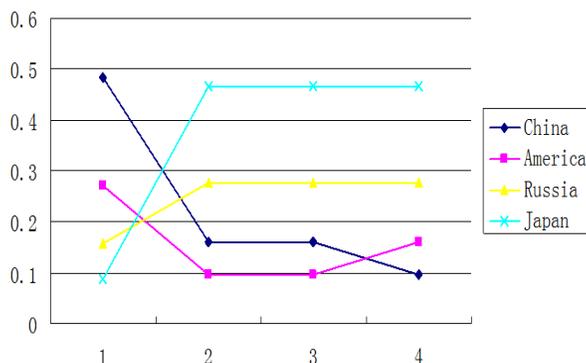


Figure 4 : Internal situation comparison chart

From Figure 4, we can easily see that the four countries economic values are roughly the same as cultural values; finally it is spiritual value that decides competitive sports value high or low, which is consistent to questionnaire survey results.

### CONCLUSION

Analytic hierarchy process mainly includes two steps, firstly it extracts practical problems that to be urgently solved as a hierarchical structure with certain logic structure, and then make qualitative comparison of problems, and then define quantitative parameters. When carry on the step two, in the process that transferring from qualitative relationship to quantitative relationship, artificial interference component is larger, so result accuracy will suffer certain impacts.

The paper applies analytic hierarchy process into researching competitive sports value highest country problem, takes China, America, Russia and Japan four countries as research objects, by analyzing competitive sports spiritual value, economic value, cultural value and political value these four aspects, we get conclusion. China is a country with highest competitive sports value, the conclusion conforms to real life. The conclusion will produce positive impacts on future sports value and other problems studies.

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