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Research Article

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Research and application of the analytical hierarchy model based on sports industry resource optimization and structure layout strategy

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ABSTRACT

Firstly, from the perspective of optimizing sports industry, four factors of judging schemes are obtained. They are the number of employees in the sports industry, its resources, the soundness of relevant policies and its impacts on the economy. Then the analytical hierarchy research is conducted. With the acceleration of China's new-type urbanization, the demand for sports facilities in new-type cities and towns has been increasing year by year. Stadiums or sports facility groups should bring into full play the covering effect. Thus, in response, this paper builds a hexagonal honeycomb model according to geographical features. This paper establishes a structural layout model and uses the honeycomb model to study the sports service model.

Key words: Cellular network; sports industry; AHP method

INTRODUCTION

Being a veritable sunrise industry, the sports industry consists of physical industry and mental industry. As a component of national economy, the sports industry attaches importance to market efficiency and economic benefits. But different from other industries, it is characterized with improving the quality of residents, developing social production and achieving the comprehensive individual and national development.

1.1 Analysis of current domestic situation
In recent years, China has hosted a great number of sports events, leading to rapidly increasing demand for sports venues. Besides, with people's growing consciousness of sports, demands for sports ranging from sports facilities in residential communities to major sports games have been increasing year by year. As a matter of fact, sports facilities or venues not only generate favorable cultural benefits but also bring objective economic benefits for sports venues.

2. OPTIMIZATION OF SPORTS INDUSTRY RESOURCES

2.1 Building a hierarchical structure
Establish the target layer, criterion layer and scheme layer. Target layer represents the most important sports industry. Criterion layer-(influencing factors of the scheme): c_1 represents the number of employees in that sports industry, c_2 the impact of the sports industry on economy, c_3 resources owned by that industry and c_5 the soundness of policies pertaining to that sports industry. Scheme layer consists of A_1-sports goods and construction, A_2-commercial sports, A_3- leisure Sports

2.2 Constructing a judgment (pair-wise comparison) matrix
On the basis of the scale table ranging from 1 to 9 shown in table 1, the weight analysis is conducted.

Tab. 1: 1～9 scale stable

Scale a_{ij}	Definition
1	i factor is equally important with j factor.
3	i factor is slightly more important than j factor.
5	i factor is relatively more important than j factor.
7	i factor is much more important than j factor.
9	i factor is extremely more important than j factor.
2, 4, 6, 8,	corresponding scale value of the intermediate state between the judgments above
reciprocal	If i factor is compared with j factor, then the judgment value is a_{ji} =1/ a_{ij} , a_{ii} =1

Figure 1 is the graph ranging from scale 1 to 9.

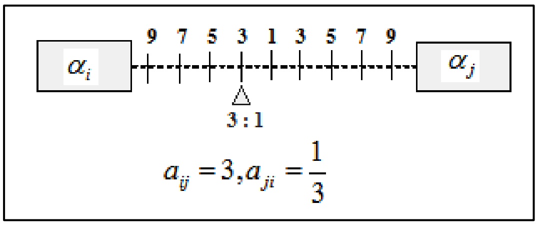


Fig. 1: Scale graph from 1 to 9

Tab. 2: Comparison matrix

G	c_1	c_2	c_3	c_4
c_1	1	8	5	3
c_2	1/8	1	1/2	1/6
c_3	1/5	2	1	1/3
c_4	1/3	6	3	1

Tab. 3: Comparison matrix

c_1	A_1	A_2	A_3
A_1	1	5	1/5
A_2	1/5	1	1/5
A_3	5	5	1

Tab. 4: Comparison matrix

c_2	A_1	A_2	A_3
A_1	1	3	3
A_2	1/3	1	3
A_3	1/3	1/3	1

Firstly, find the solution of the judgment matrix according to the principles above and by referring to the scale setting from 1 to 9. Then based on the experience of experts and the author and through referring to extensive literature, pair-wise comparison matrixes under four principles are obtained and they are shown in the following tables.

Tab. 5: Comparison matrix

c_3	A_1	A_2	A_3	c_4	A_1	A_2	A_3
A_1	1	5	3	A_1	1	1/5	1/8
A_2	1/5	1	3	A_2	5	1	1/3
A_3	1/3	1/3	1	A_3	8	3	1

2.4 Single hierarchical arrangement and its consistency test

Consistency indexes are examined. Suppose $\lambda_{\max}$ is the maximum eigen-value and n the order of comparison matrix, then we have $CI = \frac{\lambda_{\max} - n}{n-1}$. The smaller CI is, the closer the judgment matrix is to complete consistency. The bigger CI is, the less known the judgment matrix is.

2.5 Total hierarchical arrangement and its consistency test

$$A = \begin{Bmatrix} 1 & 8 & 5 & 3 \\ 1/8 & 1 & 1/2 & 1/6 \\ 1/5 & 2 & 1 & 1/3 \\ 1/3 & 6 & 3 & 1 \end{Bmatrix}$$

$$Column\ vectornormalization \begin{Bmatrix} 0.603 & 0.470 & 0.526 & 0.667 \\ 0.075 & 0.059 & 0.053 & 0.037 \\ 0.121 & 0.118 & 0.105 & 0.074 \\ 0.201 & 0.353 & 0.316 & 0.222 \end{Bmatrix}$$

$$Row\ sum \begin{Bmatrix} 2.266 \\ 0.224 \\ 0.418 \\ 1.092 \end{Bmatrix}$$

$$Normalization \begin{Bmatrix} 0.567 \\ 0.056 \\ 0.104 \\ 0.273 \end{Bmatrix} = \mathrm{W}^{(0)}$$

$$AW^{(0)} = \begin{Bmatrix} 1 & 8 & 5 & 5 \\ 1/8 & 1 & 1/2 & 1/6 \\ 1/5 & 2 & 1 & 1/3 \\ 1/3 & 6 & 3 & 1 \end{Bmatrix} \begin{Bmatrix} 0.567 \\ 0.056 \\ 0.104 \\ 0.273 \end{Bmatrix} = \begin{Bmatrix} 2.554 \\ 0.225 \\ 0.422 \\ 1.110 \end{Bmatrix}$$

$$\lambda_{\max}^{(0)} = \frac{1}{4}\left(\frac{2.354}{0.567} + \frac{0.225}{0.056} + \frac{0.422}{0.104} + \frac{1.110}{0.273} \right) = 4.073$$

$$w^{(0)} = \begin{pmatrix} 0.567 \\ 0.056 \\ 0.104 \\ 0.273 \end{pmatrix}$$

Likewise, the judgment matrix can be calculated:

$$B_1 = \begin{Bmatrix} 1 & 5 & 1/5 \\ 1/5 & 1 & 1/5 \\ 5 & 5 & 1 \end{Bmatrix}, B_2 = \begin{Bmatrix} 1 & 3 & 3 \\ 1/3 & 1 & 3 \\ 1/3 & 1/3 & 1 \end{Bmatrix}, B_3 = \begin{Bmatrix} 1 & 5 & 3 \\ 1/5 & 1 & 3 \\ 1/3 & 1/3 & 1 \end{Bmatrix}, B_4 = \begin{Bmatrix} 1 & 1/5 & 1/8 \\ 5 & 1 & 1/3 \\ 8 & 3 & 1 \end{Bmatrix}$$

The corresponding maximum eigen-values and eigenvectors are as follows in proper order:

$$\lambda^{(1)}{}_{\max} = 3.31, \omega^{(1)}{}_1 = \begin{Bmatrix} 0.252 \\ 0.089 \\ 0.66 \end{Bmatrix}$$

$$\lambda^{(2)}_{\max} = 3.12, \omega^{(1)}_{2} = \begin{Bmatrix} 0.575 \\ 0.286 \\ 0.139 \end{Bmatrix}$$

$$\lambda^{(3)}_{\max} = 3.30, \omega^{(1)}_{3} = \begin{Bmatrix} 0.624 \\ 0.240 \\ 0.136 \end{Bmatrix}$$

$$\lambda^{(4)}_{\max} = 4.05, \omega^{(1)}_{4} = \begin{Bmatrix} 0.185 \\ 0.240 \\ 0.575 \end{Bmatrix}$$

Then consistency indexes are used for examination: $CI = \frac{\lambda_{\max} - n}{n-1}$, $CR = \frac{CI}{RI}$.

Tab. 6: RI value

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

The judgment matrix A is obtained. $\lambda^{(0)}_{\max} = 4.073, RI = 0.9$, $CI = \frac{4.073-4}{4-1} = 0.24$ and $CR = \frac{CI}{RI} = \frac{0.024}{0.90} = 0.027 < 0.1$ show that the inconsistency test of A is valid and moves within the permissible range. Under this circumstance, A's eigenvector can be used to replace its weight vector.

By the same token, consistency test is conducted on judgment matrixes B_1, B_2, B_3 and B_4, after which the weight vector is acquired. The calculation results from the target layer to the scheme layer are drawn, as shown in figure 2 in the light of the hierarchical chart.

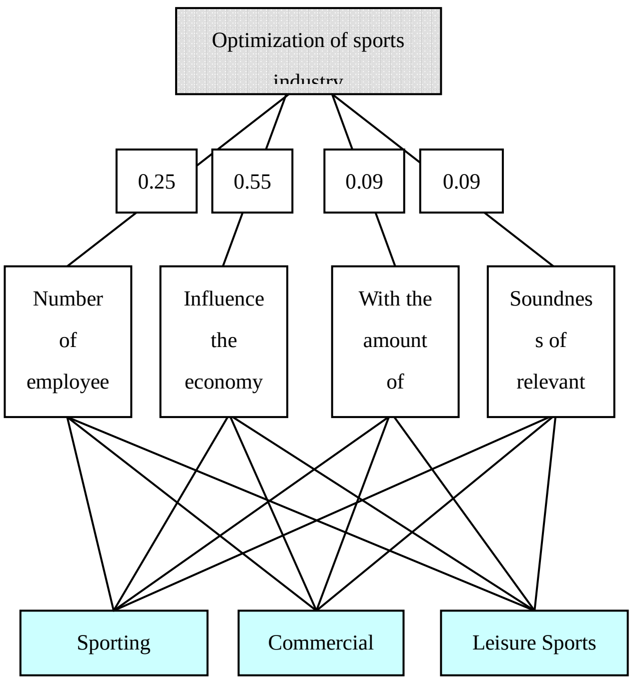


Fig. 2: Hierarchical chart

$$\begin{Bmatrix}0.258\\0.049\\0.637\end{Bmatrix},\begin{Bmatrix}0.875\\0.156\\0.186\end{Bmatrix},\begin{Bmatrix}0.674\\0.250\\0.136\end{Bmatrix},\begin{Bmatrix}0.455\\0.268\\0.575\end{Bmatrix}$$

The computation structure is as follows:

$$\omega^{(1)}=(\omega_1^{(1)},\omega_2^{(1)},\omega_3^{(1)},\omega_3^{(1)})$$
$$=\begin{Bmatrix}0.624 & 0.185 & 0.252 & 0.575\\0.234 & 0.240 & 0.089 & 0.286\\0.136 & 0.575 & 0.66 & 0.139\end{Bmatrix}$$
$$w=w^{(1)}w^{(0)}$$
$$=\begin{Bmatrix}0.245 & 0.635 & 0.624 & 0.155\\0.058 & 0.286 & 0.250 & 0.270\\0.77 & 0.445 & 0.121 & 0.575\end{Bmatrix}\begin{Bmatrix}0.587\\0.0567\\0.145\\0.253\end{Bmatrix}$$
$$=\begin{Bmatrix}0.250\\0.184\\0.547\end{Bmatrix}$$

3. OPTIMIZATION OF STRUCTURAL LAYOUT

Based on regional characteristics, this paper establishes a structural layout model and employs the cellular model for research which is mainly targeted at sports service models. Firstly, this paper figures out the number of China's newly-built sports venues in the last two decades as shown in table 7.

Tab.7: The number of China's newly-built sports venues in the last two decades

Year	Total	Stadium	Gym	Natatorium	Indoor and outdoor swimming pool	Sports venues with fixed seating
1980	709	10	9	/	44	96
1985	700	47	29	1	135	137
1990	3691	27	34	4	105	60
1995	1007	36	37	1	80	43
1999	572	6	24	/	15	14

In recent years, the demand for sports facilities has been increasing in China, which results from the current sports situation of all Chinese people. Thus, more efforts are devoted to building the sports facilities and stadiums across the country. In addition, with the acceleration of China's new-type urbanization, demands for sports facilities in new-type cities and towns have been growing year by year. Stadiums or sports facility groups should bring into play the covering effect. However, what kind of model can make the coverage area reasonable? To solve this problem, this paper establishes a hexagonal cellular model.

Tab. 8: Comparison of three kinds of shapes

Shape of residential areas	Regular triangle	Square	Regular hexagon
Neighborhood distance	r	$\sqrt{2}r$	$\sqrt{3}r$
Proportion of residential areas	$1.3r^2$	$2r^2$	$2.6r^2$
Width of overlapping areas	r	$0.59r$	$0.27r$
Proportion of overlapping areas	$1.2\pi r^2$	$0.73\pi r^2$	$0.35\pi r^2$

3.1 Hexagonal cellular model

From the perspective of the number of people who need sports service, the coverage area is circular. Under the condition of the same radiation radius r, the neighborhood distance, proportion of residential areas, width of overlapping areas and proportion of overlapping areas of three kinds of residential areas are calculated, as shown in table 8.

From table 8, we can see that the shape of regular hexagon is closest to the ideal circular form and can meet the needs of coverage area effectively. So the cellular structure is built using the center of regular hexagon which extends outward. The process is shown below.

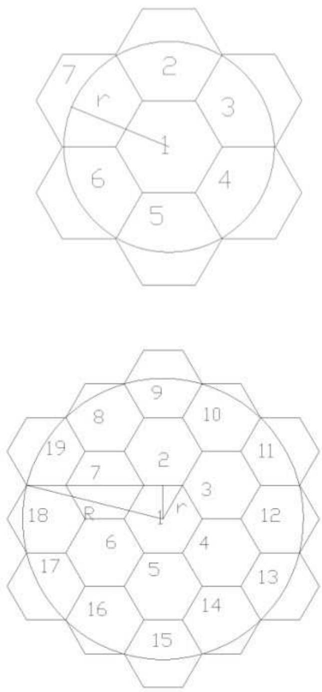


Fig. 3 Process

Tab. 9: Statistics table

The number of sports service facilities N	**Coverage radius** r	**The number of sports service facilities** N	**Coverage radius** r
1	38	1261	1.956
7	19	1569	1.784
19	15.6	1623	1.542
37	8	1659	1.667
65	7.184	1801	1.568
100	6.667	1935	1.538
156	5.298	2001	1.568
169	6.2	2269	1.536
257	5.312	2437	1.355
271	6	2611	1.348
325	3.468	2791	1.569
397	3.333	2851	1.56
489	2.957	3169	1.598
563	2.857	3527	1.459
653	2.577	3571	1.236
721	2.5	3781	1.895
817	2.283	3658	1.566
919	2.222	4116	1.235
1025	2.049	4589	1.547
6653	2.034	4364	1.35

As the boundary of circular region lies in the center of the outermost hexagon, we can get the following formula through the law.

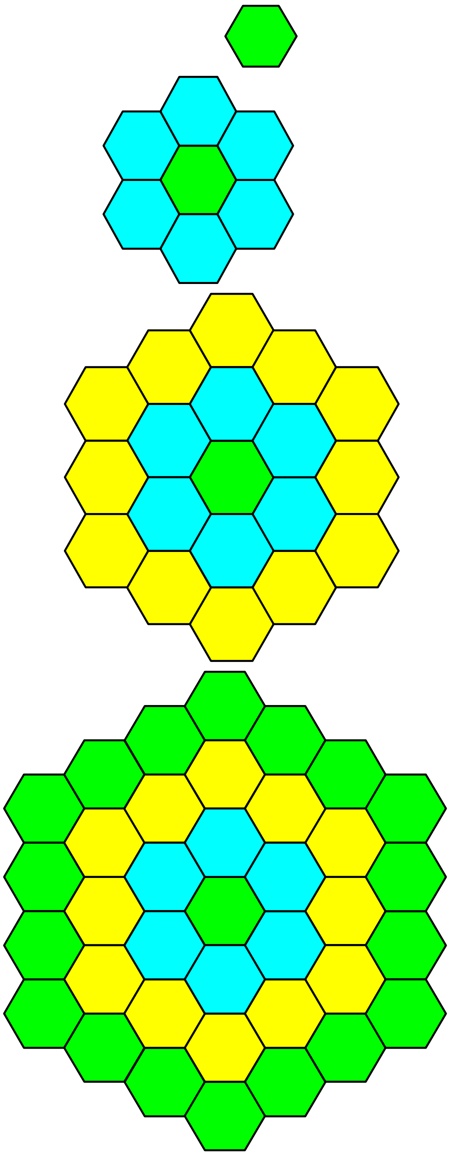
$$N = 12n^3 + 30n + 19 + 1$$

In this formula, N represents the number of hexagons needed to be spread the circular area.

$$n = \frac{D}{d}$$

In this formula, D stands for the diameter of circular area and d the diameter the inscribed circle of hexagon.

By way of calculation, this paper obtains the statistics table of the number of sports facilities or stadiums N and coverage radius r, as shown in table 9.



$N = 1$

$N = 3 + 2 + 2$

$N = 3 + 4 + 5 + 4 + 3$

$N = 4 + 5 + 6 + 7 + 6 + 5 + 4$

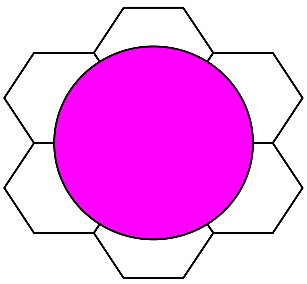


Diagram 1

As the above graphs show, this paper finds out the relationship between the diameter d and the number of hexagons N. The graph resulting from the combinations of hexagons has a higher fitting degree with the circular form.

CONCLUSION

Being one of China's sunrise industries, the sports industry consists of physical industry and mental industry. As a component of national economy, the sports industry attaches importance to market efficiency and economic benefits. But different from other industries, it is characterized with improving the quality of residents, developing social production and achieving the comprehensive individual and national development.

Stadiums or sports facility groups should bring into play the covering effect. To solve this problem, this paper establishes a hexagonal cellular model. Based on regional characteristics, this paper builds a structural layout model and employs the cellular model for research which is mainly targeted at sports service models. In recent years, China has hosted a great number of sports events, leading to rapidly increasing demand for sports venues. Besides, with people's growing consciousness of sports, demands for sports ranging from sports facilities in residential communities to major sports games have been increasing year by year. As a matter of fact, sports facilities or venues not only generate favorable cultural benefits but also bring objective economic benefits for sports venues.

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