Study and Applications of Analytic Hierarchy Process (AHP) on Basketball Offence

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ABSTRACT

In the studies of basketball competitions, the focus is mainly on the players' offensive capacity that may affect the outcome of the game. The offensive capacity of a team is decided by many factors, so it is of great necessity to set up an evaluation index system in order to further explore those various factors. This paper aims at analyzing the offensive effects of different level of offensive capacity during the basketball competitions and developing an index system to evaluate basketball offensive capacity in order to provide basketball players with a rational approach of training and improving competition skills. This paper first analyzes basketball offensive capacity in detail by extracting indicators of offensive capacity and setting up a multilayer index system to evaluate the offensive capacity of a team. It then quantifies all the indicators according to Fuzzy Mathematics Theory. At last the paper presents the process of offensive capacity evaluation based on AHP, providing a theoretical basis for more scientific and accurate evaluation of basketball offensive capacity.

Key words: Evaluation index system of offensive capacity; judgment matrix; analytical hierarchy process; consistency check

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INTRODUCTION

A huge number of people around the world are crazy about basketball, a competitive sport that requires teamwork and collaboration. Offense and defense are the two postures during the competition, the former one being the main indicator to evaluate a team's performance. This paper conducts an analysis of offense to explore a rational approach for targeted training of the team, hoping to contribute to the improvement of the skills of basketball players.

Many researchers have made their efforts on the study of evaluating offensive capacity as well as the application of AHP model. Wang Pingdeng (2008) analyzes various factors that influence medium-term talent selections of top basketball players and sets up a hierarchical structural medium-term talent selection index system, offering a scientific theoretical basis to basketball training. Liu Xing(2011) studies characteristics and organization of exterior attacks by center players, pointing out that it is a development trend of modern basketball for centers to become exteriorized．He also brings up suggestions for center players to be equipped with strong interior offensive ability, exterior offensive ability as well as organizing ability. Su Yuejin, et al (2011) study the development patterns of Taekwondo in universities and colleges by using AHP, pointing out a coordinated development mode where the Taekwondo optional course is the main focus while the society, associations, clubs and school team of Taekwondo are supplements. They also quantify the subjective factors that influence Taekwondo's development in colleges and universities, such as teachers' teaching methods and teaching organizations (taking up 0.3066) and students' attitudes and basic skills (taking up 0.1534), providing the foundation for assessment of Taekwondo's development in higher educational institutes.

Based on the previous studies, this paper focuses on analyzing the technique characteristics of basketball, extracting the indicators of offensive capacity which offers the foundation to the AHP index system, and presenting the

evaluation process and computing methods of AHP in the evaluation index system of offensive capacity.

EXTRACTION AND QUANTIFICATION OF EVALUATION INDICATORS OF TEAM'S OFFENSIVE CAPACITY

Basketball is a sport with time limit and group collaboration. In the basketball competitions, both the two teams are trying to win scores and prevent the other side of gaining scores, and the winner is the one with higher scores. As long as it's a competition, there must be offense and defense. It's usually said that attack is the best defense, which is reasonable to some extent. Since there is only one ball in the game, the attack of one side certainly means the defense of the other side. But in terms of evaluating the strength of a team, offensive capacity is a relatively more reliable indicator. For the purpose of gaining a scientific and reasonable evaluation on team's offensive capacity, this chapter tries to first analyze the technique characteristics of basketball competition and extract evaluation indicators of the team's offensive capacity. In order to conduct quantitative analysis in the next step, the indicators need to be quantified, so in this chapter the methods of extracting indicators and quantification are analyzed, providing the basis for the development of evaluation index system of offensive capacity and the quantitative analysis.

2.1 Extraction of the evaluation indicators of team's offensive capacity

The evaluation of the offensive capacity of a team in the competition can be analyzed from three aspects: the applying ability of offensive techniques, the cooperative capacity in offence play and offense style. The evaluation indicators are also extracted from these three aspects.

In the course of offense-defense, the applying ability of offensive techniques is embodied in the following seven aspects:

1) Motion offense: motion offense refers to the various moves a player adopts during offense in order to alter his position, direction and speed or strive for a better height. The purpose is to ensure that the player can maintain or seize vantage position. This indicator also significantly reflects the player's offensive capacity, competitive level and attacking style.

2) Passing: Passing ability refers to the pass of the basketball with purpose and organization. It intends to disrupt the defensive formation of the opponents, control their defense and creating opportunities for layup and making the basket through team cooperation. This indicator shows the applying ability of offensive techniques.

3) Dribbling: Dribbling refers to bouncing the ball continuously to control the ball, adjust the position and break the defense. Dribbling intends to adjust position to pass the ball inside, or to use misdirection tactics to attract defenders, surpass opponents and break the defense in order to shoot. Dribbling can be an evaluation indicator of a team's offensive capacity.

4) Breaking: Breaking refers to an offensive technique used by players to use step moving as well as dribbling techniques to quickly break the defense. It includes cross-kicking, Swivel shoulder, push and drop the ball and speed up. The number of breakings in a match can show the team's applying ability of offensive techniques.

5) Cutting: Cutting means the offenders away from the ball create various attack combinations to seize advantageous offending time and positions. Players use alterations of moving direction and speed to break away from and surpass the defenders to move rapidly and directly to the basket. Cutting is a relatively more effective offense, so it is an important indicator of applying ability of offensive techniques.

6) Shooting: Shooting is an important method for players to win scores. Players can shoot with single hand or two hands. This is the major technique of offense, and is the only way of scoring, so shooting ability is an important indicator to show the applying ability of offensive techniques.

7) Offensive rebound: In this technique, offenders quickly judge the ball's rebound direction and drop point after the miss shot, and then get rid of the defenders by using deceptive movement, seize the vantage position under the basket and jump to catch the ball immediately. This technique is the key part of regaining the possession of the ball and conducting the second attack, therefore it is also an important indicator of applying ability of offensive techniques.

If X represents the applying capacity of offensive techniques., x_1 means motion offense capacity, x_2 means passing capacity, x_3 means dribbling capacity, x_4 means breaking capacity, x_5 means cutting capacity, x_6

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means shooting capacity and x_7 refers to offensive rebound capacity, then the formula (1) can represent the relations between the variables above.

$$X = \sum_{i=1}^{7} x_i = x_1 + x_2 + \cdots + x_7 + \varepsilon_x \tag{1}$$

In formula (1), ε_x represents other indicators of applying capacity of offensive techniques except for $x_i(i=1,2,\cdots,7)$. If $x_i(i=1,2,\cdots,7)$ can reflect the applying capacity in a larger extent, then $\varepsilon_x \to 0$.

The extraction of indicators on cooperation ability in offense play can be analyzed from the following five perspectives:

1) Combination passes: It's a simple combination form where offenders apply passing and accelerated cutting to get rid of the defense and create attacking opportunities. This technique can be an indicator of evaluating the cooperative capacity in offence play.

2) Screen: It refers to the technique used by offenders to use their body to block the defenders in order to get rid of the defense and have chances of passing or shooting. It is an important indicator to show the tacit understanding between and flexibility of the screeners, so it is counted as an evaluation indicator of the cooperative capacity in offence play.

3) Breaking combination: It refers to a cooperative method used to break the defense by dribbling and induce the opponents to fill in so that offenders can pass the ball to teammates. It's a technique used to attract help defense or fill in when defense is intense, so it can be regarded as an indicator of the cooperative capacity in offence play.

4) Pivot pass： The offender grabs the vantage point of attacking and catches the ball when he is back to or sideways on the basket, cooperating with the outside teammates to cut in without the ball in order to find attacking opportunities. This technique can strengthen the cooperation between outside and inside players and is commonly used when faced with man-for-man tag and zone defense, so it can be an indicator for the cooperative capacity in offence play.

5) Fast Break: During the transition offense, the team rushes to form a good offense within the shortest time when the opponents are not ready to defend. The core of this technique is to buy time and create attacking chances, which requires all teammates to cooperate and finish every link very fast. This technique can be an indicator for the cooperative capacity in offence play.

If Y represents the cooperative capacity in offence play, y_1 represents combination pass capacity, y_2 represents screening capacity, y_3 represents breaking combination capacity, y_4 represents pivot pass capacity, and y_5 refers to fast break capacity, then Formula (2) can show the relationships between these variables:

$$Y = \sum_{i=1}^{5} y_i = y_1 + y_2 + \cdots + y_5 + \varepsilon_y \tag{2}$$

ε_y in Formula (2) represents the sum of other indicators of the cooperative capacity in offence play except for $y_i(i=1,2,\cdots,5)$. If $y_i(i=1,2,\cdots,5)$ can reflect the cooperative capacity Y in a larger extent, then $\varepsilon_y \to 0$.

The indicators of a team's offense style are mainly extracted from two perspectives, namely players' mentality in competitions and their cooperation ability. Three indicators are found as followings:

1) the degree of being resolute

2) the degree of perseverance

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3) the degree of calmness

These three factors are necessary if a team wants to show its normal offensive capacity. The higher the degrees are, the stronger a team's offensive style is. If Z represents offensive style, z_1 represents the capacity of players to use strategies, z_2 represents volitional quality of players and z_3 refers to players' mental outlook, then Formula (3) can show the relationships between these variables:

$$Z = \sum_{i=1}^{3} z_i = z_1 + z_2 + z_3 + \varepsilon_z \tag{3}$$

In Formula (3), ε_z represents the sum of other indicators of players' offensive style except for $z_i(i=1,2,3)$. If $z_i(i=1,2,3)$ can reflect the offensive style in a larger extent, then $\varepsilon_z \to 0$.

If W is employed to represent the aggregative indicator of a team's offensive capacity, then the relationships between W and X, Y, Z can be shown in Formula (4):

$$W = X + Y + Z \tag{4}$$

2.2 Data acquisition and quantification
The evaluation index has five scales: very good, good, average, poor and very poor. The performance is scored in centesimal system, in which "very good" ranges from 100-90, "good" ranges from 89-80, "average" lies in 79-70, "poor" lies in 69-60 while "very poor" ranges from 59-0. Rating matrix is formed with the upper limit of each scale: "very good" corresponds with 100, "good" with 89, "average" with 79, "poor" with 69 and "very poor" with 59. The rating matrix is $(100 \quad 89 \quad 79 \quad 69 \quad 59)^T$.

An evaluation group is composed of N judges, all of whom cannot abstain from voting. Judges will evaluate the capacity of x_1 according to the following four indicators: accurate observation and judgment, timely speed change, proper application of shift techniques and steady center of body weight. The total ballot number is N; $n_1, n_2, \cdots, n_5$ represents different scales from "very good" to "very poor" respectively. In Table 1, $g_{ij}(i=1,\cdots,4; j=1,2,\cdots,5)$ is used to distinguish the five scales in the four evaluating indicators.

Tab. 1: A player's capacity of evaluated by evaluation group

Evaluation scales	Very good	Good	Average	Poor	Very poor
	Score range (100-90)	Score range (89-80)	Score range (79-70)	Score range (69-60)	Score range (59-0)
accurate observation and judgment	g11	g12	g13	g14	g15
timely speed change	g21	g22	g23	g24	g25
proper application of shift techniques	g31	g32	g33	g34	g35
steady center of body weight	g41	g42	g43	g44	g45
Note: gij represents the number of votes from evaluators in different categories.					

According to the result from Table 1, the final score of each indicator can be calculated by Formula (4):

$$\begin{pmatrix} mark_1 \\ mark_2 \\ mark_3 \\ mark_4 \end{pmatrix} = \frac{1}{N} \begin{bmatrix} g11 & g12 & g13 & g14 & g15 \\ g21 & g22 & g23 & g24 & g25 \\ g31 & g32 & g33 & g34 & g35 \\ g41 & g42 & g43 & g44 & g45 \end{bmatrix} \begin{bmatrix} 100 \\ 79 \\ 80 \\ 69 \\ 59 \end{bmatrix} \tag{4}$$

In Formula (4), $\dfrac{g11}{N}$ represents the ratio of "very good" in the indicator of accurate observation and judgment. If the weight of this indicator is α_1, the weight of timely speed change is α_2, the weight of proper application of shift techniques is α_3, and the weight of steady center of body weight is α_4, then the weight matrix is $\Lambda = \begin{pmatrix} \alpha_1 & \alpha_2 & \alpha_3 & \alpha_4 \end{pmatrix}$. The relationship of the weight matrix, the single factor evaluation matrix M, the rating matrix and the total score is shown in Formula (5).

$$\mathbf{MARK} = \Lambda \circ M \cdot \begin{pmatrix} 100 & 89 & 79 & 69 & 59 \end{pmatrix}^T \quad (5)$$

If $\Lambda M = \begin{pmatrix} \beta_1 & \beta_2 & \beta_3 & \beta_4 & \beta_5 \end{pmatrix}$, then Formula (6) can be drawn:

$$\Lambda \circ M = \frac{\Lambda M}{\beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5} \quad (6)$$

THE DEVELOPMENT OF EVALUATION INDEX SYSTEM OF OFFENSIVE CAPACITY IN BASKETBALL COMPETITIONS AND AHP ANALYSIS

3.1 Basketball offense evaluation index system and hierarchical structure

In order to comprehensively evaluate the offensive capacity of a team, this paper adopts the method of AHP analysis. A proper and reasonable application of this method requires a hierarchical system construction of the related indicators. After analyzing indicators in Chapter 2.1, the author extracts 1 first-class indicator, 3 second-class indicators and 15 third-class indicators. First –class indicator is shown above, namely the offensive capacity represented by W. Second-class indicators refer to the capacity of applying offensive techniques represented by X, the cooperation ability in offense play represented by Y and offense style represented by Z. Third-class indicators refer to $x_1, x_2, x_3, x_4, x_5, x_6, x_7$ under X, y_1, y_2, y_3, y_4, y_5 under Y and z_1, z_2, z_3 under Z. In order to evaluate these indicators more accurately, this paper further explores more detailed evaluation indicators for the 15 third-class indicators. Take x_1 as an example. If more detailed indicators for the third-class indicator x_1, namely the capacity of motion offense, include accurate observation and judgment, timely speed change, proper application of shift techniques and steady center of body weight, then these four indicators are represented by x11、x12、x13 and x14. Corresponding indicators are represented by xij、yij and zij. This paper summarizes 46 fourth-class indicators, and the numbers of the fourth-class indicators under certain third-class indicators are listed in Table 2.

Tab. 2: Numbers of fourth-class indicators under third-class indicators

3rd	x_1	x_2	x_3	x_4	x_5	x_6	x_7	y_1	y_2	y_3	y_4	y_5	z_1	z_2	z_3
4th	4	5	3	3	3	3	3	3	3	3	3	4	2	2	2
Note: 3rd refers to the third-class indicators; 4th refers to fourth-class indicators. Numbers in the second row represents the numbers of fourth-class indicators under each third-class indicator.															

The hierarchical structure of the evaluation index system of offensive capacity is shown in Figure 1.
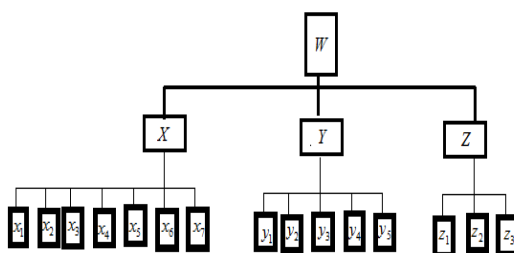

Fig. 1: Evaluation index system of offensive capacity of basketball players

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In Figure 1, the fourth-class indicators are not depicted. The more detailed indicators are listed in Table 3.

Tab. 3

Third-class indicators	Fourth-class indicators	Detailed indicators	Third-class indicators	Fourth-class indicators	Detailed indicators
x_1	x11	accurate observation and judgment	y_1	y11	timely cut
	x12	timely speed change		y12	timely pass
	x13	proper application of shift techniques		y13	Good cooperation between teammates
	x14	steady center of body weight	y_2	y21	Timely screen
x_2	x21	Pass to main offending player		y22	Proper and flexible screen
	x22	Pass to compounding area		y23	cohesion and coherence after screening
	x23	Proper cut after pass	y_3	y31	Timely cut and proper approach
	x24	Catch with offensive threat		y32	Timely relay and clever pass
	x25	Proper pass and catch		y33	Coherent techniques and good cooperation
x_3	x31	Timely dribble with purpose	y_4	y41	Offensive post
	x32	Proper techniques in running		y42	Correct judgment and timely pass of the post
	x33	Coherent techniques in running		y43	Flexible techniques and good cooperation
x_4	x41	Timely break and proper approach	y_5	y51	strong awareness of fast break
	x42	Coherent techniques		y52	Accurate and fast outlet pass
	x43	Good coordination and steady center of body weight		y53	Quick start
x_5	x51	timely cut and correct approach		y54	Proper combination of pass and dribbling
	x52	start and surpass opponents quickly	z_1	z11	Devoted to thinking and training
	x53	Coherent techniques after cutting		z12	Endure hardships and have strong team spirit
x_6	x61	Strong capacity of resisting fake	z_2	z21	Resolute and courageous
	x62	Right timing and way of shooting		z22	Focused and confident
	x63	Coherent shooting techniques	z_3	z31	Calm and sober-minded
x_7	x71	Correct judgment of bounce direction of the ball		z32	Competitive and desire for victory
	x72	Quick start to crash the board	Note: third-class indicators are represented by x_i, y_i, z_i		
	x73	Take position properly			

3.2 Process and principles of selecting indicators of all levels

Step 1 Construction of judgment matrix with pairwise comparison

The ordering of the indicators can be simplified as the comparison between a series of pairwise factors. This paper introduces Saaty (1-9 ratio scale) and transforms it into the form of matrix. The details of the ratio scale are shown in Table 4.

Tab. 4:Saaty (1-9 ratio scale)

Scale scores	Comparative importance	explanation
1	Of same importance	The two indicators are of the same importance
3	Slightly more important	One indicator is slightly more important than the other
5	Obviously more important	One indicator is obviously more important than the other
7	Strongly more important	One indicator is strongly more important than the other
9	Extremely more important	One indicator is extremely more important than the other
2,4,6,8	Between adjacent degrees	The comparative importance is between the adjacent degrees

According to the ratio scale standard in Table 4, judgment matrix can be drawn as in Formula (7):

$$\mathbf{A} = \begin{bmatrix} A_k & B_1 & B_2 & \cdots & B_n \\ B_1 & b_{11} & b_{12} & \cdots & b_{1n} \\ B_2 & b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ B_n & b_{n1} & b_{n2} & \cdots & b_{nn} \end{bmatrix} \quad (7)$$

Step 2 Transform the initialized judgment matrix $\mathbf{A}$ into comprehensive judgment matrix M

First the initialized judgment matrix is computed according to geometric mean. The ratio of every two indicators comes out as results. The results are expected to transform into final matrix M. The calculation process of M is shown in Formula (8).

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$$\begin{cases} \mathbf{M}(S) = \left[m(S)_{ij} \right]_{n \times n} \\ m_{ij} = k^* \sqrt[k^*]{\coprod_{S=1}^{k^*} a(S)_{ij}}, S = 1, 2, \cdots, k; i, j = 1, 2, \cdots, n \end{cases} \tag{8}$$

Step 3 Calculate the eigenvector corresponded with the maximum eigenvalue in comprehensive judgment matrix, normalize the eigenvector and then get the weight of each indicator.

First, every column of the judgment matrix should be normalized. Then add each row of the matrix and normalize the column vector after addition. The normalized column vector is the eigenvector corresponded with the maximum eigenvalue. At last the maximum eigenvalue can be arrived at.

Step 4　Consistency test of comprehensive judgment matrix. The calculation of consistency index CI is shown in Formula (9):

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{9}$$

When comprehensive judgment matrix has complete consistency, $CI = 0$. The higher CI is, the less consistency it has. In order to confirm the membership grade of CI, the author introduces the mean random consistency index RI in the 1-9 matrix, as is shown in Table 5.

Tab. 5: The mean random consistency index in1-9 matrix

1	2	3	4	5	6	7	8	9
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

When the order of comprehensive judgment matrix is over 2, the ratio of CI of the judgment matrix to RI of the matrix with the same order is called CR, the random consistency ratio of judgment matrix. When $CR < 0.10$, judgment matrix has satisfying consistency, otherwise the judgment matrix should be adjusted.

CONCLUSION

This paper analyzes the offensive capacity of basketball players from three aspects: applying ability of offensive techniques, the cooperative capacity and offense style. 1 first-class indicator, 3 second-class indicators and 15 third-class indicators are extracted, providing the basis for setting up the evaluation index system of offensive capacity for basketball teams.

Considering scientific quality and the characteristics of indicators, this paper offers details of the fourth-class indicators, providing basis for AHP quantitative analysis.

According to the procedures and principles of AHP analysis method, this paper presents the evaluation process of a team's offensive capacity. Due to the individuality of different teams, it's hard to arrive at standard suggestions by simulating data from only one team. Therefore this paper only gives process and principles of evaluation without simulating data.

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