Comprehensive evaluation of community fitness environment in multiple cities based on AHP-DEA integrated model

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Abstract. Based on the correlation between AHP and DEA, this study uses five aspects, four levels and 26 indicators to construct the evaluation index system and hierarchical structure model of fitness environment in urban communities along the ancient tea-horse road, and calculate the weights of criterion layer and index layer. the first-hand survey data is used to comprehensively evaluate the fitness environment of 9 urban communities, and the comparison and analysis of the individual cities evaluated are used to provide a paradigm reference for similar research.

1. Introduction
The “Belt and Road” initiative can realize the strategic alignment of various countries and jointly respond to the challenges currently facing the world economy. It is in the common interests of all countries. It promotes mutual respect, democratic consultation and joint decision-making among all countries, and creates a new path for the integration of diverse civilizations. Now’s actions have embodied the spiritual essence of a community of shared future for mankind and opened up a new world of win-win cooperation. This is true from country to country, not to mention that between cities, as a linear cultural heritage, the Ancient Tea Horse Road is adjacent to the border. It is one of the highest trade channels in the world today. It is the way of national integration, the road of Buddhism to the east, and the world civilization. The main channel is a unique human civilization channel where diverse cultures coexist in harmony. The fitness environment of urban communities affects residents' fitness activities to a large extent, and plays an important role in shaping community culture. We make qualitative analysis and quantitative evaluation on the fitness environment of urban communities along the ancient Tea Horse Road. Based on the comparative analysis of the evaluated individual cities, it can objectively point out the strengths and weaknesses of the fitness environment of a certain city along the route, and then use cities with better environments to drive others along the route. The development of urban community sports can achieve a multiplier effect with dots and lines, with complementary advantages. In addition, some scholars have analysed the related issues of the community fitness environment from several perspectives. The relevant research results provide a good perspective and method reference for this study, but they lack evaluation and empirical research on the combination of quantitative and qualitative community fitness environment. In view of this, take the cities along the Ancient Tea Horse Road as the research area, use Analytic Hierarchy Process (AHP) and Data Envelopment Analysis (DEA) to comprehensively assess the current status of the community fitness environment in this area, and analyse the impact on the urban communities along the line. The factors of the fitness environment make the input of the community more reasonable, the
resources are used more efficiently, and the planning and implementation are more targeted, providing a reference for the improvement of the community fitness environment in the region.

2. Data comes from an overview of the research process

The questionnaire categorization identified 5 categories of the content of this study, namely the 5 indicators of the criterion layer ($F_j$) in Table 1. To ensure the validity of the questionnaire, the 11 factors obtained by induction were used as the item items. Choose the answer using the 5-level Likert scale, assign values: 1, 0.8, 0.5, 0.2, 0, and the answers are: "A is good", "B is better", "C is fair", "D is poor", "E is bad". The reliability of the questionnaire was tested with Cronbach's alpha coefficient [1]. Through the reliability analysis of each item, the dimensional clones of 11 factors were all $\geq 0.71$. The data of the 11 indicators with # in Table 2 are derived from the questionnaire survey completed by the author during the winter and summer vacations of 2016-2017. Taking into account the practical feasibility of the implementation of the questionnaire survey, the survey area is selected from the 9 cities along the Tea Horse Road in 27 communities (3 communities in each city) selected according to the area and population of the community and other factors. The sample has a certain geographical area. In this survey, after the researchers contacted the community management staff and the community leaders, they adopted random sampling methods, distributed the questionnaires to the community residents and collected them. A total of 540 questionnaires (20 for each community), Recovered 526 questionnaires, the return rate of questionnaires was 97.41%. After repeated inspection and verification, 17 invalid questionnaires were eliminated, and 509 questionnaires actually valid.

3. Theoretical model analysis process

3.1. Analytical Hierarchy Process (AHP) analysis process

3.1.1. Establish an evaluation index system

Refer to Song Jie and other scholars' discussion on the evaluation factors of community fitness environment [2], combined with the reality of the community fitness environment along the Tea Horse Road, mainly select venue facilities ($F_1$), ecological environment ($F_2$), and comprehensive management ($F_3$), Community sports and fitness organizations and services ($F_4$), and sports culture atmosphere ($F_5$). Since the sports population is a demographic and sports phenomenon that has developed to a certain historical stage in the economy and society, it is an important social sports

| Target layer (O) | Evaluation index system of fitness environment |
|------------------|-----------------------------------------------|
| Criteron layer ($F_j$) | (F_1) | (F_2) | (F_3) | (F_4) | (F_5) |
| Index layer ($x_i$) | Venue location ($x_1$) | Number of venues ($x_2$) | Area of the venue ($x_3$) | Venue quality ($x_4$) | Number and type of instruments ($x_5$) | Equipment setting position ($x_6$) | Instrument quality ($x_7$) | Atmospheric SO mean value ($x_8$) | Atmospheric STP average ($x_9$) | Equivalent sound level of noise products ($x_{10}$) | Green coverage rate of fitness area ($x_{12}$) | rules and regulations ($x_{12}$) | Regulatory authorities ($x_{13}$) | Physical fitness monitoring department ($x_{14}$) | Training department ($x_{15}$) | Environmental health service ($x_{16}$) | Health promotion situation ($x_{17}$) | Scientific fitness guidance service ($x_{18}$) | Exercise prescription ($x_{19}$) | Maintenance service of venue equipment ($x_{20}$) | Conduct fitness lectures ($x_{21}$) | fitness activities ($x_{22}$) | Health promotion situation ($x_{23}$) | Community sports organizations and the number of teams ($x_{24}$) | Fitness communication and cooperation ($x_{25}$) | Proportion of the population participating in sports ($x_{26}$) |
indicator Therefore, in the design of this research, we considered adding the index of “proportion of people participating in sports \((x_{26})\)” at the criterion level-sports cultural atmosphere \((F_5)\), in order to construct the urban community fitness environment evaluation index system, and specifically evaluate the content of the index system see Table 1.

3.1.2. Construct a hierarchical structure model

In order to make the research route clear, 9 representative node cities in the three provinces of Yunnan, Sichuan and Tibet along the Ancient Tea Horse Road were selected as decision-making units (DMU). For confidentiality, the specifics are expressed as C1-C9, these 9 cities all play an important role in the social and economic functions along the route, and have certain economic driving functions, as well as urban economies of scale and polarization and diffusion. Construct a hierarchical structure model of the community fitness environment through the selected city. The model is interlocked and advanced layer by layer, including the target layer (O), criterion layer, index layer and decision-making unit (project layer). The specific structure is shown in the Figure 1.

![Hierarchical structure model of urban community fitness environment evaluation.](image)

3.1.3. Analytical Hierarchy Process (AHP) analysis process

3.1.3.1. Establish an evaluation index system

Expressed by the 1–9-degree scale method [3], compare the indicators of the same level in pairs, record the importance of the \(C_{ij}\) factor \(i\) to the factor \(j\), and rank according to its importance to get the criterion level and index the weight judgment matrix of the layer. The judgment matrix is:

\[
\begin{pmatrix}
c_{11} & c_{12} & \cdots & c_{1n} \\
c_{21} & c_{22} & \cdots & c_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
c_{n1} & c_{n2} & \cdots & c_{nn}
\end{pmatrix}
\]

(1)

3.1.3.2. Calculate the index weight value

Calculation methods include least square method, characteristic root method, sum method, square root method, etc. The calculation in this paper uses the square root method, and the specific calculation process is as follows:

Step1: Calculate the score of each row of the judgment matrix \(M_j\)

\[
M_j = \prod_{k=1}^{n} T_{jk} \quad (j = 1, 2, \ldots, n)
\]

(2)

Step2: Calculate the \(n\) power root of \(M_j\)

\[
\sigma_j = \sqrt[n]{M_j}
\]

(3)
Step3: Normalize \( \vec{W} = [\vec{w}_1, \vec{w}_2, ..., \vec{w}_n]^T \)

\[
  w_j = \frac{\sigma_j}{\sum_{j=1}^{n} \sigma_j}
\]

(4)

where \( \vec{W} = [\vec{w}_1, \vec{w}_2, ..., \vec{w}_n]^T \) is the weight value of each indicator.

3.1.3.3. Consistency test of judgment matrix

The specific operation has 3 steps as follows:

Step1: Calculate the largest characteristic root of the matrix

\[
  \lambda_{\text{max}} = \frac{1}{n} \sum_{j=1}^{n} (AW)_{jj}
\]

(5)

Step2: Calculate the consistency index CI

\[
  CI = \frac{\lambda_{\text{max}} - n}{n - 1}
\]

(6)

where \( n \) is the order of the judgment matrix.

Step3: Calculate the random agreement ratio CR

\[
  CR = \frac{CI}{RI}
\]

(7)

where refer to [4] for the value \( RI \). If the random consistency ratio \( CR < 0.10 \), then the consistency of the judgment matrix is satisfactory, otherwise the value of the judgment matrix elements needs to be adjusted.

3.2. Data Envelopment Analysis (DEA) analysis process

Data Envelopment Analysis (DEA) is a typical method to study the comprehensive efficiency of multiple outputs under multiple input situations. The first model is named \( \mathcal{C}^2 \mathcal{R} \). This model assumes that there are \( m \) kinds of inputs, \( n \) kinds of outputs, and \( p \) kinds of output. Evaluation decision-making unit (DMU), in the practice of community fitness environment evaluation, it is assumed that there are \( m \) input elements that affect the state of the community fitness environment, there are \( n \) output elements that reflect the state of the community fitness environment, and there are \( p \) community fitness environment evaluation the DMUs, where the \( j \)-th input of the evaluation decision unit \( DMU_j \) is recorded as \( x_j(x_{j1}, x_{j2}, ..., x_{jm})^T \), and the output is recorded as: \( y_j(y_{j1}, y_{j2}, ..., y_{jm})^T \), then:

\[
  \min \left[ \theta - (e^T s^- + e^T s^+) \right]
\]

\[
  \sum_{j=1}^{n} \lambda_j x_j + s^- = \theta x_0
\]

s.t.

\[
  \sum_{j=1}^{n} \lambda_j y_j - s^- = y_0
\]

\[
  \lambda_j \geq 0, j = 1, 2, ..., p
\]

\[
  s^- \geq 0, s^+ \geq 0
\]

(8)

(9)
In formula (8) and (9), $x_0$ and $y_0$ are the input and output indicators of the $j_0$-th decision-making unit arbitrarily assumed; $\theta$ is the relative efficiency value of the decision-making unit $DMU_{j_0}$ ($0 \leq \theta \leq 1$), That is, the effective degree of input relative to output, it reflects the reasonable degree of resource allocation of $DMU_{j_0}$, the larger the $\theta$, the more reasonable the resource allocation; $\varepsilon$ is non-Archimedean infinitesimal, and $\varepsilon$ is often taken as extremely small in practical applications Positive number; $e^T$ is the unit row vector; $\lambda_j$ is the optimal solution of the model; $s^-$ is the residual variable, and $s^+$ is the slack variable. According to the different values of $\theta$, $s^-$ and $s^+$, the decision-making unit can be divided into the following three categories:

Type 1: If $\theta = 1$ and $s^- = 0$, $s^+ = 0$, $DMU_{j_0}$ is called DEA effective. This shows that the community sports and fitness environment in this area is very good, the input elements of the fitness environment have reached the best combination, and the maximum output effect has been achieved.

Type 2: If $\theta = 1$ and at least one $s^- > 0$ or certain $s^+ > 0$, $DMU_{j_0}$ is called DEA weakly effective. This shows that the community sports and fitness environment in this area is better. If $s^- > 0$, it indicates that the input element of $i$ has an underutilized amount $s^-$; if $s^+$ is greater than 0, it indicates that there is a difference between $s^+$ of the output element and the maximum output value.

Type 3: If $\theta < 1$, $DMU_{j_0}$ is non-DEA valid. This shows that the community sports and fitness environment in this area needs to be further improved, and the original output can be maintained by reducing the input to the original input ratio $\theta$.

The general steps of DEA method application are: clarify the purpose of evaluation, select DMU, establish an input/output evaluation index system, collect and organize data, select and calculate the DEA model, analyse the evaluation results, and make decision-making recommendations [5]. Through the analysis and comparison of the community fitness environment evaluation index system and the hierarchical structure model of the urban communities along the Ancient Tea Horse Road, according to the principle of the DEA model and the principle of input and output index selection [6], according to the principle of unity and comparability of data, At the same time, considering the availability and combining the actual conditions of the community fitness environment in the cities along the Ancient Tea Horse Road, the following input-output indicators and decision-making units are set. Input indicators: 21 indicators of venue facilities, number of venues, number and types of equipment, scientific fitness guidance services, physical fitness monitoring and training in the criteria level $F_1$, $F_2$, $F_3$, $F_4$; output indicators: criteria layer ($F_5$) Five indicators of fitness activities and sports events development, fitness promotion, etc.; the decision-making unit is the specific urban community. In the calculation process, the surveyed values were normalized, and DEA-Solver software was used to calculate the evaluation value of $\theta$.

### 3.3. AHP and DEA model integration

Using the linear weighting method to combine the AHP evaluation model and the DEA evaluation model, it can objectively reflect the effectiveness of the input and output of the community fitness environment of the evaluated DMU, and it can also accurately grasp the reality of the fitness environment in the region situation. The calculation formula for the integration of AHP and DEA models is:

$$A = \alpha y + (1 - \alpha) \theta^*$$  \hspace{1cm} (10)

In the formula (10), $A$ is the comprehensive evaluation value; $y$ is the evaluation value of the AHP model; $\alpha$ is subjective preference coefficient, which takes any value in $[0,1]$, and its specific value is
given by the decision maker according to his preference (this article \( \alpha \) is 0.5); \( 1-\alpha \) is the objective preference coefficient; \( \theta^* \) is the evaluation value of the DEA model.

4. Research results and analysis

4.1. Analysis of Analytic Hierarchy Process (AHP) evaluation results

According to the judgment matrix \( C \) (formula 3) described above, due to space limitations, we will not list them one by one. The weight vector \( \{W\} \) is calculated using Yaahp0.5.3 software, and the consistency test is performed to calculate the \( F_j \) and \( x_j \) indicators. The weight value \( w_j \) (see Table 1 for details) and the CR value of each matrix, where the CR values of \( O-F, F_1-x, F_2-x, F_3-x, F_4-x, \) and \( F_5-x \) are 0.0317, 0.0421, 0.0363, 0.0205, 0.0167, 0.0090. According to formula (9), it can be determined that the judgment matrix satisfies the consistency test. After dimensionless processing, the sample index value \( S_j \) is obtained. Using the weighted sum algorithm, the AHP evaluation value \( y_i \) of city \( j \) is obtained. The calculation formula is:

\[
y_j = \sum_{i=1}^{9} S_j^i w_j \quad (j = 1, 2, ..., 9; i = 1, 2, ..., 26)
\]

The ranking of the evaluation results obtained by simply using the analytic hierarchy process is: \( C_1 > C_9 > C_3 > C_4 > C_8 > C_5 > C_7 > C_2 > C_6 \). Among them, the AHP evaluation value of urban community fitness environment of \( C_1, C_9, \) and \( C_3 \) ranks first, \( C_6, C_2, \) and \( C_7 \) urban community fitness environment evaluation values rank relatively low. The prerequisite for the accuracy of the analytic hierarchy process evaluation results is on the basis of reasonable weight distribution. However, the fuzzy evaluation of qualitative index values and the determination of weights by decision makers are subject to a certain degree. In view of this, it is necessary to exclude people as subjective the influence of factors on the evaluation value can get more realistic evaluation results.

4.2. Data Envelopment Analysis (DEA) Evaluation Results Analysis

The most prominent advantage of DEA is the assumption of any weight in disorder. The weight of each input and output is not based on the subjective determination of the evaluator, but the optimal weight obtained from the actual data of the decision-making unit [7], among which 11 are with # The indicator data comes from the questionnaire. Other data comes from the "2016 Yunnan Statistical Yearbook", "2016 Sichuan Statistical Yearbook", "2016 Tibet Statistical Yearbook 7", 2016 statistical yearbooks of various cities, local and municipal sports bureaus, cultural and sports radio and television Bureau, Environmental Protection Agency and other relevant departments, specific variable assignment and descriptive statistical analysis are shown in Table 2.

The calculation results in Table 3 show that the effective value of the community fitness environment in \( C_1, C_3, \) and \( C_8 \) cities reached 1. According to the data envelopment method model decision unit classification, this area is DEA effective, indicating that the community fitness environment in these 3 cities is good , The input-output ratio of the fitness environment is balanced, and the effective value of the remaining 6 cities has not reached 1, which indicates that these 6 cities are non-DEA effective, that is, the input-output of the fitness environment in the region has not reached the ideal The effectiveness also directly reflects the poor overall fitness environment of the urban communities along the Ancient Tea Horse Road. From the evaluation value of DEA, the evaluation results of 9 cities are clearly distinguished, which also shows that the standards and indicators are in the Reasonable proportion in the entire evaluation system.

Table 2. Variable assignment and descriptive statistical analysis

| Variables and sign | Variable hierarchy and assignment | mean±SD | \( x_{\min} \) | \( x_{\max} \) |
|-------------------|----------------------------------|---------|-------------|-------------|
| \( x_1^0 \)       | A  B  C  D  E                    | 0.88±0.45 | 0.5         | 1           |
4.3. Evaluation Results and Comprehensive Analysis of AHP and DEA Integrated Model

Using formula (10), the value of 0.5 is used to calculate the comprehensive evaluation value of the integrated model. It is not difficult to see from the statistical results that it is different from the AHP evaluation value. The Tea Horse Road 9 prefecture-level city urban community fitness environment AHP-DEA integrated evaluation value order is: C1>C3>C9>C8>C4>C5>C2>C7>C6.

Table 3. Comprehensive Evaluation Results and Ranking of Community Sports Environment

| City | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 |
|------|----|----|----|----|----|----|----|----|----|
| AHP ranking of evaluation values | 1 | 8 | 3 | 4 | 6 | 9 | 7 | 5 | 2 |
| AHP-DEA integrated model evaluation value | 0.8883 | 0.7449 | 0.8585 | 0.7982 | 0.7847 | 0.7278 | 0.7311 | 0.8442 | 0.8492 |
| AHP-DEA ranking of integrated model evaluation values | 1 | 7 | 2 | 5 | 6 | 9 | 8 | 4 | 3 |
5. Conclusion
At present, there are many theoretical and qualitative researches in community fitness environment evaluation research, and few quantitative and empirical researches. This study is based on the correlation between analytic hierarchy process (AHP) and data envelopment analysis (DEA). On the basis of comprehensive consideration of venue facilities, ecological environment, comprehensive management, community sports and fitness organizations and services, and sports culture atmosphere, a number of urban community fitness environment evaluation index systems were constructed, weight calculation and analysis were carried out using the analytic hierarchy process, and the survey data was used to comprehensively evaluate and evaluate the fitness environment of 27 communities in 9 cities. In contrast, how to select and determine the evaluation factors more scientifically, whether the evaluation factors change with different regions, and the quantitative calculation of evaluation factors still need to be further studied and improved. In addition, taking the tea-horse road as an example for evaluation and analysis, its representativeness and rationality still require a large amount of actual sample data and practice to test.

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