Evaluation system of urban smart tourism competitiveness based on AHP-entropy weight method

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ABSTRACT
In order to quantitatively evaluate the competitiveness of smart tourism cities efficiently and reasonably, a smart tourism city competitiveness evaluation system composed of four primary indicators such as infrastructure, economic basis, scientific and technological basis and environmental basis and 15 secondary indicators such as the number of mobile phone users at the end of the year and the number of urban Internet users is constructed, which is comprehensively weighted by hierarchical analysis method and entropy weight method. The empirical case of competitiveness evaluation of 13 cities in Jiangsu Province shows that the evaluation system can quantitatively evaluate the competitiveness of urban smart tourism comprehensively and objectively. The main factors affecting the competitiveness of urban smart tourism are urban infrastructure construction and economic foundation. Increasing investment in 5G, artificial intelligence and other information technology and enhancing urban economic strength are the key strategies to improve the competitiveness of urban tourism.

Keywords: urban smart tourism; tourism competitiveness; evaluation system; analytic hierarchy process (AHP); entropy weight method

1. Introduction
The globalization and diversification of tourism demand have greatly promoted the development of tourism, and the tourism industry has gradually developed into a multi-dimensional and multi-level comprehensive industry. Under the background of big data, information is highly concentrated, and the combination of tourism and Internet information technology has derived the “Internet plus tourism”, which has promoted the informationization process of traditional tourism industry, and has brought about new markets such as smart scenic spots, smart tourism and so on. Enhancing tourism competitiveness and maintaining the sustainable development of tourism has become an important goal. The development mode of traditional tourism industry can no longer meet the needs of the times, so the intelligent construction of tourism industry is imperative. Therefore, it is very important to build a smart tourism competitiveness evaluation system and promote the development of smart tourism in China.
Scholars at home and abroad have studied the competitiveness of urban smart tourism from different angles, and pointed out the development direction of smart tourism competitiveness and the impact of tourism competitiveness on urban development[1−3]. However, there is little literature on the evaluation methods and evaluation models related to urban smart tourism competitiveness, and the quantitative analysis of the importance of indicators is rarely involved. In fact, the analysis of urban smart tourism competitiveness involves science and technology, economy, environment and other issues. It is a multi-objective decision-making management process, which requires multi-objective decision-making research. However, the corresponding research[4−9] conducted by scholars only obtains the research results from a single quantitative method, and the analysis dimension is not comprehensive enough. Therefore, combined with domestic and foreign literature, this paper constructs a multi-dimensional evaluation index system of urban smart tourism, and combined with the data in expert in-depth interview, questionnaire survey and statistical yearbook, comprehensively uses analytic hierarchy process (AHP) and entropy weight method to obtain the comprehensive weight of the index, objectively measures the importance of each index, and takes 13 cities in Jiangsu Province as cases for case analysis, to comprehensively and objectively evaluate the smart tourism competitiveness of cities.

2. Construction of evaluation system

2.1. Index selection and data source

Urban infrastructure, economic foundation, scientific and technological foundation and environmental foundation have an important impact on the development of urban smart tourism. Based on referring to relevant studies at home and abroad, this paper abstracts four primary indicators and 15 secondary indicators for the evaluation of urban smart tourism competitiveness, as shown in Table 1.

| Primary index                        | Secondary index                                      | Literature source |
|--------------------------------------|------------------------------------------------------|-------------------|
| Smart tourism infrastructure $C_1$   | Number of mobile phone users at the end of the year $V_1$ (unit: %) | [10]              |
|                                      | Number of urban Internet users $V_2$ (unit: %)       |                   |
|                                      | Urban Road area per capita $V_3$ (unit: m²)          |                   |
|                                      | Proportion of tertiary industry in GDP $V_4$ (unit: %)|                   |
| Smart tourism economic foundation $C_2$ | Per capita GDP $V_5$ (unit: yuan)                  | [14]              |
|                                      | International tourism revenue $V_6$ (unit: USD 10000) |                   |
|                                      | Domestic tourism revenue $V_7$ (unit: 10000 yuan)    | [15][19]          |
|                                      | Number of invention patent applications $V_8$ (unit: pcs.) | [16][17]        |
| Smart Tourism Technology Foundation $C_3$ | Invention patent authorization $V_9$ (unit: pcs.)    | [16][17]          |
|                                      | Output value of high-tech industry $V_{10}$ (unit: 10000 yuan) | [17]          |
|                                      | Local financial science and technology expenditure $V_{11}$ (unit: 10000 yuan) | [15][20]     |
|                                      | Urban greening coverage $V_{12}$ (unit: %)          | [18][513]        |
| Smart tourism environment foundation $C_4$ | Excellent air quality rate $V_{13}$ (unit: %)       | [19]              |
|                                      | Centralized sewage treatment rate $V_{14}$ (unit: %) | [18][513]        |
|                                      | Harmless treatment rate of domestic waste $V_{15}$ (unit: %) | [20]          |

According to the principle of scientific objectivity, secondary indicators are obtained through statistical yearbook and literature review. The index data are mainly from China Statistical Yearbook 2017[21], China Urban Statistical Yearbook 2017[22] and Jiangsu statistical yearbook 2017[23]. E number of mobile phone users at the end of the year and the proportion of the total number of mobile phone users in the city are objectively calculated in the index, the excellent rate of air quality = (days with excellent air quality + days with good air quality)/365 × 100%, harmless treatment rate of domestic waste = annual removal and transportation volume of domestic waste/(daily treatment capacity of harmless treat-
ment plant) × 365) × 100%.

2.2. Determination of weight

Firstly, the subjective weight of the index is obtained by means of expert in-depth interview and questionnaire. In this study, an expert questionnaire on the competitiveness of urban smart tourism was designed and distributed to 8 experts. Among them, three are university scholars studying urban tourism management, three are project managers of travel agencies, and two are public servants of the tourism administration responsible for management business. After inspection, the consistency rate of the eight answers is less than 0.1, which is effective. Therefore, the opinions of the expert group are summarized, and the weights of each primary index and secondary index are obtained based on AHP algorithm. The results are shown in Table 2.

Then, the entropy weight method is applied to obtain the objective weight of the index, and the steps are as follows:

\[
x_{ij}^* = \frac{x_{ij} - \min(x_{1j}, x_{2j}, \ldots, x_{nj})}{\max(x_{1j}, x_{2j}, \ldots, x_{nj}) - \min(x_{1j}, x_{2j}, \ldots, x_{nj})}
\]

Thus, the standardized matrix is obtained:

\[
x = \begin{pmatrix} 1.71 & 1.73 & 1.14 & \cdots & 2.00 \\ 1.43 & 1.45 & 1.39 & \cdots & 1.68 \\ 1.40 & 1.32 & 1.21 & \cdots & 2.00 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1.06 & 1.00 & 1.45 & \cdots & 2.00 \end{pmatrix}_{13 \times 15}
\]

Step 3: Calculate the proportion of the \( i \)th city in the \( j \)th index. The proportion of each scheme in each corresponding index \( P \) is:

\[
x = \begin{pmatrix} 0.10 & 0.11 & 0.07 & \cdots & 0.08 \\ 0.09 & 0.09 & 0.08 & \cdots & 0.07 \\ 0.08 & 0.08 & 0.07 & \cdots & 0.08 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0.06 & 0.06 & 0.08 & \cdots & 0.08 \end{pmatrix}_{13 \times 15}
\]

Step 4: Calculate the entropy weight \( e_j \) of the \( j \)th index, and the result is: \( e_1 = 0.991, e_2 = 0.990, e_3 = 0.992, e_4 = 0.995, e_5 = 0.989, e_6 = 0.991, e_7 = 0.989, e_8 = 0.992, e_9 = 0.992, e_{10} = 0.994, e_{11} = 0.991, e_{12} = 0.995, e_{13} = 0.995, e_{14} = 0.995, e_{15} = 0.995. \)

Step 5: Calculate the difference coefficient \( g_i \) of the \( j \)th index, and the result is: \( g_1 = 0.0087, g_2 = 0.0097, g_3 = 0.0087, g_4 = 0.0055, g_5 = 0.0102, g_6 = 0.0090, g_7 = 0.0108, g_8 = 0.0079, g_9 = 0.0079, g_{10} = 0.0010, g_{11} = 0.0087, g_{12} = 0.0056, g_{13} = 0.0049, g_{14} = 0.0052, g_{15} = 0.0049. \)

Step 6: Calculate the entropy weight of each index, and the weight distribution results are shown in Table 2.

The comprehensive weight is obtained by combining AHP method with entropy weight method, and the calculation equation is:

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

In equation (5), \( r_j \) is the subjective weight of index \( j \) and \( w_j \) is the objective weight of index \( j \). The calculation results are shown in Table 2.
Table 2. Indicator weights of the evaluation system of smart tourism destination competitiveness

| Primary index | Secondary index |
|---------------|-----------------|
| Name | Weight | Name | Weight |
|      | AHP method | Entropy weight method | Comprehensive |      | AHP method | Entropy weight method | Comprehensive | Comprehensive weight ranking |
| $C_1$ | 0.563 | 0.331 | 0.734 | $V_1$ | 0.187 | 0.123 | 0.253 | 2 |
| $C_2$ | 0.249 | 0.318 | 0.211 | $V_2$ | 0.321 | 0.121 | 0.428 | 1 |
| $C_3$ | 0.049 | 0.317 | 0.042 | $V_3$ | 0.055 | 0.087 | 0.053 | 4 |
| $C_4$ | 0.140 | 0.034 | 0.013 | $V_4$ | 0.087 | 0.049 | 0.047 | 5 |

According to the comprehensive weight ranking in Table 2, the top three are the number of urban Internet users $V_2$, the number of mobile phone users at the end of the year $V_1$ and the per capita GDP $V_5$. The total weight of these three secondary indicators accounts for 80.4%, indicating that Internet technology and smart phones are particularly important to the development of urban smart tourism in the information age. The number of invention patent applications $V_8$ (ranked 13th), the harmless treatment rate of domestic waste $V_{13}$ (ranked 14th) and the urban greening coverage rate $V_{12}$ (ranked 15th) rank lower, indicating that they have little impact on the competitiveness of urban smart tourism. The urban infrastructure construction (such as 5G technology to improve internet speed, free wireless network, etc.) and the urban economic foundation (tertiary industry, per capita GDP, etc.) determine the competitiveness level of urban smart tourism.

3. Empirical cases

As a relatively developed province in China, Jiangsu’s GDP ranking has been ranked second in the country since 2007. Many cities in southern Jiangsu, such as Wuxi, Suzhou and Nanjing, are important cities in the Yangtze River Delta. With the popularization and application of artificial intelligence, big data and other technologies, urban smart tourism will be the development direction of urban tourism in the future. Therefore, the author takes 13 prefecture level cities with different degrees of development in Jiangsu Province as an example to analyze the urban tourism competitiveness, in order to provide reference for the improvement of China’s urban tourism competitiveness. The relevant data are from Jiangsu statistical yearbook 2017, and the comprehensive scores of each city are obtained through equation (6):

$$s_i = \sum_{j=1}^{m} w_j \cdot p_{ij}, i = 1, 2, ..., n; j = 1, 2, ..., m \quad (6)$$

In the multi-index evaluation system, due to the different nature of each evaluation index, it usually has different dimensions and orders of magnitude. When the level of each index varies greatly, if the original index value is directly used for analysis, the role of the index with higher value in the comprehensive analysis will be highlighted and the role of the index with lower value will be relatively weak.
ened. Therefore, in order to ensure the reliability of the results, the extreme value method is used to standardize the original data. The standardized equation of extreme value method is:

\[
p_{ij} = \frac{x_{ij} - \min(x_{1j}, x_{2j}, \ldots, x_{nj})}{\max(x_{1j}, x_{2j}, \ldots, x_{nj}) - \min(x_{1j}, x_{2j}, \ldots, x_{nj})}, \quad i = 1, 2, \ldots, n; \quad j = 1, 2, \ldots, m
\]

### Table 3. Scores and rankings of tourism destination competitiveness in Jiangsu China

| City       | C1 score | C2 score | C3 score | C4 score | Comprehensive score | Comprehensive ranking |
|------------|----------|----------|----------|----------|---------------------|-----------------------|
| Nanjing    | 0.681    | 0.178    | 0.021    | 0.011    | 0.891               | 2                     |
| Wuxi       | 0.578    | 0.172    | 0.017    | 0.010    | 0.777               | 3                     |
| Xuzhou     | 0.133    | 0.050    | 0.008    | 0.005    | 0.195               | 9                     |
| Changzhou  | 0.547    | 0.134    | 0.011    | 0.010    | 0.701               | 4                     |
| Suzhou     | 0.722    | 0.195    | 0.044    | 0.010    | 0.971               | 1                     |
| Nantong    | 0.283    | 0.083    | 0.012    | 0.008    | 0.387               | 7                     |
| Lianyungang| 0.106    | 0.018    | 0.001    | 0.009    | 0.134               | 10                    |
| Huai’an    | 0.030    | 0.040    | 0.002    | 0.009    | 0.081               | 12                    |
| Yancheng   | 0.075    | 0.030    | 0.010    | 0.010    | 0.125               | 11                    |
| Yangzhou   | 0.295    | 0.086    | 0.005    | 0.008    | 0.395               | 6                     |
| Zhenjiang  | 0.330    | 0.121    | 0.006    | 0.008    | 0.465               | 5                     |
| Taizhou    | 0.207    | 0.071    | 0.006    | 0.008    | 0.292               | 8                     |
| Suqian     | 0.024    | 0.000    | 0.000    | 0.008    | 0.032               | 13                    |
| Average    | 0.308    | 0.091    | 0.011    | 0.009    | 0.419               |                       |

It can be seen from Table 3 that the scores of 13 prefecture level cities in Jiangsu Province are significantly different in the evaluation system of urban smart tourism competitiveness. In terms of smart tourism infrastructure \( C_1 \), Suzhou and Nanjing are far ahead, indicating that the smart tourism infrastructure of these two cities is well constructed; in terms of smart tourism economic foundation \( C_2 \), Suzhou, Nanjing and Wuxi have obvious advantages, while other eight cities do not reach the provincial average. Generally speaking, the application of urban Internet technology, the construction of urban roads and other infrastructure, the economic basis such as the city’s per capita GDP and the proportion of the tertiary industry in GDP determine the tourism competitiveness level of the city, and each city can improve according to its performance in various indicators.

### 4. Conclusions

In order to comprehensively and objectively quantify the construction of smart tourism in each city and provide a basis for the adjustment of smart tourism policies in the city, based on previous studies, this paper extracts four primary indicators of smart tourism infrastructure, smart tourism economy, smart tourism science and technology and smart tourism environment, and 15 secondary indicators such as the number of mobile phone users at the end...
Evaluation system of urban smart tourism competitiveness based on AHP-entropy weight methods

of the year and the number of urban Internet users, combining the subjective and objective weights obtained by AHP and entropy weight method, reconstruct and build the urban smart tourism competitiveness evaluation system, and take 13 prefecture-level cities in Jiangsu Province as samples to evaluate the smart tourism competitiveness of each city. The results show that: (1) the urban smart tourism competitiveness evaluation system based on AHP-entropy weight method constructed in this study can quantitatively evaluate the urban smart tourism competitiveness comprehensively and objectively. (2) Infrastructure construction is the basis for improving the competitiveness of urban tourism. Increasing the investment in urban Internet technology such as 5G technology, providing free wireless network in public places and improving urban roads can provide guarantee for the improvement of urban tourism competitiveness. (3) The economic foundation of a city determines the competitiveness of urban tourism. By vigorously developing the tertiary industry, improving the per capita GDP of cities and the happiness index of urban residents are the key to attracting outsiders to enter urban tourism.

Due to space limitation, this paper does not further analyze the sensitivity of the model. In subsequent research, specific methods can be considered to verify the evaluation index to make it more scientific.

Conflict of interest

The authors declare no conflict of interest.

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