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ORIGINAL RESEARCH ARTICLE

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.

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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**.

Table 1. Indicators of smart tourism destination competitiveness

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: %)	[11]
	Urban Road area per capita V_3 (unit: m^2)	[12]
Smart tourism economic foundation C_2	Proportion of tertiary industry in GDP V_4 (unit: %)	[13]
	Per capita GDP V_5 (unit: yuan)	[14]
	International tourism revenue V_6 (unit: USD 10,000)	[15] 19
	Domestic tourism revenue V_7 (unit: 10,000 yuan)	[15] 19
Smart tourism technology foundation C_3	Number of invention patent applications V_8 (unit: pcs.)	[16] 71
	Invention patent authorization V_9 (unit: pcs.)	[16] 71
	Output value of high-tech industry V_{10} (unit: 10,000 yuan)	[17]
	Local financial science and technology expenditure V_{11} (unit: 10,000 yuan)	[15] 20
Smart tourism environment foundation C_4	Urban greening coverage V_{12} (unit: %)	[18] 513
	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 treatment 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:

Step 1: Sort out the data and establish a matrix. Analyze and process the data of 2017 national and provincial statistical yearbooks[21–23], and obtain equation (1):

$$x = \begin{pmatrix} 1114.72 & 373.66 & 23.42 & \cdots & 100.00 \\ 799.86 & 269.95 & 26.61 & \cdots & 75.81 \\ 762.01 & 223.61 & 24.41 & \cdots & 100.00 \\ \vdots & \vdots & \vdots & & \vdots \\ 371.56 & 105.72 & 27.31 & \cdots & 100.00 \end{pmatrix}_{13\times15} \quad (1)$$

Among them, matrix X is a two-dimensional data frame with 13 rows and 15 columns, representing the performance scores of 13 cities in Jiangsu Province on 15 secondary indicators. Taking x_{11} = 1,114.72 as an example, this data represents the actual value of mobile phone user (V_1) index in Nanjing at the end of the year.

Step 2: Non negative treatment. Since the selected indicators are positive indicators, the larger the better, so we must transform them into non negative. The equation for calculating the non-negative treatment value of the j^{th} index in the i^{th} city is:

$$x_{ij}' = \frac{x_{ij} - \min(x_{1j},\ x_{2j},\ \cdots,\ x_{nj})}{\max(x_{1j},\ x_{2j},\ \cdots,\ x_{nj}) - \min(x_{1j},\ x_{2j},\ \cdots,\ x_{nj})} + 1, i = 1, 2, \ldots, n; j = 1, 2, \ldots, m \quad (2)$$

Thus, the standardized matrix is obtained:

$$x = \begin{pmatrix} 1.71 & 1.73 & 1.14 & \cdots & 2.00 \\ 1.43 & 1.45 & 1.39 & \cdots & 1.68 \\ 1.40 & 1.32 & 1.21 & \cdots & 2.00 \\ \vdots & \vdots & \vdots & & \vdots \\ 1.06 & 1.00 & 1.45 & \cdots & 2.00 \end{pmatrix}_{13\times15} \quad (3)$$

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:

$$x = \begin{pmatrix} 0.10 & 0.11 & 0.07 & \cdots & 0.08 \\ 0.09 & 0.09 & 0.08 & \cdots & 0.07 \\ 0.08 & 0.08 & 0.07 & \cdots & 0.08 \\ \vdots & \vdots & \vdots & & \vdots \\ 0.06 & 0.06 & 0.08 & \cdots & 0.08 \end{pmatrix}_{13\times15} \quad (4)$$

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_j 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} = 00049, g_{14} = 0.0052, g_{15} = 0.0049.

Step 6: Calculate the objective 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:

$$w_j^* = \frac{r_j w_j}{\sum_{j=1}^{n} r_j w_j} \quad (5)$$

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				
	Weight				Weight			
Name	AHP method	Entropy weight method	Comprehensive	Name	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
				V_2	0.321	0.121	0.428	1
				V_3	0.055	0.087	0.053	4
C_2	0.249	0.318	0.211	V_4	0.087	0.049	0.047	5
				V_5	0.121	0.092	0.123	3
				V_6	0.013	0.081	0.012	8
				V_7	0.028	0.096	0.030	6
C_3	0.049	0.317	0.042	V_8	0.003	0.082	0.003	13
				V_9	0.005	0.083	0.005	11
				V_{10}	0.016	0.062	0.011	9
				V_{11}	0.025	0.090	0.025	7
C_4	0.140	0.034	0.013	V_{12}	0.010	0.009	0.001	15
				V_{13}	0.075	0.008	0.007	10
				V_{14}	0.034	0.009	0.003	12
				V_{15}	0.021	0.008	0.002	14

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_{15} (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*[23], and the comprehensive scores of each city are obtained through equation (6)[24]:

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

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 weakened. 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:

$$p_{ij} = \frac{x_{ij} - \min(x_{1j},\ x_{2j},\ \cdots,\ x_{nj})}{\max(x_{1j},\ x_{2j},\ \cdots,\ x_{nj}) - \min(x_{1j},\ x_{2j},\ \cdots,\ x_{nj})},\ i = 1, 2, \ldots, n; j = 1, 2, \ldots, m \quad (7)$$

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

City	C_1 score	C_2 score	C_3 score	C_4 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, Changzhou and Zhenjiang are also relatively good, and other cities have low scores; in terms of smart tourism science and technology foundation C_3, Suzhou scored the highest, indicating that it has strong scientific and technological innovation ability, Nanjing, Wuxi and Nantong are better, and other cities scored lower; in terms of C_4, the foundation of smart tourism environment, Nanjing has the strongest environmental support ability. Except Xuzhou, other cities have similar scores, and the gap is small. In the process of building a smart tourism city, smart tourism infrastructure plays an important role and occupies an extremely important position. Suzhou has the best performance in infrastructure construction among all cities, so it also performs well based on economy, science and technology and environment, with the highest comprehensive score.

From the comprehensive score of smart tourism competitiveness of 13 prefecture level cities in Jiangsu Province, there are significant differences among cities Suzhou, Nanjing, Wuxi, Changzhou and Zhenjiang are above the average score (0.419), while the 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 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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