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Evaluation Method of Urban Tourism Carrying Capacity based on Analytic Hierarchy Process

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ABSTRACT

The development of the urban tourism scale has promoted the economic development of tourism destinations, but it has also posed challenges to various resources and the environment in these destinations. Tourism carrying capacity is an important indicator that reflects the environmental status of a tourist city. Therefore, this paper constructs an evaluation index system and method for urban tourism carrying capacity based on the Analytic Hierarchy Process. Experimental results show that this evaluation method can effectively evaluate the tourism carrying capacity of different periods. The selected indicators can reflect the correlation between influencing factors and carrying capacity and accurately reflect the actual status of urban tourism carrying capacity. This method provides practical and scientific data and information to support the long-term harmonious development of tourism destinations.

Keywords: Analytic Hierarchy Process, Urban Tourism,Tourism Carrying Capacity, Capacity Evaluation

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1. Introduction

The development and application of Internet technology have transformed the traditional monotonous tourism market. The intelligent and diversified tourism methods and the increasing demand for tourism have driven the development of tourism culture, scenic spots, and urban construction. As an essential component of the tourism market, urban tourism has been favored by many tourists. Tourists can experience different urban lifestyles and deepen their understanding of urban culture and history when traveling to various cities. In recent years, many tourist cities have vigorously developed smart tourism, creating new types of tourism through technologies such as the Internet of Things, the Internet, and big data. This has improved service efficiency and convenience, enhanced the tourist experience, and attracted more tourists, leading to a positive development cycle. However, with the economic growth and rapid development of the tourism industry, the number of tourists choosing urban

tourism has grown exponentially. While the economic growth of tourism destinations increases, it also faces many challenges. Unlike traditional tourism concepts, new tourism models include urban tourism infrastructure, transportation convenience, urban culture dissemination, tourism service quality, food, and scenic spots, influencing tourists' travel decisions and experiences [1]. When the number of tourists in a city grows too rapidly, it not only affects tourists' travel experience but also leads to many negative issues for the destination city, such as overloaded public service facilities, traffic congestion, disruption of everyday local residents' lives, severe damage to the ecological environment, and even a significant decline or recession in the city's economic growth [2].

In recent years, the sustainable development of urban tourism, the harmonious development of urban tourism and the ecological environment, etc., have become the focus of researchers and the future development trend of tourist cities. Urban tourism carrying capacity is a key factor affecting the sustainable development of urban tourism. It is a comprehensive index based on the carrying capacity value size division obtained from the city's environmental elements. It includes the natural ecological environment, resource environment, social and cultural environment, service management environment, and infrastructure environment [3]. Therefore, based on the characteristics of urban tourism, this paper constructs an evaluation index system for urban tourism carrying capacity and combines the Analytic Hierarchy Process to build an evaluation model for urban tourism carrying capacity, thereby improving the scientificity and accuracy of capacity evaluation.

2. Current Status of Tourism Carrying Capacity Research

The concept of tourism carrying capacity can be traced back to the 1930s, originating from population studies. In the following three to four decades, research on carrying capacity gradually deepened, and scholars proposed the concept of recreational carrying capacity, suggesting that different tourist destinations have varying carrying capacities [4]. In the 1980s, the World Tourism Organization began to focus on research on the carrying capacity of the tourism environment. It proposed a quantitative method to consider the important characteristics of tourism carrying capacity. In the 1990s, researchers pointed out that tourism carrying capacity can reflect the acceptance level of tourist numbers by the natural and social environment of tourist destinations, and it can be integrated with the concept of sustainable development, showing consistency between the two [5]. In the 21st century, there has been a change in people's understanding of the relationship between humans and nature, and researchers have reached a consensus on the relationship between tourism carrying capacity and tourists' perceptions. They have also increased their attention to the ecological environment of tourism destinations [6]. During this development phase, more scholars achieved numerical calculations of tourism carrying capacity through different evaluation methods and models, incorporating natural resources and human acceptance into the relevant systems. In the early stage, scholars explored the relationship between tourism environmental carrying capacity, the social subsystem, and the relationship between tourist usage and tourism impacts through different quantitative models [7]. However, some scholars pointed out that a simple statistical analysis of specific data does not have practical significance for studying tourism carrying capacity. Instead, it should be studied in conjunction with tourism development's actual needs and conditions [8]. Some researchers focused on exploring the impact of tourism development on residents in tourist destinations and analyzed the probability of conflicts among residents caused by different types of tourism development. Other researchers constructed a warning system for tourism service capacity based on BP neural networks, providing decision information data for improving the service system of tourist destinations [9]. Furthermore, some scholars analyzed the urban tourism environmental carrying capacity using the fuzzy comprehensive evaluation method, focusing on carrying capacity under excessive tourism

development [10]. Additionally, scholars constructed environmental carrying capacity evaluation indicators for leisure tourist cities, enriching the content of ecological carrying capacity calculation models. With the development of information technology and big data, more scholars have built composite carrying capacity evaluation methods and systems based on big data, adding more diversified indicator factors based on the original indicators and presenting the tourism carrying capacity situation from multiple perspectives.

3. Urban Tourism Carrying Capacity Evaluation Model Based on Analytic Hierarchy Process (AHP)

3.1 Urban Tourism Carrying Capacity Evaluation Indicators

Currently, there is no unified system for selecting urban tourism carrying capacity evaluation indicators, and its comprehensiveness makes it inherently complex. At the same time, urban tourism carrying capacity can be regarded as the threshold of urban tourism activities. That is, tourism activities completed within the threshold can promote the city's overall development and attract more tourists. Once this threshold is exceeded, the urban environment and resources will be damaged, resulting in negative impacts. Therefore, urban tourism carrying capacity has a bi-directionality and value range. Additionally, urban tourism carrying capacity is not static; it will change with the development of various aspects of the city, making it dynamic. Finally, there is an apparent correlation between urban tourism carrying capacity and the local tourism market, which will change with the fluctuations of the tourism market, resulting in temporal variations. Therefore, a singular urban tourism carrying capacity indicator cannot comprehensively reflect the real situation of urban tourism carrying capacity and its correlation with different influencing factors. Scholar Butler, in studying the development of the tourism destination life cycle, divided the life cycle of tourist destinations into six stages based on the number of tourists. The destination bears different environmental pressures in each stage, as shown in Figure 1.

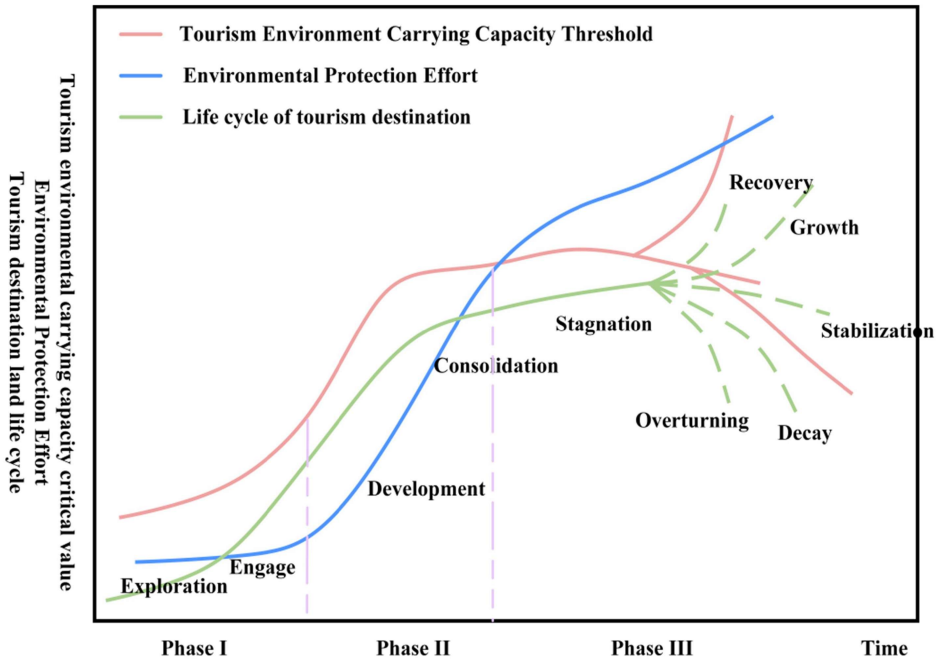

Figure 1. Correlation between the Lifecycle of Different Tourism Destinations and their Environmental Carrying Capacity and Environmental Protection Level

Based on the correlation between the lifecycle, environmental carrying capacity, and environmental protection level depicted in the above figure, this paper adheres to scientificity, pertinence, and systematicity principles. Accordingly, the following urban tourism carrying capacity evaluation indicators have been selected, as shown in Figure 2. This indicator system consists of three levels: the objective level, the criterion level, and the indicators. The objective level represents the evaluation of urban tourism carrying capacity. In contrast, the criterion level includes urban resource carrying capacity, ecological environment carrying capacity, service level carrying capacity, infrastructure carrying capacity, and social and cultural carrying capacity. Each criterion contains corresponding indicators: resource carrying capacity includes the physical space carrying capacity (total urban space, water bodies, green spaces, recreational areas, sports fields, roads, etc.) and resource attractiveness (the degree to which characteristic resources attract tourists); ecological environment carrying capacity includes waste disposal capacity, natural environment quality and conditions, noise pollution, green coverage rate, and environmental environment attractiveness; service level carrying capacity consists of the allocation and presence of service management personnel, overall service quality, dedication of employees, and tourists' satisfaction with service levels; infrastructure carrying capacity includes dining supply capacity, accommodation capacity, tour safety facilities, public restrooms and resting facilities, transportation facilities, communication facilities, etc.; social and cultural carrying capacity includes tourist density, local public safety conditions, the friendliness of local residents, etc.

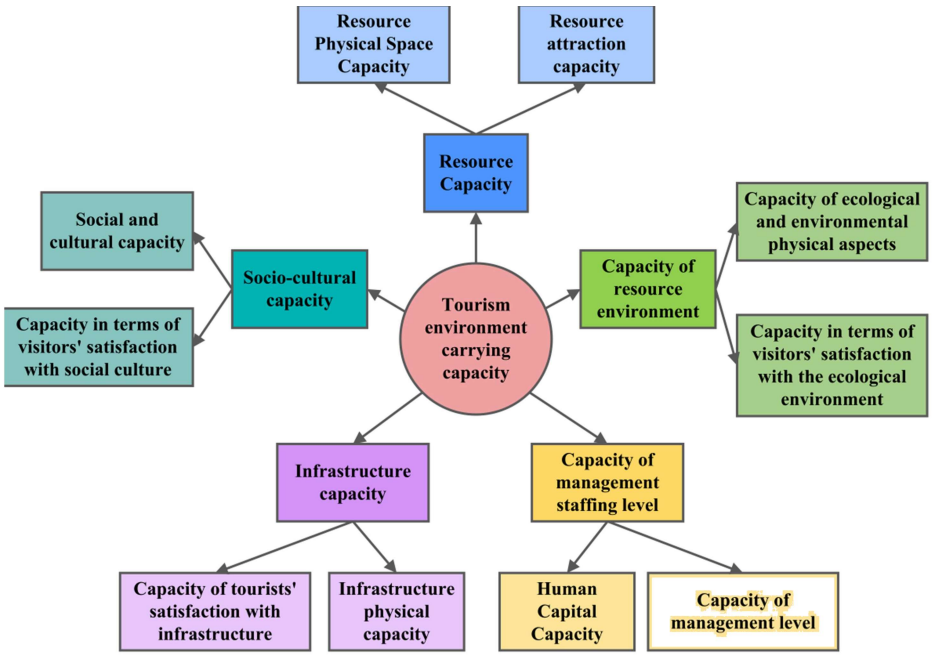

Figure 2. City Tourism Carrying Capacity Evaluation Indicator System

3.2 Determination of Indicator Weights Based on Analytic Hierarchy Process

There are differences in the strength of the correlation between the urban tourism carrying capacity evaluation indicators and their carrying capacity. This means that different factors have varying degrees of impact on the carrying capacity. Therefore, it is necessary to determine the weights of the selected indicators. This paper chooses to use the Analytic Hierarchy Process (AHP) to determine the indicator weights. AHP decomposes the decision-making content into corresponding hierarchies and uses qualitative and quantitative methods for demonstration,

ultimately obtaining the optimal decision-making solution. As the city tourism carrying capacity evaluation indicator system contains numerous indicators and has strong comprehensiveness, after hierarchy decomposition to form the indicator layer, the relevant ranking of the hierarchies will be determined through fuzzy quantification to achieve the optimization of the decision-making solution.

First, it is necessary to construct a judgment matrix. Suppose "*a_ij*" describes the importance of factor "*i*" relative to factor "*j*", and all elements in the matrix "*A*" are positive. If there exists "$a\_ij \neq 1/a\_ji$", then it forms a reciprocal judgment matrix. If "$a\_ij = 1/a\_ji$" holds true for all "*i*" and "*j*", and "$a\_ij \neq 1$" for all elements, then the matrix "*A*" belongs to a consistent reciprocal judgment matrix. This study used expert scoring to compare the importance of city tourism carrying capacity evaluation factors pairwise, and the relevant content was eventually determined. Then, based on expert scoring, the weights of the indicators were calculated. To obtain more reasonable indicator weights, twenty experts in the field of tourism resource-carrying capacity research were invited to compare the importance of indicators at each level of the evaluation system and provide comprehensive ratings for the indicators. The judgment matrix, after weighted geometric mean operation, was transformed into a reciprocal judgment matrix with comprehensive characteristics. The judgment matrix weights and the corresponding carrying capacity matrix were obtained through quantification calculations.

A consistency test was performed on the characteristic vector and characteristic root of each judgment matrix according to formula (1) to verify the scientificity and rationality of the obtained judgment matrix weights.

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(MW)_i}{W_i} \tag{1}$$

The maximum feature roots are represented as $\lambda_{\max}$, $M = \begin{bmatrix} m_{11} & m_{12} & \ldots & m_{1j} \\ m_{21} & m_{22} & \ldots & m_{2j} \\ \ldots & \ldots & \ldots & \ldots \\ m_{i1} & m_{i2} & \ldots & m_{ij} \end{bmatrix}$, the component values with sequence numbers are described as i, the corresponding hierarchy of the judgment matrix is represented as $(MW)_i$, and its approximate eigenvector value is represented as W_i.

Formula (2) is the calculation formula for consistency indicators

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{2}$$

When the value of the indicator is zero, it indicates that the matrix is completely consistent. The closer the value is to zero, the better the consistency of the matrix.

The consistency ratio of the judgment matrix is shown in formula (3):

$$CR = \frac{CI}{RI} \tag{3}$$

The average random consistency index is denoted as. When the ratio is not less than 0.1, it indicates that the judgment matrix needs adjustment. When it is not greater than 0.1, it means that the judgment matrix passes the consistency test.

After determining the factors for evaluating urban tourism carrying capacity, the fuzzy comprehensive evaluation method will be used to calculate the comprehensive evaluation value of urban tourism carrying capacity. The evaluation factors are described in a set manner, denoted as, and the number of indicators is denoted as. The set of linguistic evaluation comments is represented as indicating the states of factors in the factor set. The linguistic evaluation comments include adjacent evaluation grade standards, wherethe membership functions of the evaluation grade standards are shown in (4)-(6).

$$r_1 = \begin{cases} 1 & u_j < v_1 \\ \dfrac{u_j - v_1}{v_2 - v_1} & v_1 < u_j < v_2 \end{cases} \tag{4}$$

$$r_2 = \begin{cases} 1 - r_1 & u_j \le v_2 \\ \dfrac{u_j - v_2}{v_3 - v_2} & v_2 < u_j < v_3 \end{cases} \tag{5}$$

$$r_i = \begin{cases} 1 - r_{i-1} & v_{i-1} \le u_j \le v_i \\ \dfrac{u_j - v_i}{v_i - v_{i-1}} & v_i < u_j < v_{i+1} \\ 0 & u_j \ge v_{i+1} \end{cases} \tag{6}$$

According to the above formula, the membership matrix can be obtained, as shown in formula (7):

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} \tag{7}$$

4. Results of the City Tourism Carrying Capacity Evaluation Model Based on Analytic Hierarchy Process (AHP)

This study applied the analytic hierarchy process (AHP) based evaluation model of urban tourism carrying capacity to a specific tourist city for quantitative evaluation. Due to the strong temporal variation in urban tourism, the comprehensive carrying capacity evaluation results for the year may not fully reflect the carrying capacity during the peak tourism season. Therefore, in the application experiment, evaluations were conducted for the annual and carrying capacity during the peak tourism week, as shown in Figure 3.

The data in the figure shows that the evaluation result for the annual carrying capacity of the tourist city is generally in a weak load state, indicating that it can basically meet the needs and requirements of tourists. Among the four indicators, the carrying capacity of tourism facilities and the environment is significantly higher than the other three. Although it is still in a weak load state, this only reflects its average state. Under dynamic conditions, it may experience fully loaded or overloaded situations.

Combining the evaluation results of the carrying capacity during the peak tourism week, it can be seen that the carrying capacity of tourism facilities, the environment, and the social environment are severely overloaded. This indicates that the public facilities in the city cannot meet the demands of tourists during the peak tourism season, and it may cause certain inconveniences to the local residents, leading to social-environmental problems and resulting in a severe overload of the social environment.

In addition, although the city's ecological environment is assessed as being in an appropriate load state during the peak tourism week, its carrying capacity index value is close to 1, indicating that the city's ecological environment is already close to its limit. Without taking appropriate ecological protection measures, the probability of ecological environment damage will increase.

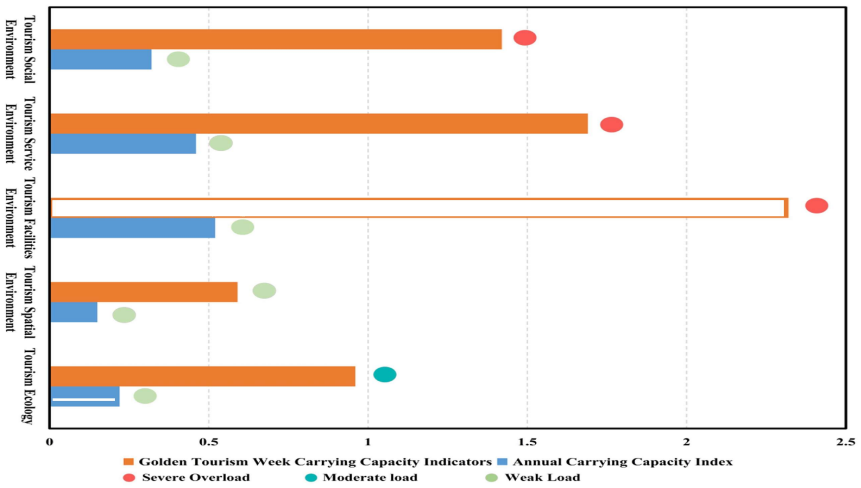

Figure 3. Evaluation Results of Tourism Carrying Capacity in a Certain Tourist City

As shown in Figure 4, the statistical results of tourists' satisfaction with the city's tourism resources are presented. From the data in the figure, it can be observed that tourists are delighted with the city's natural resources, followed by satisfaction with local customs and cultural heritage. However, the satisfaction levels for dining and shopping environments are relatively low, indicating a lower satisfaction with the city's public facility environment. This suggests that during the off-peak tourism season, the city's facilities and environment can meet the needs of residents and tourists to a certain extent. However, during the peak tourism week, it becomes apparent that the facilities and services are insufficient to meet the demands of tourists. This reduces tourists' overall experience in the city and diminishes its attractiveness to other potential visitors. Combining this with the spatial environment evaluation results shown in Figure 3, it is evident that there is still significant potential for development in the city's tourism space, which could provide spatial support for future facility and environment improvements.

In conclusion, the city tourism carrying capacity evaluation model based on the Analytic Hierarchy Process (AHP) constructed in this study effectively evaluates various aspects of urban tourism carrying capacity during its application. It also allows for selecting evaluation periods based on demand, combining short-term and long-term evaluations, and providing more comprehensive tourism carrying capacity evaluation data for destination cities. Furthermore, the constructed evaluation index system for carrying capacity aligns with urban tourism carrying capacity characteristics, effectively reflecting the correlation between various influencing factors and carrying capacity and providing data and information to support decision-making for developing tourist destinations.

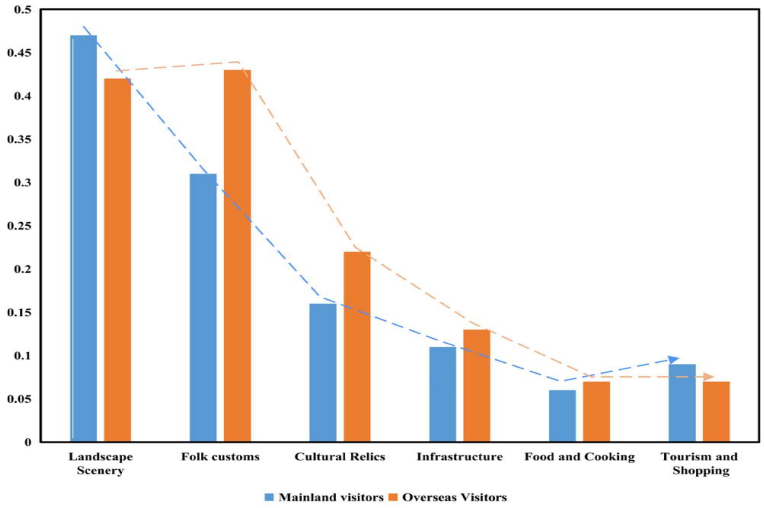

Figure 4. Statistical Results of Tourists' Satisfaction with Tourism Resources in the City

5. Conclusion

The development of the tourism market can promote tourist destinations' economic and social environment. However, with the continuous growth of tourist numbers, the contradiction between tourist demand and the environmental carrying capacity of tourist destinations has become increasingly apparent. To better facilitate long-term development plans for tourist destinations, this study used the Analytic Hierarchy Process to construct a city tourism carrying capacity evaluation method and index system, selecting indicators that effectively reflect the influencing factors of urban tourism carrying capacity. The experimental results show that the city tourism carrying capacity evaluation model based on the Analytic Hierarchy Process can effectively and scientifically assess the carrying capacity of different periods for tourist destinations, providing valid and reasonable evaluation results. Moreover, this model can also statistically analyze individual evaluation indicators, presenting the carrying capacity of tourist destinations from multiple perspectives and providing scientific and reliable data and information support for the development of tourism in the city, thereby promoting the implementation of long-term sustainable development plans for urban tourism.

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