

Research on Tourism Sustainability Assessment Model Based on Entropy Power Hierarchical Analysis Approach

Mingyang Yuan[#], Jinmei Du^{*,#}

College of Astronautics, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, China

*Corresponding author: Jinmei Du (Email: 152210205@nuaa.edu.cn)

[#]These authors contributed equally.

Abstract: Focusing on tourism sustainability research, this paper constructs a comprehensive assessment system using the city of Juneau as an example. First, This paper identifies three main indicators by harmonizing economic, ecological and social factors. Then we identified 11 closely related secondary indicators. Finally, the weight of each indicator in the evaluation system was determined through entropy weighting-hierarchical analysis. In the assessment of sustainable tourism development in Juneau, ecological factors (50% weight) have the greatest impact on destination sustainability, with greenhouse gas emissions (24% of ecological issues) being the core challenge, directly accelerating glacier melting; social factors (33% weight) need to balance the number of tourists (10% of social issues) to avoid the negative impacts of overcrowding on the experience of residents and tourists, and to guard against the Economic factors (17% weighting) show that the annual income from local tourism (7% of economic issues) is a direct driver of sustainable development, but that the income of tourism workers is lower than the regional per capita level and needs to be improved. It is worth noting that there are significant correlations between indicators, such as a strong correlation between the number of tourists and greenhouse gas emissions. The study suggests controlling the size of tourists, optimizing income distribution and strengthening emission reduction measures to promote the synergistic sustainable development of ecological, social and economic dimensions. The model can effectively reflect the status of tourism sustainability. This study provides a scientific basis for tourism planning.

Keywords: Sustainable Tourism, Evaluation Model, Entropy Weights-Hierarchical Analysis.

1. Introduction

Numerous scholars have carried out research on the sustainable development of tourism. In China Collective Economy, Wang Zhang puts forward a study on the sustainable development of tourism in rural areas, analysing the sustainable development of rural economy and ecological environmental protection, and carrying out corresponding tourism planning [1]. In China Resource Utilisation, Jingping He puts forward the concept of circular economy in tourism scenic spots, aiming to improve the scenic spot's enjoyment by reducing the impact of tourists on the ecological environment, thus promoting the economic development of tourism scenic spots [2]. These studies have provided ideas for sustainable tourism development from different

perspectives, but the research on the construction of a comprehensive evaluation system for Juno City with integrated multiple factors is still to be improved, although the economic development and ecological environment and other factors have been taken into account, but the issue of the residents' sense of well-being has not been taken into account, which cannot be changed to adapt to the actual situation of the local area of Juneau, and at the same time, it has not been able to build up a reliable evaluation index about the sustainability of the tourists[3]. Therefore, this study aims to construct an integrated ecological, economic and social tourism sustainability assessment model, which can provide a scientific decision-making basis for the sustainable development of tourism in Juneau and similar areas. Figure 1 from <https://www.travelalaska.com/destinations/cities-towns/juneau>.



(a) Aerial view of Juneau



(b) Skiing in Juneau

Figure 1. The Beauty of Juneau

2. Materials and methods

2.1. Data acquisition and pre-processing

2.1.1. Data collection

This study collects data on various aspects of the City of

Juneau, covering data on the number of visitors over the years, the number of residents, the size of the labor force, and the air quality index, which were obtained from the sources shown in Table 1:

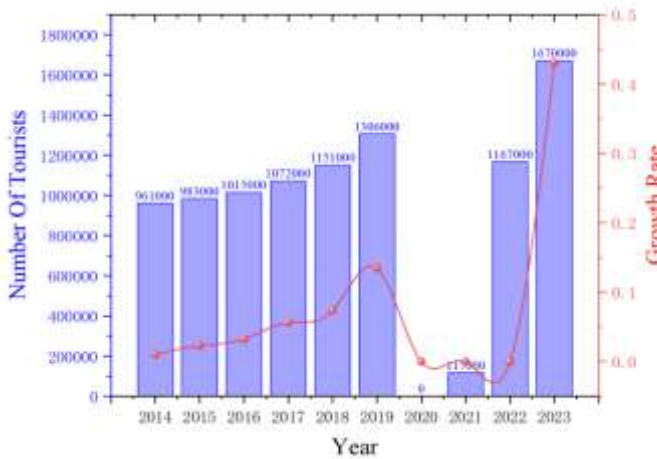
Table 1. Data and Database Websites

Database Names	Database Names
Personal Income in the Juneau	https://www.census.gov/programs-surveys/acs/data
Juneau Air Quality Index	https://aqs.epa.gov/aqsweb/airdata/download-files.html
Size of the Juneau Labor Force	https://www.bls.gov/lau
Juneau Poverty Rate	https://www.census.gov/programs-surveys/acs/data
Number of people in the Juneau	https://www2.census.gov/programs-surveys/popest/tables
Unemployment rate in the Juneau	https://www2.census.gov/programs-surveys/popest/tables
Number of visitors to the Juneau	https://juneau.org/wp-content/uploads
Revenue from tourism in the	https://juneau.org/wp-content/uploads
Juneau Household Income	https://juneau.org/wp-content/uploads

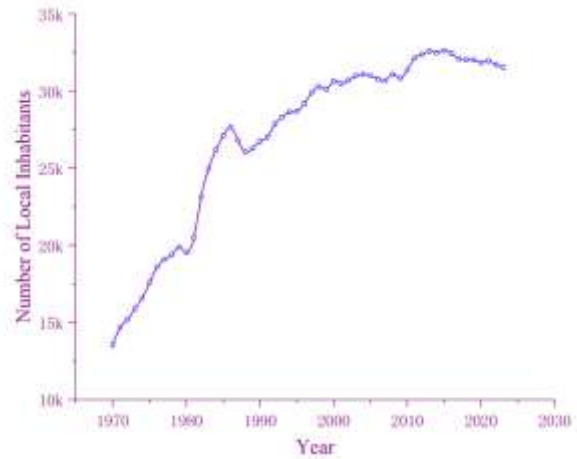
2.1.2. Data Visualization

In order to provide a more intuitive understanding of the overall distribution, trends and extent of the data, the

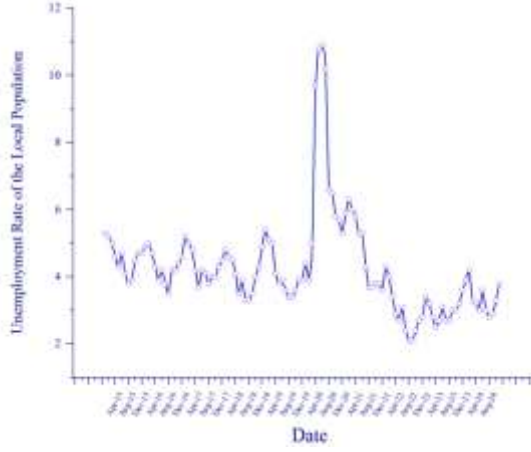
collected data were visualized in this paper and presented in Figure 2.



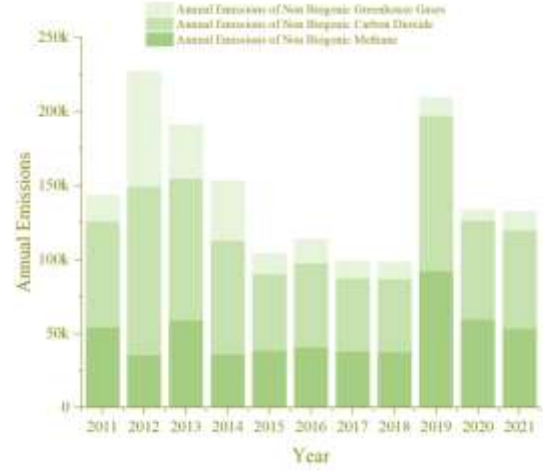
(a) Juneau Visitor Count and Growth Rate 2014-2023



(b) Number of residents in Juneau



(c) Size of Juneau's labor force



(d) Greenhouse gas emissions

Figure 2. Neural network structure

3. Results and analysis

3.1. The establishment of simulation model

Considering the factors affecting sustainability, we selected three first-level indicators, social, ecological and economic, and 11 second-level indicators for their corresponding expansion [4].

Social factors: Sustainability includes social factors such as stable number of tourists, strong motivation of tourists to travel, good quality of tourists' behavior and social harmony and stability. Social factors play a profound role in the sustainability of tourist destinations. In this paper, 5 secondary indicators of social factors (number of tourists, number of local residents, size of local labor rate, unemployment rate of local residents and local infrastructure construction) are selected.

Ecological factors: Sustainability encompasses ecological factors such as the sustainable use of natural resources, environmental pollution and governance, and climate change and governance capacity. Ecological factors are the basis of sustainable development in tourist destinations. In this paper,

3 secondary indicators of ecological factors (local air quality index, greenhouse gas emissions and average concentration of diesel particulate matter) were selected.

Economic factors: Sustainable development and economic factors interact and promote each other. Economic development is the effect of the realization of sustainable development, and sustainable development cannot be separated from economic support and technical and financial inputs. In this paper, 3 secondary indicators of economic factors (annual personal income of local residents, local poverty rate and annual income from local tourism) are selected.

3.2. Solution of Indicator Weights

3.2.1. Solution of the Weights of the First-level Indicators

Analytical Hierarchy Process (AHP) is a combination of qualitative and quantitative, systematic and hierarchical analysis method [5]. The determination of the weights of the first-level indicators depends on human subjective consciousness, and this paper adopts the hierarchical analysis method to solve the problem. The solution process of hierarchical analysis is shown in Table 2:

Table 2. The process of AHP solving

Step 1: Model the hierarchy
Step 2: Construct a judgment matrix
Step 3: Consistency test on the judgment matrix
Step4: The weights of the first-level indicators were outputted

To rank the above three first-level indicators, we examined local policies, economy, ecology, and society, and concluded

that ecology>society>economy. The judgment matrix for the first-level indicators is constructed in Table 3:

Table 3. Judgement matrix for first-level indicators

	Society	Ecology	Economy
Society	1	0.3333	0.5
Ecology	3	1	1.5
Economy	2	0.6667	1

The consistency test was performed on them and the consistency indicator was calculated using the formula:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (1)$$

where CI is a coherence indicator, $\lambda_{\max}$ is the largest eigenvalue of the matrix, n is the matrix order. Based on n = 3 here, find the corresponding average random number indicator RI=0.52. The consistency ratio CR is calculated as:

$$CR = \frac{CI}{RI} \quad (2)$$

Calculated $CR \ll 0.1$, indicates that the consistency of this judgment matrix is acceptable. The formula for finding the weights by arithmetic mean is:

$$W_j = \frac{1}{n} \sum_{i=1}^n \frac{a_{ij}}{\sum_{k=1}^n a_{kj}} \quad (3)$$

Where W_j is the weight of the indicator j and a_{ij} is the value of the i column of the j row of the matrix.

The weights of the three first-level indicators were obtained as $W_{ecol} = 0.5000$, $W_{soc} = 0.3333$ and $W_{econ} = 0.1667$

Table 4. The process of EWM solving

Step 1: Importing data into MATLAB to standardize the indicators
Step 2: Calculate the entropy value of the standardized indicator
Step 3: Calculation of the coefficient of variation for each indicator
Step4: The weights of the second-level indicators are outputted

Among the secondary indicators, there are cost-based indicators (the smaller the better), benefit-based indicators (the larger the better) and interval-based indicators, and different normalization is carried out for different types of indicators with the processing formula:

- Benefit-based Indicators: the larger, the better

$$\tilde{x}_{ij} = \frac{\max(x_i) - x_{ij}}{\min(x_i) - \max(x_i)} \quad (4)$$

- Cost-based Indicators: the smaller, the better

$$\tilde{x}_{ij} = \frac{\max(x_i) - x_{ij}}{\min(x_i) - \max(x_i)} \quad (5)$$

- Interval-based Indicators : The optimal value of the interval attribute lies within an interval [a, b]

$$M = \max\{a - \min(x_i), \max(x_i) - b\}$$

$$\tilde{x}_{ij} = \begin{cases} 1 - \frac{a - x_{ij}}{M} & , x_{ij} < a \\ 1 & , a \leq x_{ij} \leq b \\ 1 - \frac{x_{ij} - b}{M} & , x_{ij} > b \end{cases} \quad (6)$$

$$W_j = \begin{cases} w_j \cdot W_{ecol} & , \text{if the first-level indicator for indicator j is Ecology} \\ w_j \cdot W_{soc} & , \text{if the first-level indicator for indicator j is Society} \\ w_j \cdot W_{econ} & , \text{if the first-level indicator for indicator j is economy} \end{cases} \quad (10)$$

3.3. Presentation and Analysis of Results

We use the above model to find the weights of the first-

respectively.

3.2.2. Solution of the Weights of the Second-level Indicators

The basic idea of entropy weight method (EWM) is to determine the objective weights based on the magnitude of variability of the indicators [6]. Generally speaking, if the information entropy of a certain indicator is smaller, it indicates that the greater the degree of variability of the indicator's value, the greater the amount of information provided, and the more information provided, the greater the role played in the comprehensive evaluation, and the greater its weight. The first-level indicators can be quantified with specific data, so the entropy weight method is used to find their weights relative to the respective first-level indicators. The basic steps of the entropy weight method of solving are shown in Table 4:

For normalized data, the entropy value of indicator j is calculated by the formula:

$$e_j = -k \sum_{i=1}^n x_{ij} \ln(x_{ij}), j = 1, \dots, m \quad (7)$$

where e_j is the entropy value of indicator j, m is the total number of indicators and $k = 1/\ln > 0$.

satisfies the $e_j \geq 0$.

The coefficient of variation for indicator j is formulated as:

$$d_j = 1 - e_j, j = 1, \dots, m \quad (8)$$

where d_j is the coefficient of variation for indicator j.

The weight of indicator j is formulated as:

$$w_j = \frac{d_j}{\sum_{j=1}^m d_j}, j = 1, \dots, m \quad (9)$$

Where w_j is Weight of each second-level indicator j in relation to its first-level indicator. The weight of each secondary indicator in relation to tourism sustainability is calculated as follows:

level indicators and second-level indicators and present them in Figure 3:

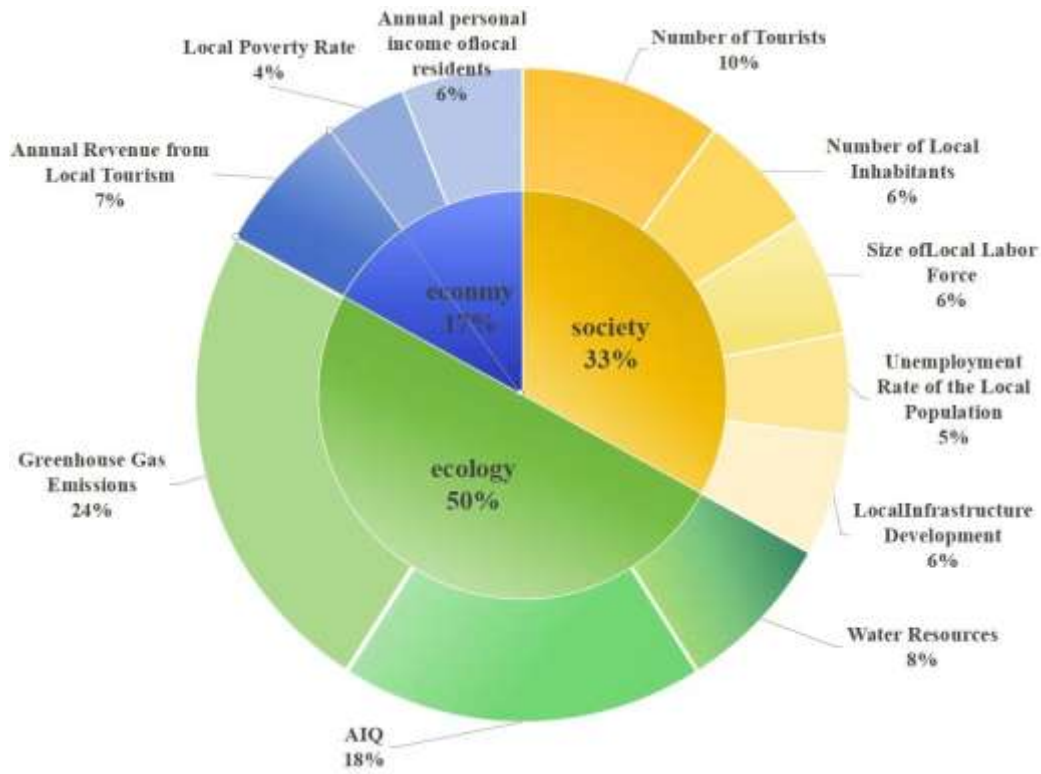


Figure 3. Weighting of Indicators

In Figure 3, we can see that for the first-level indicators, the greatest degree of impact on the sustainability of a tourist destination is ecological (50%), followed by social (33%), and the smallest is economic (17%). In the context of the current situation in Juneau, the most important ecological concern for the development of sustainable tourism is the emission of greenhouse gases (24%), which has a significant impact on the rate of glacier melting in Juneau. Socially, the number of tourists (10%) should be kept within reasonable limits, as too many tourists can cause overcrowding, which can lead to a bad experience for both local residents and tourists. Too few tourists can cause problems such as increased unemployment among local residents. In terms of economy, the annual income from local tourism (7%) is the direct effect of tourism sustainability and the direct focus of tourism sustainability. Overall, we reviewed the information and found that the local per capita income level is relatively high, but the per capita income of tourism workers is lower than the overall per capita income, and the salary of tourism workers needs to be improved. At the same time, there are some interactions between the indicators, for example, there is a strong correlation between greenhouse gas emissions and the number of tourists. Evaluation model provides direction for subsequent sustainability optimisation processes.

4. Conclusions

This paper successfully constructs a tourism sustainability assessment model based on entropy weight hierarchical analysis, which is innovative in the selection of indicators and the establishment of functions by comprehensively considering various factors.

However, the model also has some limitations, such as a high degree of dependence on data, in order to fully take into account the impact of unexpected events and other factors,

future research can focus on optimizing the acquisition of data to improve the accuracy and comprehensiveness of the data, and at the same time, incorporate the unexpected events into the scope of the model, to further improve the assessment system of tourism sustainability. This will provide more universal guidance for the sustainable development of global tourism.

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