Ecological Safety Evaluation of Tourism Destination Based on Matter-Element

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Abstract

There are many tourism cities in China and sustainable development of urban tourism has become an important field of tourism research. An ecological safety evaluation index system of tourism city was constructed. The evaluation index system was composed of resource, environmental, economic and social subsystem. Classification standard of evaluation indexes was discussed. Then an evaluation model based on fuzzy matter-element theory was established. Finally a case study on Kaifeng city was developed. The results showed that there was a tendency of gradual improvement in ecological safety condition of Kaifeng city. However, ecological safety condition during the period belonged to critically safe grade. Therefore, ecological safety condition of Kaifeng was unsatisfactory. The study can provide scientific basis for decision-making of local governments, help people know the influences of tourism activities on ecological environment scientifically and timely, and help tourists advance ecological consciousness.

Keywords: fuzzy matter-element, ecological safety, tourism city, tourism destination

1. Introduction

During the past half century, global tourism industry developed rapidly. Now tourism industry has become one of the largest industries with the best momentum of economic growth around the world. However, the rapid development of tourism has brought about many negative impacts on tourism destinations. The large-scale tourism activities influence water body, atmosphere, biological world and human beings of tourism destinations greatly. For example, the vehicles (especially the cars) in tourism areas discharge plenty of co_2; tourists in tourism areas (including catering, washing, bathing, food processing, and so on) consume a mass of water resource; the dustbins damages ecological environment; air and water pollution lead to the death of forests and flowers; the large number of activities results in the death of vegetation and the solidification of soil; the excessive land reclamation in natural protection areas leads to the loss of habitats of wild animals, aggravates the relations between carnivores and non-carnivores, and limits the movement of animals; residents of poor areas hunt and kill a mass of wild animals because of the desire of making money.

The above factors damage ecosystems of tourism destinations. According to statistical data provided by National Commission of Man and Biosphere, protection targets in 22 percent of natural reserves are damaged and the resources in 11 percent of natural reserves degenerate. These problems influence not only the physical and mental health of the residents, but also the ecological system of tourism destinations greatly. How to monitor ecosystems of tourism cities dynamically and comprehensively, so as to find the problems in urban ecosystem, to take corresponding measures, and to promote the coordinated development among society, economy and environment of tourism destinations has become a hot research topic.

Ecological safety of tourism destinations can be defined from a broad and narrow sense. Ecological safety of tourism destinations from a broad sense means the absence of threats to human's life, health, ease, basic rights, life ensure sources, necessary resources, social sequence and capability to acclimate environmental changes etc, including natural ecological safety, economic safety and social safety, and composing a complex false ecological system. Ecological safety of tourism destinations from a narrow sense means tourism destinations are in a safe condition, tourism activities won't disarrange productive and living

operations, and won't damage social, cultural and economic environments of tourism destinations. Whether an ecosystem of tourism destination is safe or not depends on two factors. The first factor is whether the ecosystem itself is safe, which means that whether the structure of the ecosystem is complete. The second factor is whether the ecosystem is safe to human beings, which means that whether the service provided by the ecosystem can satisfy the needs of human beings.

Some scholars evaluate ecological safety conditions of tourism destinations. Based on ecological security theory, Xuewang Dong (2003) set forth the ecological security theory about the sustainable development of tourist destinations systematically. Then he studied the theory and methods of evaluation of ecological security of tourist destination and found the theoretic framework of them. At last, according to the above theory and method, as a case, he analyzed Wudalianchi National Park & Nature Reserve and put forward some practical conclusions [1]. Taking Kaifeng city as an example, Xinxiang Cao (2006) constructed a compound ecological safety alarm system of tourism including three sub-systems of environment pressure, environment quality and environment protection and controlling. Based on the thought of critical limit of ecosystem environment ability development and fuzzy mathematics assessment method, the paper discussed ecological safety alarm of tourism in Kaifeng city [2]. Based on the ecological footprint model, Xinxiang Cao (2006) designed a series of indexes system to assess ecological security and set up a ratio to make sure the situation of ecological safety, took Kaifeng City as an example, adopted the method of ecological footprint analysis and constructed an evaluation method and indexes system [3]. Cuihong Wang (2006) introduced the application of the P-S-R model to the evaluation of the eco-environmental security of Wuyishan Scenery Area [4]. Focusing on the instruction of Wulingyuan core scenic spot in Zhangjiajie city and achieving the goal of establishing the best scenic spots in the world, Yuelin Long (2006) put forward the reasonable design and management measures from the aspects of harmonious relationship between human being and nature, landscape ecological safety and sustainable development as well [5]. From the security of the relationship between human and nature, tourist ecological consumption characteristic and global climate change, Jinhe Zhang (2008) put forward the conception of ecological security for tourism destination, and defined the conception in two ways by broad sense and narrow sense. Based on the theory and method of ecological footprint, he put forward the ecological security measuring model, and taking the Jiuzhaigou National Nature Reserve (JNNR) as an example, he calculated and analyzed the ecological security index and the intra and inter-regional impact on the JNNR in 2004 [6]. Peng Zhang (2009) used pressure-state-response model and fuzzy mathematics to assess ecological safety conditions of the 35 tourism cities. Results show that ecological safety levels of the cities in eastern coastal areas are higher than that of the cities in northwest and western regions [7]. Based on the theory and research methods of ecological security and PSR index system mode, Xinyuan Li (2010) established indicators system of ecological evaluation about bamboo forest eco-tourism area in Gaoping of Nanping from three aspects of eco-environmental stress, eco-environmental state and eco-environmental response. Using this system, the author developed a quantitative evaluation on the situation of the ecological safety in research area [8]. In light of the meaning of ecological safety and the characteristics of ecosystem of mountain scenic resorts, Ruoning Li (2010) established an assessment index system for ecological safety by the method of Analytic Hierarch Process (AHP) [9].

2. Research Method
2.1. Ecological Safety Evaluation Index System of Tourism City

Compared with general cities, the difference of tourism cities lies in that the existence of these cities mainly depends on resources and their ecological problems are more serious.

In current urban safety evaluation, ecosystem is generally divided into three subsystems, namely environmental, economic and social subsystems. Considering the particularity of tourism cities, we divide urban ecosystem into four subsystems, namely resource, environmental, economic and social subsystem. Following the principles of availability, comparability, practicality and comprehensiveness, we choose different indexes in each system layer. Ecological safety evaluation index system of tourism city is shown in Table 1.

After confirmation of evaluation index system, classification standard must be determined. We divide ecological safety into five grades: unsafe, relatively unsafe, critically safe, relatively safe and safe grade.

We consult the suggested value of ecological city and environment protection model city commonly recognized as the standard value of safe grade, and the international or national minimum value as the limitation value of unsafe grade [10-15]. Then, the boundary value between relatively safe grade and critically safe grade are acquired by downwardly fluctuation 20% on the former basis, the boundary value between relatively unsafe grade and critically safe grade are attained by upwardly fluctuation 20% on the latter basis. Subsequently, standard value of critically safe grade determined by former and latter means is mutually regulated to yield the termination value. Classification standard of indexes is shown in Table 1.

Table 1. Ecological Safety Evaluation Index System and Classification Standard

System layer	Index layer	Unit	Ecological safety grade				
			Unsafe	Relatively Unsafe	Critically Safe	Relatively Safe	Safe
Resource subsystem	Per capita cultivated land	hm^2	<0.02	0.02-0.03	0.03-0.05	0.05-0.08	>0.08
	Per capita water capacity	m^3	<500	500-1000	1000-5000	5000-8000	>8000
	Reserves consumption rate of tourism resource	%	>70	60-70	45-60	30-45	<30
	Development and use rate of tourism resource	%	<20	20-35	35-50	50-70	>70
Environme-ntal subsystem	Organism abundance index	—	<25	25-35	35-55	55-75	>75
	Percentage of forest cover	%	<20	20-30	30-40	40-50	>50
	Disposal rate of urban domestic sewage	%	<20	20-40	40-60	60-80	>80
	Quality index of water environment	—	<30	30-50	50-70	70-85	>85
	Index of air pollution	—	>200	200-150	150-100	100-50	<50
Economic subsystem	Per capita GDP	10^4 RMB	<3	3-5	5-10	10-20	>20
	Annual average growth rate of GDP	%	<2	2-6	6-8	8-10	>10
	Percentage of tourism income in GDP	%	<30	30-50	50-60	60-80	>80
	Percentage of tertiary industry to GDP	%	<20	20-30	30-50	50-64	64-80
	Percentage of environmental protection investment to GDP	%	<1.5	1.5-2	2-3	3-5	>5
	Energy consumption for million yuan GDP	tce	>2	2-1.5	1.5-1	1-0.7	<0.7
	Water consumption for million yuan GDP	m^3	>1000	1000-700	700-300	300-100	<100
Social subsystem	Unemployment rate of urban population	%	>4.2	4.2-3.6	3.6-3.0	3.0-1.2	<1.2
	Engel coefficient of urban population	—	>0.6	0.5-0.6	0.3-0.5	0.2-0.3	<0.2
	Per capita educated age limit	year	<7	7-9	9-14	14-16	>16
	Expected life of population	year	<55	55-60	60-70	70-80	>80

2.2. Evaluation Model of Ecological Safety of Tourism City Based on Fuzzy Matter-Element

Fuzzy matter-element. Fuzzy matter-element uses "matter, character, fuzzy value" as the primary element to describe a matter [16]. Suppose M is a matter, C is the character of M, and x is fuzzy value of C, then there exists an ordered fuzzy matter-element: $R=(M,C,x)$. If M has n characters $C_1,C_2,\ldots,C_n$ and their corresponding values $x_1,x_2,\ldots,x_n$, R is called an n-dimensional fuzzy matter-element. If n-dimensional fuzzy matter-elements of m matters combine, they form R_{mn}, which is defined as:

$$R_{mn} = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ C_1 & x_{11} & x_{21} & \cdots & x_{m1} \\ C_2 & x_{12} & x_{22} & \cdots & x_{m2} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ C_n & x_{1n} & x_{2n} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

Where R_{mn} is a compound fuzzy matter-element of m things with n fuzzy characters, M_j (j=1,2,…,m) is the jth thing, C_i(i=1,2,…,n) is the ith character, x_{ij} is fuzzy value of the jth thing against the ith character [17].

Standard fuzzy matter-element matrix. According to evaluation standards of urban ecological safety, we calculate safety exponents of indexes and establish standard fuzzy matter-element matrix [18].

Safety exponents of positive indexes are calculated by the following formulas.
Safe grade:

$$u_{ij} = 2 + 2 \times (d_1 - x_{ij})/d_1 \left(if \ \ x_{ij} > d_1 \right) \tag{2}$$

Relatively safe grade:

$$u_{ij} = 4 + 2 \times (d_2 - x_{ij})/(d_1 - d_2)\left(if \ \ d_2 < x_{ij} \le d_1 \right) \tag{3}$$

Critically safe grade:

$$u_{ij} = 6 + 2 \times (d_3 - x_{ij})/(d_2 - d_3)\left(if \ \ d_3 < x_{ij} \le d_2 \right) \tag{4}$$

Relatively unsafe grade:

$$u_{ij} = 8 + 2 \times (d_4 - x_{ij})/(d_3 - d_4)\left(if \ \ d_4 < x_{ij} \le d_3 \right) \tag{5}$$

Unsafe grade:

$$u_{ij} = 8 + 2 \times (d_4 - x_{ij})/d_4 \left(if \ \ x_{ij} \le d_4 \right) \tag{6}$$

Formulas of safe exponents of cost indexes are as follows:
Safe grade:

$$u_{ij} = 2 + 2 \times (x_{ij} - d_4)/d_1 \left(if \ \ x_{ij} \le d_4 \right) \tag{7}$$

Relatively safe grade:

$$u_{ij} = 4 + 2 \times (x_{ij} - d_3)/(d_3 - d_4)\left(if \ \ d_4 \le x_{ij} < d_3 \right) \tag{8}$$

Critically safe grade:

$$u_{ij} = 6 + 2 \times (x_{ij} - d_2)/(d_2 - d_3)\left(if \ \ d_3 \le x_{ij} < d_2 \right) \tag{9}$$

Relatively unsafe grade:

$$u_{ij} = 8 + 2 \times (x_{ij} - d_1)/(d_1 - d_2)\left(if \ \ d_2 \le x_{ij} < d_1 \right) \tag{10}$$

Unsafe grade:

$$u_{ij} = 8 + 2 \times (x_{ij} - d_1)/d_1 \left(if \ \ d_1 \le x_{ij} \right) \tag{11}$$

According to above formulas, value range of u_{ij} is from 0 to 10. If the value of u_{ij} is less than 0 or more than 10, we take its value as 0 and 10 respectively [19-20]. Then standard fuzzy matter-element matrix is as follows:

$$R_{ij} = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ C_1 & u_{11} & u_{21} & \cdots & u_{m1} \\ C_2 & u_{12} & u_{22} & \cdots & u_{m2} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ C_n & u_{1n} & u_{2n} & \cdots & u_{mn} \end{bmatrix}$$

(12)

Where R_{ij}(i=1,2,…,n; j=1,2,…,m) is standard fuzzy matter-element of the jth thing against the ith character.

Reference standard of urban ecological safety. Reference standard is the foundation to judge the safety condition of urban ecosystem. The determination of reference standard should conform to the principle of optimal subordinate degree, which means that each evaluation index is subject to the corresponding fuzzy value of each evaluation index in standard samples. Interval values of the five grades are divided between [0, 10] (as shown in Table 2).

Table 2. Grades of Urban Ecological Safety and Indexes Ranges

Safety grade	Safety level range	Positive index range	Negative index range
Safe	[0,2)	>d_1	<d_4
Relatively safe	[2,4)	[d_1, d_2)	[d_4, d_3)
Critically safe	[4,6)	[d_2, d_3)	[d_3, d_2)
Relatively unsafe	[6,8)	[d_3, d_4)	[d_2, d_1)
Unsafe	[8,10)	≤d_4	≥d_1

Calculation of indexes weights. Methods to endow indexes weights are divided into subjective and objective method. Among subjective method, weights of indexes are determined according to the opinions of appraisers. The disadvantage of subjective method lies in that the results are influences by subjective factors to a large extent. In objective method, weights of indexes are determined by the interactions between indexes or variation degrees of index values. We use entropy method to endow indexes weights [21].

The steps of improved entropy method are as follows:

The first step is to set up the judgment matrix $X=(x_{ij})_{s×n}$ (i=1, 2,… s; j=1, 2,…, n), where s is the number of evaluation objects, n is the number of evaluation indexes, x_{ij} denotes measured value of the jth index against the ith object.

The second step is to non-dimensionalize the indexes according to the following formula:

$$x'_{ij} = (x_{ij} - \bar{x}_j)/\sigma_j$$

(13)

Where x'_{ij} is the value of x_{ij} after non-dimensionalization, $\bar{x}_j$ is mean value of the jth index, and σ_j is standard deviation of the jth index.

The third step is to move the coordinate to eliminate negative values:

$$x''_{ij} = x'_{ij} + K$$

(14)

Where K is the range the coordinate moves and x''_{ij} is the value of x'_{ij} after the movement.

The fourth step is to calculate the proportion of x''_{ij}:

$$R_{ij} = x''_{ij} / \sum_{i=1}^{m} x''_{ij}$$

(15)

The fifth step is to calculate entropy value of the jth index:

$$e_j = -\left(\sum_{i=1}^{s} R_{ij} \ln R_{ij} \right) \Big/ \ln s \tag{16}$$

Where $e_j \in [0,1]$.

The sixth step is to calculate divergence coefficient of the jth index:

$$g_j = 1 - e_j \tag{17}$$

The larger g_j, the more important x_j in the evaluation system.
The seventh step is to calculate weight of the jth index:

$$w_j = g_j \Big/ \sum_{j=1}^{n} g_j \tag{18}$$

Then we obtain the set of indexes weights W_i ($W_i=(W_1,W_2, …,W_n)$).
Calculation of total exponent of ecological safety of tourism city. According to standard fuzzy matter-element and the set of indexes weights, total exponent of urban ecological safety is calculated by the following formula:

$$I_i = W_i \times R_{ij} = (W_1, W_2, \cdots, W_n) \times \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ C_1 & u_{11} & u_{21} & \cdots & u_{m1} \\ C_2 & u_{12} & u_{22} & \cdots & u_{m2} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ C_n & u_{1n} & u_{2n} & \cdots & u_{mn} \end{bmatrix} = (I_1, I_2, \cdots, I_m) \tag{19}$$

Where I_i is total exponent of urban ecological safety, W_i is the set of indexes weights, and R_{ij} is standard fuzzy matter-element matrix [22]. In terms of the value of I_i, we can judge conditions of urban ecological safety.
Characters of urban ecosystem corresponding to each grade are as follows:
Safe grade: service function of urban ecosystem is perfect. Ecological environment is not endangered, urban ecosystem structure is complete and function is strong. Urban ecosystem has strong abilities of recovery and regeneration. Problems of ecological environment are not obvious and ecological disasters are less.
Relatively safe grade: service function of urban ecosystem is relatively perfect. Ecological environment is endangered slightly, urban ecosystem structure is relatively complete and urban ecosystem function is good. Urban ecosystem is easy to recover after perturbation. Problems of ecological environment are not obvious and ecological disasters are less.
Critically safe grade: service function of urban ecosystem deteriorates. Ecological environment is endangered to a certain extent. Urban ecosystem structure changes and can maintain the basic function but is apt to degrade after perturbation. Problems of ecological environment appear and ecological disasters occur from time to time.
Relatively unsafe grade: service function of urban ecosystem deteriorates seriously. Ecological environment is endangered, urban ecosystem structure is destroyed to a great degree and urban ecosystem function degrades and is incomplete. The recovery and reconstruction of urban ecosystem is difficult. Problems of ecological environment are relatively severe and there are many ecological disasters.
Unsafe grade: service function of urban ecosystem is on the verge of collapse and the reversion of ecological process is very difficult. Ecological environment is endangered severely and urban ecosystem structure is incomplete and urban ecosystem function is loosed. The recovery and reconstruction of urban ecosystem is very difficult. Problems of ecological environment are severe and are apt to evolve into ecological disasters.

3. Results and Discussion
3.1. Case Study

In the eastern part of Henan Province, to the southern bank of Huanghe River (Yellow River), bordering with Shandong Province at northeastern part, Kaifeng covers a total area of 6466 square meters with the population of 4.4 million. There are five counties and five districts under its administration. It's one of the state first groups of historic cultural famous cities. Kaifeng has abundant tourism resource, the major scenic spots include the Iron Tower, the Dragon Pavilion, Xiangguo Monastery, etc, and the newly constructed Imperial Street of Song Capital, Garden Landscape in Qingming Festival at Bian River, Tianbo Residence of Yang's Family built after the architecture style of Northern Song Dynasty, reappear the prosperity scene of the ancient capital. The local specialties are Kaifeng watermelon, Lankao bean curd, Zhuxianzhen dried bean curd, Kaifeng steamed pie, Kaifeng embroidery, Zhuxianzhen New Year Pictures. These scenic spots attract abundant tourists at home and abroad. During recent years, with the rapid development of tourism industry in Kaifeng, urban ecosystem is endangered by the large-scale tourism. We evaluate ecological safety condition of Kaifeng from 2001 to 2010 in this paper.

To develop urban ecological safety evaluation, the first step is to establish a compound fuzzy matter-element. According to (1), we take urban ecological safety conditions from 2001 to 2010 as the ten things and the twenty indexes as characters. Then we establish a compound fuzzy matter-element. The second step is to calculate safety exponents of indexes. Then we obtain a standard fuzzy matter-element matrix. The third step is to endow indexes weights. The fourth step is to calculate total exponent of urban ecological safety. According to (19), we calculate total exponents of urban ecological safety in the ten years (as shown in Table 3).

Table 3. Ecological Safety Evaluation Result of Kaifeng City

Year	Total safety exponent	Safety grade
2001	5.614	Critically safe
2002	5.494	Critically safe
2003	5.433	Critically safe
2004	5.307	Critically safe
2005	5.089	Critically safe
2006	4.905	Critically safe
2007	4.871	Critically safe
2008	4.784	Critically safe
2009	4.622	Critically safe
2010	4.457	Critically safe

3.2. Suggestions on Strengthening Ecological Construction

The first countmeasure is to strengthen ecological safety consciousness. Managers of scenic areas should carry out necessary education and training on the workers and help them establish sustainable idea and work method. Managers should also implement tourism environmental auditing regime and regard the change of ecological environment as an important evidence to appraise cadres. In addition, concerned agencies should carry out national ecological education (especially teenagers and workers), so as to train ecological consciousness and raise educational qualities of the residents.

The second countmeasure is to change development model of tourism industry. Presently development model of tourism industry of Kaifeng city is extensive. This means that the tourism industry develops at the cost of resource exhaustion and environmental pollution. Its prominent characteristic is the one-side stress on the growth of tourist amount and tourism income and the ignorance of tourism quality degradation and environmental pollution. Therefore, the extensive development model of tourism industry goes back on the principle and the requirement of sustainable development and must be changed. We must follow the theory of environmental economy, strengthen the research and application of the valuation of tourism resource and environment, and bring the cost of resource and environment into the input-output system of tourism industry. The aim is to reflect the actual economic, social and ecological benefits of tourism industry and to promote the intensive development model of tourism industry.

The third countmeasure is to attach importance to tourist functional distribution and fix optimum ecological capacity. Concerned departments can divide scenic spots of Kaifeng city into several areas, including the Iron Tower Area, the Great Xiangguo Temple Area, the Dragon Pavilion Area, the Lord Bao's Temple Area, the Garden Landscape Area in Qingming Festival at Bian River, the Imperial Street Area in the Capital City of Song Dynasty. They should calculate ecological niche of tourists, animals and plants of each scenic spot according to ecological niche principle. They can estimate the dynamic change of tourist amount combing with the characteristic of different seasons and calculate ecological capacity of each scenic spot. They should also take some measures to guarantee the implementation of tourism capacity [23].

The fourth countmeasure is to carry out ecological monitoring and recovery. Concerned departments should carry out environmental monitoring on scenic spots at regular time in virtue of advanced monitoring instruments and scientific monitoring methods. They should also carry out environmental impact assessment and environmental auditing and calculate environmental carrying capacity. In addition, they should dispose tourism dustbins in virtue of traditional and modern high-technologies.

4. Conclusion

The paper develops a study on ecological safety evaluation of Kaifeng city. The results show ecological safety condition of Kaifeng is unsatisfactory and needs to be improved. The paper also puts forward suggestions on strengthening ecological construction of Kaifeng city. In the study, classification standard of evaluation index system should be further studied.

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