

Early-warning Analysis for Carrying Capacity in Nandaihe International Amusement Centre Based on Fuzzy Inference and Gray Forecasting

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Abstract—Nandaihe international amusement centre spot as an example is analyzed in this paper. The paper presents a method based on fuzzy inference and gray forecasting, indexes of tourism environment carrying capacity in scenic spots is established, extract fuzzy rules based on historical data, simulate the situation of tourism environment carrying capacity based on fuzzy inference, gray forecasting model is built for single feature index respectively, and various models are combined in system state formula to forecast, then the forecasting result is used to early-warning with the fuzzy inference model. At last, the method designed is effective.

Keywords—Fuzzy Inference; Gray Forecasting; Early-warning Model; Carrying Capacity

I. INTRODUCTION

The tourism environment is the basic conditions for tourism survival and sustainable development. With the development of China's tourism industry, tourism demand rapid expansion, but most of the tourism attractions in the original base is relatively weak, tourist holiday travel is relatively concentrated, and the uneven spatial distribution, resulting in problems of supply and demand, tourism activities on the negative impact of the environment has become increasingly prominent. To achieve the sustainable development of tourism attractions, domestic and foreign scholars in recent years have some research in the early warning of tourist attractions, provide the basis of scientific decision-making for the scenic managers [1]. There are lots of empirical knowledge in the warning theory of tourism field, there are some differences in different types of early warning indicators, and tourism activities is seasonal and random fluctuations, how to select scientific and reasonable indicators and to minimize the influence of human factors in early warning analysis is one of the urgent problem in tourism environment early warning research.

To make the right warning of tourism environment carrying capacity is difficult, because the scenic operating data is lacked and incomplete, which mostly non-linear relationship of the historical data is difficult to predict. On the other hand, the alarm threshold is difficult to determine, since academia is not a unified standard. The system based on gray system theory is studied which the partial information is known. Continuous gray differential function is used for gray prediction model by anglicizing and making predictions for development and changes of the system.

The early-warning model of tourism environment carrying capacity has a high complexity and nonlinearity, while the previous model in traditional sense paid more attention to the linear research and existed large errors. How to research the nonlinear in early-warning systems of the tourism environment carrying capacity and how to apply expert knowledge to the study of the early-warning systems of tourism environment carrying capacity need to solve urgently. At present, for highly complex nonlinear system of tourism environment carrying capacity, intelligent algorithm can simplify the model and obtain good optimization results. In reference [2], BP neural network is a good attempt on early-warning systems of sustainable tourism development. Fuzzy inference system adapts to the nonlinear system that doesn't get an accuracy mathematical model and has uncertain factor. In this paper, the fuzzy inference is introduced into the process of the tourism environment carrying capacity to deal with nonlinearity and uncertainty, indexes of early-warning system of carrying capacity in scenic spots is established, extract fuzzy rules based on historical data, gray forecasting model is built for single feature index respectively, and various models are combined in system state formula to forecast, then the forecasting result is used to early-warning with the fuzzy inference model. At last, an example proves that the early-warning model designed is effective [3].

Nandaihe Resort is located in south-east of Qinhuangdao City, Hebei Province, paralleling with the famous summer resort—Beidaihe, a bridge connected with a coastline of 17.5 kilometers, the total area is 20 square kilometers. Since the Nandaihe international entertainment center is opened up, caused a "Nandaihe Tourism boom" quickly. Economic benefits are from 53 million yuan in 2006, rising to \$ 1.15 billion yuan in 2011. Tourist quantity was 110.81 million in 2005, increasing to 240.68 million in 2011. Especially since 2008, the lack of coordination of the tourism environment carrying capacity and tourist quantity gradually revealed. Qinhuangdao is a temperate monsoon climate; the number of tourists is increased significantly in May to October. The tourist quantity comes to the peak in July and August and most of the city tourism spots are resulted in different levels of load carrying which is disadvantage to the sustainable tourist areas. In this paper, the fuzzy inference is introduced into the process of TECC to deal with nonlinearity and uncertainty, indexes of early-warning system of carrying capacity in scenic spots is established, extract fuzzy rules

based on historical data, gray forecasting model is built for single feature index respectively, and various models are combined in system state formula to forecast, then the forecasting result is used to early-warning with the fuzzy inference model. An example proves that the model designed is effective.

II. INDEX ABOUT TECC OF NANDAIHE INTERNATIONAL AMUSEMENT CENTRE

Due to the complexity of the tourism environment system, which involves many factors, the experts of domestic and foreign do not form a single authoritative definition to the tourism environment carrying capacity.

Firstly, based on system analysis and reasonable comprehensive of the selected factors that affect the TECC, this paper uses method of experts investigate and selects warning indicators and important limiting factor of TECC. Secondly, this paper combines with the opinions of experts, visits and monitors the related early-warning indicators. Finally, removes some relatively small impact factors in traditional TECC index, and complements the index appropriately, respectively include the natural environment carrying capacity (F1), economic environment carrying capacity (F2) and social environment carrying capacity (F3), where x_1, x_2, \dots, x_{13} is corresponding base indicators [1,2], and this paper establishes the early-warning indicator system, shown in Table 1.

TABLE I. INDEX OF THE TOURISM ENVIRONMENT CARRYING CAPACITY

F1	x_1 : ecological environment carrying capacity	
	x_2 : tourism resources space carrying capacity	
F2	F21: Infrastructure carrying capacity	x_3 : water facilities carrying capacity
		x_4 : power facilities carrying capacity
		x_5 : communication carrying capacity
		x_6 : transport carrying capacity
	F22: tourism service facilities carrying capacity	x_7 : accommodation carrying capacity
		x_8 : dining facilities carrying capacity
		x_9 : recreational carrying capacity
		x_{10} : shopping facilities carrying capacity
		x_{11} : carrying capacity of the management level
		x_{12} : capacity of local residents mental endurance situation
		x_{13} : tourism aesthetic perception carrying capacity

In this paper, the fuzzy reasoning method is adopted for TECC which is the Nandaihe international amuse center in 2012 July, their specific input data collected are based on the Survey Method. Tourism environment carrying rate (TECR) that reflects the using of TECC is defined the relationship of tourist quantity (TQ) and TECC.

$$TECR = \frac{TQ}{TECC} \quad (1)$$

According to the different levels of TECC, set the warning interval Y_i , When TECC is in “Weak-load conditions”, shows the situation where environment has been protected, but the economic benefits of tourism has not been fully exploited; When the utilization degree of the TECC is in the range of $[y_a, y_b)$, shows that the economic benefits are guaranteed on the basis of the protection of the environment; When the utilization degree of the tourism environment is in the $[y_b, y_c)$ interval, shows that tourism environment is damaged in different degrees; If the utilization degree of the tourism environment is in the interval $[y_c, 1]$, shows that the tourism environment is highly overloaded, as shown in Table 2.

TABLE II. WARNING SIGNAL TABLE

(Y_i)	$[0, y_a)$	$[y_a, y_b)$	$[y_b, y_c)$	$[y_c, 1]$
<i>Utilization state</i>	<i>Weak</i>	<i>Normal</i>	<i>Low</i>	<i>High</i>
alarm level	First	None	Second	Third

Established a system of early-warning indicators, based on these indicators can generate fuzzy rules for fuzzy inference, there are two ways, first using expert knowledge to generate fuzzy inference rules, the second using various indicators of historical data to generate a fuzzy inference rules. The fuzzy inference rules generated by the expert knowledge have human factors, in this paper, the second way is adopted.

III. GENERATION OF FUZZY INFERENCE RULES

Using fuzzy inference rules, assuming $\{U_1, U_2, \dots, U_{13}\}$ is the range for the basic indicators $\{x_1, x_2, \dots, x_{13}\}$ in the system of early-warning indicators, where $U_i = [x_i^-, x_i^+]$, $i = 1, 2, \dots, 13$, Y is the early-warning target variable, its domain is $[0, 1]$. The general form of fuzzy inference rules is:

If x_1 is A_1 and x_2 is A_2 and x_{13} is A_{13} then y is B ,

where $A_i \in U_i, B \in [0, 1]$

$(x_1^1, x_2^1, \dots, x_{13}^1; y_1), (x_1^2, x_2^2, \dots, x_{13}^2; y_2), \dots,$

$(x_1^m, x_2^m, \dots, x_{13}^m; y_m)$, the learning steps is as follows:

Firstly, each interval corresponds to a fuzzy set $A_i^j (j = 1, 2, \dots, N_i)$, can be membership functions of arbitrary shape. In order to calculate simple, membership function is taken as the triangle. Similarly, the four fuzzy sets are defined in $[0, 1]$, the membership function is still taken as a triangle.

Secondly, for the p -th input and output data $(x_1^p, x_2^p, \dots, x_{13}^p; y_p)$, calculated on a different interval $x_1^p, x_2^p, \dots, x_{13}^p$ and y_p corresponds to the degree of membership, data $x_1^p, x_2^p, \dots, x_{13}^p$ and y_p are located in the maximum degree of the corresponding interval. m input-output pairs can produce m fuzzy rules.

Thirdly, determine the strength of the fuzzy rules. Because the number of input and output data are usually a lot, and each data produce a rule. Rules are likely to generate conflict. To avoid conflicts, give the strength for each rule, make only one rule with the greatest strength in a conflict group. This will not only resolve the conflict, and the number of rules is greatly reduced. The definition of rule strength is seen in [4].

At last, the rules are generated which does not conflict with other rules, and the rules of conflict groups with the greatest strength. Using the singleton fuzzifier, the product inference engine and the center-average defuzzifier based on the fuzzy rule base created, expressed as follows:

$$y = f(x) = \frac{\sum_{l=1}^M \bar{y}^l (\prod_{i=1}^{13} \mu_{A_i}^l(x_i))}{\sum_{l=1}^M (\prod_{i=1}^{13} \mu_{A_i}^l(x_i))} \quad (2)$$

Where \bar{y}^l is the center of the fuzzy set B, M is the number of fuzzy rules in the rule base, $x=(x_1, x_2, \dots, x_{13})$. Base indicators $\{x_1, x_2, \dots, x_{13}\}$ in the early warning system is denoted by $x_n(t)$, where $n \in [1, 13]$, t denotes the time, so select the value of the k-based indicators can constitute the $n \times k$ dimension feature state space[5].

$$\begin{bmatrix} x_1(1) & x_1(2) & \cdots & x_1(k) \\ x_2(1) & x_2(2) & \cdots & x_2(k) \\ \vdots & \vdots & \ddots & \vdots \\ x_n(1) & x_n(2) & \cdots & x_n(k) \end{bmatrix} \quad (3)$$

Gray prediction model GM (1,1) is used for a single time series prediction which can not reflect the variable interaction, the gray GM(1,n) model can describe the relationship between the variables, but generally not used for prediction.

To establish the GM (1,1) gray model for all indicators in TECC:

$$\frac{dx_i^{(1)}}{dt} + a_i x_i^{(1)} = u_i \quad (4)$$

Solving based on the least squares method:

$$B_i = \begin{bmatrix} -\frac{1}{2}(x_i^{(1)}(1) + x_i^{(1)}(2)) & 1 \\ -\frac{1}{2}(x_i^{(1)}(2) + x_i^{(1)}(3)) & 1 \\ \vdots & \vdots \\ -\frac{1}{2}(x_i^{(1)}(k-1) + x_i^{(1)}(k)) & 1 \end{bmatrix} \quad (5)$$

$$Y_i = [x_i^{(0)}(2), x_i^{(0)}(3), \dots, x_i^{(0)}(k)]^T \quad (6)$$

$$x_i^{(1)}(k) = \sum_{m=1}^k x_i^{(0)}(m) \quad (7)$$

Early warning indicators $x_i^{(0)}$ ($i = 1, 2, \dots, n$) may constitute the n multi-differential equations, transform into the standard form, we can obtain the state equation of system forecast model, the ultimate predictive result is

$$x_i^{(1)}(k+1) = \left[x_i^{(0)}(1) - \frac{u_i}{a_i} \right] e^{-a_i k} + \frac{u_i}{a_i} \quad (8)$$

$$x_i^{(0)}(k+1) = x_i^{(1)}(k+1) - x_i^{(1)}(k) \quad (9)$$

IV. EMPIRICAL RESEARCH

Monitoring levels Y of the Nandaihe international entertainment center. TECC are divided into four intervals, namely $Y = \{Y_1, Y_2, Y_3, Y_4\}$, Y_1 is [0,0.4) which is corresponded to “weak-load conditions”, Y_2 is [0.4,0.7) which is corresponded to “normal conditions”, Y_3 is [0.7,0.9) which is corresponded to “low degree overload”, Y_4 is [0.9,1] which is corresponded to “high degree overload”. The data in Table 3 of the 2006 to 2011 is used to grey predict by fuzzy reasoning method which the result is 0.7131 in 2012 July, concludes that the TECC is in a low overload state [6]

In order to a better comparative study where the utilization of TECC is generated by the fuzzy inference method. The fuzzy evaluation method mentioned in is adopted to calculate the utilization of TECC. Develop 60 questionnaires for the scenic in July 2012, the investigation objects include: 20 scenic spots managers, the selection of managers related to the area within multiple management; 20 person which is familiar with the Qinhuangdao tourism development, including the leadership of Qinhuangdao Tourism Municipal Bureau(2 people), the leadership of Qinhuangdao City in the infrastructure sector(2 people), the personnel of tourism-related enterprises (such as: hotels, travel agencies, shopping and entertainment, etc.) (10 people), university experts (6 people), tourists in the Nandaihe international entertainment center scenic spots (20 people). Finally obtain the warning state of tourism environment carrying capacity utilization in July is 0.7082 which is very close to 0.7131 by fuzzy reasoning method. The result illustrates the early-warning model designed is feasible and effective.

V. CONCLUSION

Early-warning system of tourism environment carrying capacity is a highly complex nonlinear system and it is very difficult to establish a precise mathematical model. In this

paper, the fuzzy reasoning method and grey forecasting is adopted to deal with this system. Fuzzy inference method is used to early-warning of Nandaihe International entertainment center based on the proposed evaluation index of tourism environment carrying capacity system. Nandaihe international amusement centre spot as an example proves that the early-warning model designed is feasible and effective [7].

ACKNOWLEDGMENT

This article is funded by the general project of the Ministry of Education, Humanities and Social Sciences (Western and Frontier Areas Projects) (11XJC630016), The Youth Foundation of National (10CGL046), Gansu Province Natural Science Fund Project (1112RJZA010) and Training Program at the Lanzhou University of Technology HongLiu Young Teachers (Q201213) and (Q201210).

TABLE III. STATISTICS AND FORECAST DATA OF TOURISM ENVIRONMENT CARRYING CAPACITY IN NANDAIHE INTERNATIONAL AMUSEMENT CENTRE

July Years	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}
2006	0.461	0.585	0.311	0.341	0.336	0.617	0.524	0.459	0.429	0.569	0.548	0.228	0.669
2007	0.552	0.651	0.345	0.318	0.425	0.531	0.553	0.568	0.557	0.614	0.586	0.326	0.656
2008	0.613	0.703	0.477	0.397	0.513	0.565	0.695	0.547	0.595	0.632	0.637	0.374	0.717
2009	0.627	0.667	0.452	0.453	0.588	0.734	0.672	0.634	0.667	0.656	0.723	0.447	0.753
2010	0.631	0.728	0.563	0.644	0.619	0.671	0.767	0.716	0.724	0.634	0.658	0.582	0.744
2011	0.655	0.726	0.647	0.595	0.632	0.788	0.735	0.803	0.733	0.658	0.714	0.563	0.802
The predictive value in 2012	0.671	0.731	0.611	0.574	0.648	0.813	0.751	0.812	0.741	0.662	0.723	0.572	0.811
The actual value in 2012	0.688	0.681	0.572	0.612	0.659	0.832	0.783	0.798	0.732	0.658	0.689	0.501	0.788
The predictive value in 2013	0.694	0.703	0.653	0.631	0.653	0.854	0.812	0.829	0.748	0.666	0.728	0.605	0.827

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