Establishment of Index System for Eco-city by Analytic Hierarchy Process

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Abstract

In recent years, with the rapid development of many cities in China and the massive increase of population, the problem of environmental pollution has brought great challenges to cities. The aim of the study is to establish an index system for eco-city in the developing process, taking qualitative and quantitative evaluation as the standard. The research result can reflect the development direction of eco-city construction and make city design meet the need of city sustainable development. Furthermore, it can be used as the basis for the development of eco-city system with Chinese characteristics.

Keywords： Analytic hierarchy process, Chinese characteristics, Eco-city

Introduction

In recent years, China has been becoming a world workshop and many Chinese cities are rapidly developing. Except for industrial pollution, with a huge number of farmers entering into cities to live and work, urban population rises sharply and the cities expand on a large scale. The destruction of ecological environment and frequent natural disasters have posed great challenges to the sustainable development of cities. Therefore, the traditional urban construction mode has been unable to meet the developing needs of cities at present. Under this background, eco-city construction has become the demands of city development. Through real protection of environment acts can only be realised with the will and belief of local people in the project, Environmental Plans are important means for legalisation and announcement of environmental preservation decisions [1]. According to the classification of Chinese urban functions, this study proposed a new evaluation system based on the division of eco-city regional types to further promote the process of Chinese eco-city construction from the economic, social and natural perspectives.

Literature Review

In eco-city studies, evaluation index system can not only reflect the state and nature of eco-city system, but also monitor the process of system development, analyze the routes, policies and guidelines of the eco-city construction in each city, and improve the construction efficiency of eco city. Therefore, how to establish a scientific and rigorous evaluation index system has always been the focus and difficult which scholars paid close attention to. Through the continuous exploration of scholars at home and abroad, the evaluation index system of eco city has become increasingly perfect and it has played a huge role in guiding eco-city construction. However, due to the huge regional differences and the complexity of eco-city construction in China, there are still many imperfections in the current evaluation index system. Eco-city construction is a complex project, so, we can promote its process in China only by establishing a set of evaluation system with more regional features [2].

A. Eco city

Eco city is a kind of economically efficient human settlements with ecological benign circulation, which is based on ecological principles and constructed by studying the society-economy-nature complex ecosystem and applying modern scientific and technological means such as ecological, social and systematic engineering. In eco city, people and nature coexist in harmony and mutualistic symbiosis to make efficient utilization of materials, energy and information, fully integrate technology and nature, maximize human creativity and productivity, and thus protect the physical and mental health of residents and environment quality to the maximum extent [3].

B. Index System for Eco City

"Eco city" is a complex ecosystem with the natures of natural harmony, social justice and economic efficiency based on ecological principles. The establishment of eco-city index system can make the city change from an abstract and complicated system to a quantifiable and operable specific index. It enables urban management and decision-making departments to regularly understand the current stage of development and its gap with development goals, while providing decision makers and the public with an effective information tool to know and understand the course of eco-city development. On the basis of integrating the previous research results, the specific hierarchy of framework, explanation and characteristic description for the establishment of eco-city index system were listed in Table 1.

TABLE I
ARCHITECTURE DIAGRAM ON KEY FACTOR FRAMEWORK OF ECO CITY INDEX SYSTEM FOR ECO CITY

The second level of framework	The third level of framework	Explanation and characteristic description
1. Economic development	1.1 Economic strength	Per capita GDP, annual growth rate of GDP
	1.2 Economic benefits	Unit energy consumption of GDP, unit water

	1.3 Economic structure	consumption of GDP The proportion of the third induxtry to GDP, the ratio of high-tech products to total industrial output value
2. Social relationship	2.1 Demographic indexes	Population density, per capita life expectancy, growth rate of natural population
	2.2 Infrastructure	Urban per capita housing area, urban per capita area
	2.3Social security	The proportion of unemployment rate and labor insurance to wages
3.Ecological environment The second level of framework	3.1Environmental pollutants	The emissions of CO, NO2 and O3
	3.2 Biodiversity	The number of protected areas and protected wild birds
	3.3 Urban greening	The rate of forest coverage, per capita public green area

At present, the carrying capacity of resources and environment in China is approaching the limit, so, the traditional development mode of high investment, high consumption and high pollution needs to be changed urgently. The extensive development mode not only overwhelms Chinese resources and energy resources, but also causes striking environmental problems such as haze, water pollution and so on. At the same time, the deterioration of ecological environment and its impact on people's health have become the concerns of China construction [5]. There is a contradiction between people's expectation of a better living environment and the current environmental problems, it is urgent to establish eco city with Chinese characteristics.

Methods

Analytic hierarchy process (AHP) was developed by Thomas L. Saaty and it is mainly applied to the decision problems with uncertainty and multiple evaluation criteria [6]. Decision problems occur not only in individuals, but also in social organizations, local and central governments. They are always confronted with a wide range of problems requiring decision making. In multi-criteria decision-making methods, AHP systematizes the complex problems, decomposes hierarchy from different levels and provide the routine for comprehensive evaluation through quantitative calculation [7]. The support system which was applied for decision making in sustainable land planning has obtained ideal research achievements [8]. The steps and measurement methods of AHP were shown below:

A. Calculation program

Step 1: Problem definition

Arrange and summarize related information on decision problems, and find out the system elements that can affect decision problems.

Step 2: Establishment of pairwise comparison matrix

According to Saaty's (1980) recommendation [9], the rating scale was divided into 9 scales, then pairwise comparison was conducted. If pairwise comparison matrix A was $n \cdot n$, only the rating value of $n(n\text{-}1)/2$ needed to be calculated, and the pairwise comparison of the evalution criteria a_i and a_j (i,j=1,2,3…n;$i \neq j$) was carried out to obtain the following pairwise comparison matrix A [10], which was shown in equation(1):

$$A=[a_{ij}]=\begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \cdots & \cdots & & \cdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \quad (1)$$

If the weight value of a factor is known, it can also be expressed as equation (2):

$$A=[a_{ij}]=\begin{bmatrix} 1 & a_{12} & \cdots a_{1n} \\ 1/a_{12} & 1 & \cdots a_{2n} \\ \cdots & \cdots & \cdots \\ 1/a_{1n} & 1/a_{2n} & \cdots 1 \end{bmatrix}=\begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \cdots & \cdots & & \cdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix} \quad (2)$$

There into,

$$A_{ij}=w_i/w_j,\ a_{ij}=1/a_{ij},\ w=[w_1 \quad w_2 \quad \cdots \quad w_n]=\begin{bmatrix} w_1 \\ w_2 \\ \cdots \\ w_n \end{bmatrix} \quad (3)$$

w_{ij}: the weight of factor i; i=1,2,...,n

a_{ij}: the ratio of relative importance between two elements, i=1,2,...,n; j=1,2,...,n

$$Wi=\frac{\left(\sum_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}},\ i,j=1,2...n \quad (4)$$

Step3: Calculation of eigenvalue and eigenvector

Assuming that there are n evaluation criteria in hierarchical decision structure, that is, C_1, $C_2...C_n$, its relative weigh is W_1, $W_2,...W_n$ in sequence. The equation $AW=\lambda W$ shows that w is the principal eigenvector with eigenvalue of λ of the pairing matrix A $(W_1,W_2,...W_n)$T. Pairwise comparison matrix A is a subjective judgment matrix formed by experts for pairwise comparison of criteria. The eigenvector W with the largest eigenvalue can be calculated from the level analysis to satisfy $A \cdot W=\lambda_{max} \cdot W$. Consistency index ($C.I.$) can be obtained by using λmax. If $C.I.$<0.1, it can meet the criteria for judging consistency, as shown in equation (4).

Step 4: Consistency check

In order to ensure the satisfactory consistency of the decision maker's judgment, consistency check must be performed to overcome the inconsistency problem in pairwise comparison matrix, which may be due to the difference of selected base or the inconsistency of the answer members. When consistency is not in line with requirements, it shows that there are relative problems between level elements. Saaty suggests that C.I. < 0.1 is optimum, and the maximum allowable error is C.I. < 0.2, so that consistency can be guaranteed [9], as shown in equation (5).

Consistence index (C.I.)

$$C.I=\frac{\lambda_{max}-n}{n-1} \quad (5)$$

In the equation, λ_{max} denotes the largest eigenvalue of matrix A, n denotes the number of evaluation elements, as shown in equation (6) -(8).

$$A \cdot W=\lambda_{max} \cdot W \quad (6)$$

$$A=\begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \cdots & \cdots & & \cdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \cdots \\ w_n \end{bmatrix} = \begin{bmatrix} w_1' \\ w_2' \\ \cdots \\ w_n' \end{bmatrix} \quad (7)$$

There into ,

$$\lambda_{max}=\frac{1}{n}\left(\frac{w_1}{w_1}+\frac{w_2}{w_2}+\ldots\frac{w_n}{w_n}\right) \quad (8)$$

In a matrix of the same order, the ratio of *C.I.* to *R. I.* is consistency ration (*C.R.*), as shown in equation (9).

$$C.R=\frac{C.I}{R.I} \quad (9)$$

If $C.R.<0.1$, the consistency of the matrix is satisfactory.

Results and discussion

The purpose of the expert questionnaire was to establish the indexes for building eco city and to evaluate the weight of the indexes needed for index system. According to the inspiration from the case studies related to the present study, appropriate decision strategies were selected. Moreover, the relevant professional groups, government officials, environmental and urban researchers were invited to take part in the questionnaire [11]. Firstly, the consistency ration of the results obtained from the questionnaire was calculated to judge whether the decision makers have consistency in pairwise comparison. Then, the weight of each framework was obtained by taking the geometric average values. The results (Table 2) showed that the weight of ecological environment framework was the highest (0.644), and in the comprehensive weight of evaluation indexes, the weight of ecological greening was the highest (0.350), followed by biodiversity (0.188) and environmental pollutants (0.106).

TABLE II
WEIGHT ANALYSIS ON THE EVALUATION SYSTEM OF URBAN ECOLOGICAL INDEXES

Framework	The weight of framewok	Evaluation indexes	The weight of indexes	Comprehensive weight
C1Economic framework	0.206	C1-1 Economic strength	0.212	0.044
		C1-2 Eonomic benefit	0.495	0.102
		C1-3 Economic structure	0.293	0.060
C2Social framework	0.150	C2-1 Demographic index	0.204	0.031
		C2-2 Infrastructure	0.528	0.079
		C2-3 Social security	0.268	0.040
C3Ecological environment framework	0.644	C3-1 Environmental pollutants	0.164	0.106
		C3-2 Biodiversity	0.292	0.188
		C3-3 City greening	0.544	0.350

Conclusion

This study was aimed at the establishment of eco-city indexes. The results indicated that the key evaluation indexes could be found to assess the relevant indexes of eco-city construction by combing professional knowledge, understanding of related laws, familiarity with the current trend of ecological environment. On the evaluation criteria of each dimension, the geometric average values were obtained through the results of expert questionnaire, and the expert consensus was synthesized and verified item by item. The "ecological environment" showed the highest weight (0.644) in research result framework, followed by the "economic" (0.206). In addition, the highest comprehensive weight in assessing overall evaluation indexes was urban greening (0.35). Therefore, in the development of the eco city with Chinese characteristics, ecological environment is the first to be considered, and then attentions should be paid on the construction of urban greening under the background of the existing urban green environment. And more emphasis on the construction and protection of wetlands should also be paid when opening parks and green lands, thus avoiding the cultivation of single species and enriching biodiversity. In China under construction, the economy and productive forces are still in developing, construction of eco city is not the only aim we will pursue, people's basic life should be in the first, followed by the quality of life. The impact of economic development on ecological environment is a problem which Chinese eco city must face up to. The evaluation system established in the present study can provide reference for Chinese urban development.

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