Journal of Coastal Research	SI	94	78–82	Coconut Creek, Florida	2019

Evaluating Green City Development in Coastal Regions of East China

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ABSTRACT

Li J.L., 2019. Evaluating green city developments in coastal regions of East China. *In:* Gong, D.; Zhu, H., and Liu, R. (eds.), *Selected Topics in Coastal Research: Engineering, Industry, Economy, and Sustainable Development. Journal of Coastal Research*, Special Issue No. 94, pp. 78–82. Coconut Creek (Florida), ISSN 0749-0208.

In the face of economic globalization and strained resources, the development of green economies is inevitable. The construction of green cities is an important aspect of green economic development and its connotations. Accelerating the construction of green cities is a growing trend. The construction of a green city is a complex integrated project and requires a comprehensive evaluation index system and a scientific evaluation model. In this study that fully implement the plan for promoting political, economic, social, cultural, and ecological progress. The analytic process and evaluation methods, including the frequency statistics method, theoretical analysis, and expert consultation, were used to construct the evaluation system and the green city multi-level fuzzy comprehensive evaluation model. Taking the coastal city of Shanghai in East China as an example, this paper evaluates the degree of low-carbon green development in Shanghai, carries out empirical research, and promotes the low-carbon green development of coastal cities.

ADDITIONAL INDEX WORDS: *Green city, East China coastal cities, evaluation system, comprehensive evaluation model.*

INTRODUCTION

Today, the development of green economies has become a necessity in global economic development. The construction of green cities is an inevitable process in green economic development and its connotation. Green cities have become a worldwide trend in city construction, including China's urban development. A green city is a systematic and complex structure. To promote the construction of green cities, it is necessary to have a distinct, scientific, and reasonable evaluation index system with structural integrity. As a mega-economic center city, Shanghai, a coastal city in East China, evaluates its low-carbon green development and promotes its low-carbon green development.

CONSTRUCTION OF A GREEN CITY EVALUATION SYSTEM

The development of green economies and the increase in green city construction has become a global trend, gaining both domestic and international attention. In domestic and foreign literatures, there are many studies on the evaluation of low-carbon green cities, but the overall evaluation is not very much from the perspective of system theory. Especially for coastal cities, the evaluation of low-carbon green development is relatively rare. However, there is no scientific system to comprehensively evaluate the construction of green city cities, which requires further research and exploration.

Principles for Building a Green City Evaluation System

The construction of a green city is a goal and function of complex integrated engineering. It generally comprises five aspects: democratic politics, a highly effective economy, a harmonious society, a healthy environment, and an innovative culture. These five aspects are interrelated, and influence and restrict each other, forming a complex "five in one" structure, as shown in Figure 1 below.

Green cities are complex systems. To promote the rapid development of green cities, it is necessary to build a distinct, structurally sound, scientific, and reasonable evaluation index system. The construction of green cities should follow systematic, comprehensive, dynamic, operable, and comparable principles. The systemic principle refers to developing a multiple indicator organism, i.e., when selecting an evaluation index, it must consider the political, economic, social, cultural, and environmental development indexes. These indexes are interrelated and together promote the development of green cities. The overall principle is to select indexes from a scale, structure, speed, efficiency, ability, and per capita perspective to have a comprehensive choice. The dynamic principle refers to developing an index system to reflect the dynamic changes in green city construction and related development trends.

Steps for Building a Green City Evaluation System

The analytic hierarchy process (AHP) method was used for the quantitative evaluation of green cities. In this process, a green city system and its subsystems are divided into several factors, which are then used to build the evaluation index system. The first step in this process is theoretical research. Suitable statistical theories and methods must be selected to determine the present situation regarding evaluation index systems for green cities in both domestic and foreign relevant fields. The second step involves choosing the index system. For this purpose, theoretical analysis, frequency statistics, and expert consultation were utilized. The final step is the optimization of the index system. The index system undergoes

DOI: 10.2112/SI94-014.1 received 26 January 2019; accepted in revision 21 March 2019.
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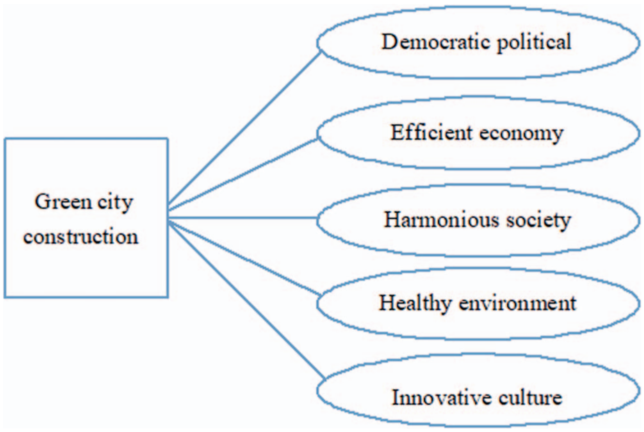

Figure 1. Chart of green city construction.

preliminary selection, further selection, and then optimization to make it more scientific and reasonable. Optimization includes single-parameter optimization and overall optimization of the index system to ensure its scientific validity as a whole.

Establishment of a Green City Evaluation Index System

Green cities are a sustainable development innovation that has political, economic, social, environmental, and cultural implications. The green economy and environment, as a unified whole, is shown in Figure 2. A green city is a combination of five subsystems: a democratic political system, a highly effective economic system, a harmonious social system, a healthy environmental system, and an innovative cultural system. Mutual relationships exist between each subsystem and these subsystems mutually influence and restrict each other in a complex "five in one" system.

The green city index system presented in this paper was derived from both domestic and international green evaluation indexes, which were designed based on political, economic, social, cultural, and environmental factors. This evaluation system comprises three levels: the target, criterion, and index layers, all of which examine the development of green city systems over time. It is on the space that reflects the overall layout, the development scale, in number on quality reflects the development of ability and potential. It includes 50 indexes, including 11 social indicators, 9 political indicators, 9 economic indicators, 10 cultural indicators, and 11 environmental indicators. This index system may help to safely design the development of green cities' five subsystems, to determine the advantages and disadvantages of urban development, and to ensure the optimal construction of green cities along the five aspects of emphasis. In practice, the index system was chosen based on the availability of data and practical feasibility. The index system built in this study is not perfect and requires further supplementation and research.

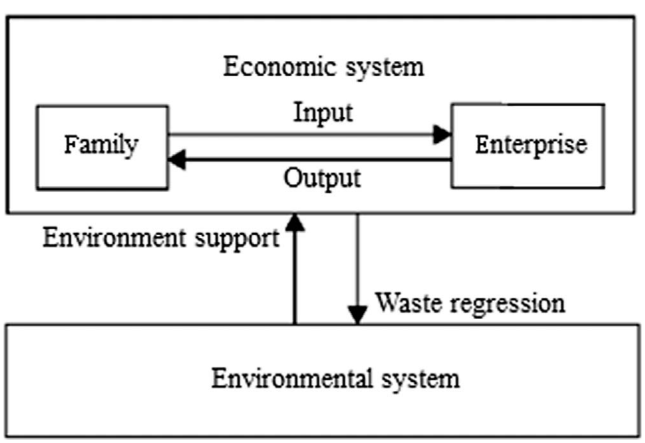

Figure 2. Economy and environment as a unified whole.

CONSTRUCTION OF A COMPREHENSIVE GREEN CITY EVALUATION MODEL

In this paper, the method of fuzzy comprehensive evaluation is used to transform qualitative evaluation into quantitative evaluation according to the theory of membership degree of fuzzy mathematics. Combined with the analytic hierarchy process, this paper makes an overall evaluation of the urban low-carbon greenness.

Fuzzy Comprehensive Evaluation Theory and Model

Fuzzy comprehensive evaluation firstly determines the evaluation factors and grades, then establishes the evaluation matrix and determines the weight, and finally carries on the fuzzy synthesis and makes the decision.

Determine the Evaluation Factors and Evaluation Level

$U = \{u_1, u_2, \ldots, u_m\}$ represents m kinds of evaluation objects, which describe the aspects from which green cities can be evaluated. This m is the number of evaluation factors. $V = \{v_1, v_2, \ldots, v_m\}$ represents n kinds of decisions, referred to as evaluation levels. This n is the number of grades, ranging from 3 to 5.

Establish the Evaluation Matrix and Determine Weights

First, focusing on evaluation factors of single factor u_i $(i = 1, 2, \ldots, m)$ for a single evaluation and evaluation class factors from the u_i to v_j $(j = 1, 2, \ldots, n)$ membership r_{ij}, the ith factor of the single factor evaluation set u_i: $r_{ij} = (r_{i1}, r_{i2}, \ldots, r_{in})$ and the M factor were used to construct a general evaluation matrix R:

$$R = (r_{ij})_{m \times n} = \begin{pmatrix} r_{11}, r_{12}, \cdots, r_{1n} \\ r_{21}, r_{22}, \cdots, r_{2n} \\ \vdots \\ r_{m1}, r_{m2}, \cdots, r_{mn} \end{pmatrix} \quad (1)$$

Based on this matrix, starting from the factors in u_i, the membership of an object is rated as v_j $(i = 1,2,\ldots,m; j = 1,2,\ldots,n)$.

Second, the index weights had to be determined. This could be done using two common methods: One way is to use the number of empowerment, which is generally a subjective speculation with experience and with strong subjective intention. However, this could lead to an evaluation error of judgment. The second way is to use mathematical methods, such as the AHP method, to remain close to the objective facts.

Fuzzy Synthesis and Decision-Making

R in the different rows represents the evaluation, from the aspect of a single factor, of the various membership degrees of the fuzzy subsets. With A different line comprehensively, which can get the overall things for all levels of fuzzy subsets.

A fuzzy subset of V, $B=(b_1, b_2, \ldots, b_n)$ is introduced, known as a fuzzy evaluation, or decision set. Therefore,

$$B = A\,R. \tag{2}$$

B is calculated for each factor based on its comprehensive evaluation object status and hierarchical level, which is governed by the maximum membership degree principle, thus, obtaining the final evaluation results.

Constructing the Green City Evaluation Model

The evaluation method was used to constructs the evaluation model for green cities. Constructing green cities involves complex system engineering and a green city evaluation model should reflect the situation of its construction. For this purpose, based on the "five in one" structure of a green city, a theory for a multi-level fuzzy comprehensive green city evaluation model is proposed.

Determine the Evaluation Set

According to its attributes, the evaluation factors set, U, was divided into five subsets: $\{U_1, U_2, U_3, U_4, U_5\}$

Establish the Evaluation Index Set of Comments

$$V = \{V_1, V_2, V_3, V_4\} = \{\text{reconstruction, ascension, standard, good}\} \tag{3}$$

Based on the above analysis, the green city index comprises 50 functions and can be divided into four subsets: reconstruction, ascension, up to standard, and quality and the corresponding scores for these subsets are 1, 2, 3, and 4, respectively. The determination of each index classification standard varies due to the nature factor. This refers to the current situation of both domestic and foreign environments. According to the environment and social economy coordinated-development theory, every effort was made to quantify the standard values. For the qualitative index of the quantitative rating scale, the degree of the index reflects the nature of the green city and is divided into four grades, while the assignment quantitatively distinguishes the different evaluation levels.

Level of Fuzzy Comprehensive Evaluation

According to the level of fuzzy evaluation of each respective U_i, the evaluation is applied as follows. First, the single factor is evaluated to establish two U_i and V fuzzy mapping f: $U_i \rightarrow F(V)$. The R_f is induced by f fuzzy relations to obtain a single matrix, R_i. Second, the weight of each factor in the U_i, $a_i=(a_{i1}, a_{i2}, \ldots, a_{ik})$ is determined; here, $\sum_{j=1}^{k} a_{ij} = 1$. Third, by conducting composite matrix operations, the level ofcomprehensive evaluation is obtained as follows:

$$b_1 = a_1 \cdot R_1 = [b_{i1}, b_{i2}, \ldots, b_{in}],\ \text{one}(i = 1, 2, \ldots, k). \tag{4}$$

Secondary Fuzzy Comprehensive Evaluation

Each U_i element is evaluated using b_i as its single element as follows:

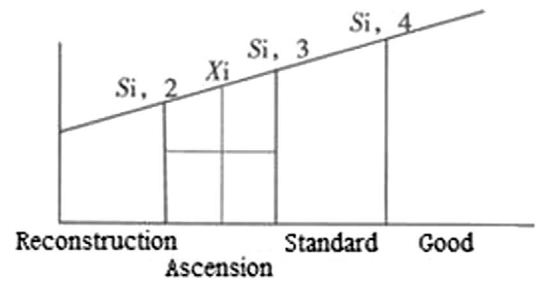

Figure 3. Membership function diagram.

$$R\begin{Bmatrix} b_1 \\ b_2 \\ \cdots \\ b_i \end{Bmatrix} = (b_{ij})_{k\times n} \tag{5}$$

This is the $U_i = \{u_1, u_2, \ldots, u_n\}$ single element evaluation matrix. Each U_i, as part of U, reflects some attribute of U. Based on the importance of their contribution, weight distribution is conducted, given by the following:

$$A = \{A_1, A_2, \ldots A_m\} \tag{6}$$

Thus, the secondary comprehensive evaluation $B=A \cdot R$ is obtained, in which A represents the weights of evaluation unit and B is the secondary comprehensive evaluation score.

Determination of Index Weights

The weighing value of the model involves determining the weighing values of the criterion and target layers. The rule layered weighted average method is used. Political, economic, social, environmental, and cultural factors are five important aspects of green city construction. Green city construction emphasizes the coordinated development of these five aspects of balance. Thus, the weighted average method is used, wherein the weight of each part of the set is 0.2, and the index weights of the index i is obtained as follows:

$$a_i = \frac{1}{m}\sum_{j=1}^{m} a_{ij},\ w = \frac{a_i}{\sum_{i=1}^{k} a_i} \tag{7}$$

Indicators of Membership

The indicators of membership degree are divided into two groups: the softer target membership degree and the developed membership degree. It is tough for the membership degree, it can be calculated according to the classification standard. Determining the classification standard first involves utilizing the current domestic popular and general evaluation index system of rules. Second, by using the most advanced international standards, a certain measure is determined.

Based on four standards, real data is divided into five ranges, as shown in Figure 3, with $S_{i,j}$ (j=1,2,3,4) comprising the four standard values for index i. The $X_i \in (S_{i,j}, S_{i,j+1})$, uses the distance of the measured values and standard values rather than the distance of the standard values, and is as close to the standard values of membership degree and $I_{i,j}$ (j=1,2,3,4). Thus, the membership degree of the piecewise function is as follows:

Table 1. *The classification table of green city degree.*

Classification standard	I (0-1.8)	II (1.8-2.8)	III (2.8-3.5)	III (3.5-4.0)
City green degree	Reconstruction	Ascension	Standard	Good

When $X_i \in (0, S_{i,1})$, then

$$I_{i,j} = 1, \text{ and } I_{i,j} = 0 (j \neq 1) \tag{8}$$

When $X_i \in (S_{i,j}, S_{i,j+1})$, it can only belong to j or j+1 (with $I_{i,j}I_{i,j+1}$), while the rest of the membership degree is 0, then

$$I_{i,j} = \left|\frac{X_i - S_{i,j}}{S_{i,j} - S_{i,j+1}}\right|, \text{ and } I_{i,j+1} = \left|\frac{X_i - S_{i,j+1}}{S_{i,j} - S_{i,j+1}}\right| \tag{9}$$

When $X_i \in (S_{i,4}, +\propto)$, then

$$I_{i,4} = 1, \text{ and } I_{i,j} = 0 (j \neq 4) \tag{10}$$

Determination of Green City Grade

The green city grade represents the degree of the secondary comprehensive evaluation score. Through standardization, these grades were determined based on the principle of the maximum membership degree evaluation level. The green city grade evaluation standards are presented in the following table:

EMPIRICAL RESEARCH

The theory of ecological carrying capacity refers to the self-balancing ability of an ecosystem. If the interference that a system has received is greater than a system's adjustment ability or carrying capacity, the system's balance will be destroyed. A region and city's sustainable development must be based on the complete and sustainable supply of resources and the long-term accommodation of the environment. The healthy development of a city requires a continuous supply of resources, while having sufficient environmental capacity to accommodate the emissions from urban development, all kinds of waste. In other words, the more comprehensive pressure exerted by a city's urban development, the lesser its urban ecological resources and environment carrying capacity will be. Thus, the urban development of a city should be limited to the scope of the elasticity of the urban ecological system, thereby not overloading the bearing limit of the ecosystem. The ecological carrying capacity theory is shown in Figure 4 below.

Shanghai is one of the coastal cities in East China. Shanghai is a coastal reform and opening-up area and a mega-economic center city. It is a high energy-consuming City lacking natural resources. Shanghai will encounter uncoordinated and unsustainable problems in its development process. Therefore, here should give full play to its advantages in science, technology, information and capital, and make the construction of a resource-saving society and an environment-friendly society an important goal of urban construction and development. Based on the decomposition of urban construction objectives and the Win-win Theory of production, life and ecology, this paper analyses the challenges and opportunities in the construction of low-carbon green city in Shanghai from the perspective of system theory, the development strategy and

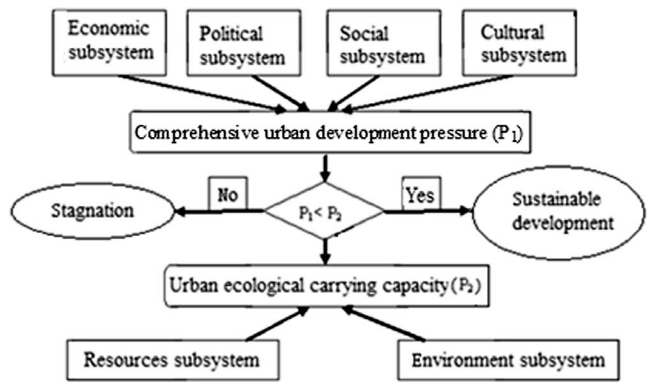

Figure 4. Diagram of the ecological carrying capacity theory.

management mode of low-carbon green city, and the strategic problems of Shanghai urban construction. According to PEST analysis method, the paper makes overall planning of politics, economy, environment, society, culture and so on. In terms of energy saving and emission reduction, this paper puts forward corresponding countermeasures from the aspects of concept, policy, system, talent, technology and industrial structure, and explores the development strategy of promoting urban construction with economic development and suiting for the construction of low-carbon green cities in Shanghai. Using this evaluation method to evaluate Shanghai's urban green development, Shanghai's urban low-carbon green degree grade is in IV, which shows that Shanghai's urban low-carbon green development is excellent. The Annual Evaluation Result Bulletin of Ecological Civilization Construction 2016 issued by the National Bureau of Statistics published the green development index of all provinces in 2016 for the first time, and the green development index and green life index of Shanghai ranked among the top five cities in China, which is consistent with the evaluation results. This shows the rationality and scientificity of the green city development evaluation.

CONCLUSIONS

The development of green economies is inevitable. Green cities are an important aspect of green economy development and have become an accelerating trend. Green city construction is a comprehensive project that considers political, economic, social, environmental, and cultural factors as a "five in one" system from the political, economic, social, cultural, and environmental design perspective. The AHP method and fuzzy comprehensive evaluation method were used to construct the evaluation system to establish a multi-level fuzzy evaluation model of green city. This evaluation of the green development of Shanghai, a coastal city in East China, is in line with the bulletin issued by the National Bureau of Statistics, which can verify the scientificity of the evaluation system and model. Based on empirical research, a green economy was developed and the construction of a green city was promoted in Shanghai.

ACKNOWLEDGMENTS

This research was financially supported by "Beijing Social Science Fund Project, China (Grant No. 18YJA003)".

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