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## Theory and method of research on ecological planning of urban landscape based on complexity theory

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### ABSTRACT

This paper discussed the sustainable development principle that planning should follow in the perspective of concept and content of ecological planning of urban landscape and then introduced complexity theory into research on ecological planning of urban landscape. Relative to “theory in planning” and “theory of planning”, complexity of ecological planning of urban landscape is divided into “complexity of planning” and “complexity in planning”. For “complexity of planning”, uncertain research method was introduced, and concept of “flexible planning” was proposed including flexibility of planning objective and flexibility of planning scheme. Planning objective and planning scheme for urban landscape were uncertain to make them be more operable. Research on urban landscape pattern that adapts to economic pattern will become the main trend of ecological planning of urban landscape in the future when looking into the future direction of ecological planning of urban landscape.

### KEYWORDS

Complexity; Ecological planning of urban landscape; Uncertainty; Flexible planning.



## INTRODUCTION

City is the artificial ecosystem established when human remould and adapt to natural environment and is a typical complexity system<sup>[1]</sup>. Urbanization is the inevitable phenomenon brought by the development of social productivity. It promotes the development of social economy in our country, but it also brings lots of problems such as air pollution, noise pollution, deficiency of regional culture, etc. These all seriously inhibit the sustainable development of urban construction and the quality of urban landscape<sup>[2]</sup>. As an important branch of application of landscape ecological application, ecological planning of urban landscape maintains the balance and construction of urban ecology. We can conduct comprehensive research on the relationship between landscape structure, spatial pattern, landscape function and landscape change from a macroscopic view<sup>[3]</sup>.

Urban landscape ecosystem is a dynamic system with large scale and complex structure. Its sustainable development is restricted by various complexity problems. Postmodern urban planning which is the application of sustainable development theory and theory and method of complexity science is a kind of new urban ecological planning pattern based on sustainable development theory and under the influence of complexity science. It solves problems that exist in urban planning. As an important component of ecological system, ecological system of urban landscape plays large influence in ecological research. This paper attempted to take complexity theory as one mainline for research on the ecological planning of urban landscape. Aiming at the complexity and uncertainty of urban landscape system, this paper studied theory and method of ecological planning of urban landscape with research method of complexity theory and combination of quantitative and qualitative analysis, which provides theoretical support and technical guidance for the sustainable development of urban ecological system.

## OVERVIEW OF ECOLOGICAL PLANNING OF URBAN LANDSCAPE

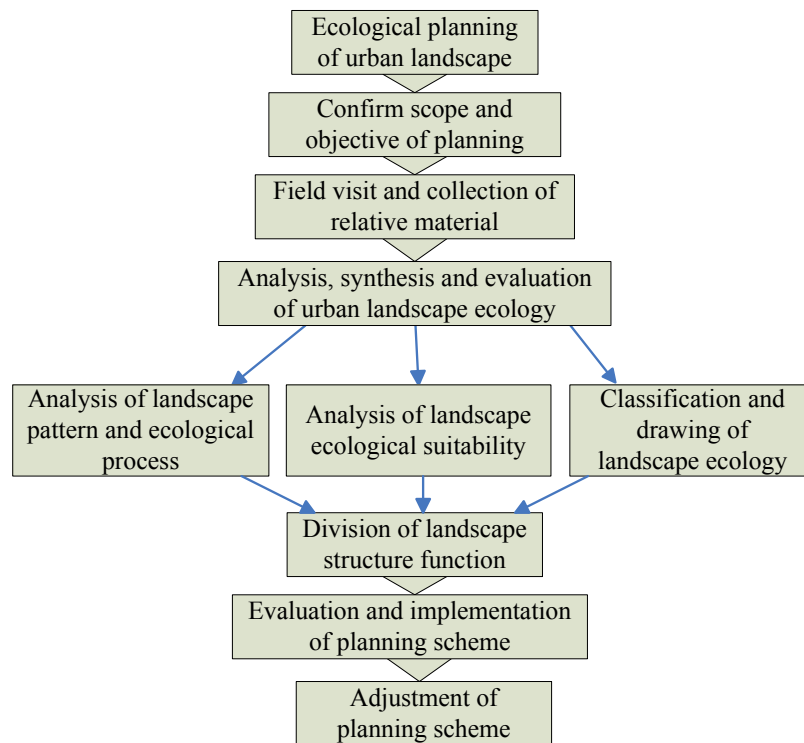
### Concept of ecological planning of urban landscape

Differing from natural and agricultural landscape, urban landscape is the man-made landscape constructed by human's own economical force and technical force. It combines the attribute of natural ecological system and human ecological system. It is composed of patch, corridor and matrix and they have no strict boundaries<sup>[4]</sup>. Ecological planning of urban landscape applied theory and method of landscape ecology to reasonably plan spatial structure of urban landscape. As a result, the amount between three elements of landscape and the spatial distribution can be reasonable, information flow, material flow and energy flow can be smooth and the landscape can conform to ecology principle and possess certain aesthetic value. Ecological planning of urban landscape is to plan and design measurement for construction, protection, adjustment and perfection of urban landscape as well as spatial distribution and allocation according to the characteristics of structure, function and dynamic change of urban landscape<sup>[5]</sup>.

### Research content and procedure of ecological planning of urban landscape

Ecological planning of urban landscape unites economy, society and nature together. It is also the combination of natural ecological system and human ecological system. Besides the collection and investigation of basic material of urban landscape, planning should also focus on protection of sensitive area, spatial planning of ecological vegetation and appearance and building of urban. Secondary, we can analyze ecological planning of urban landscape in the perspective of macroscopic and meso view<sup>[6]</sup>. The former is mainly about overall planning on urban land utilization, optimization of land utilization pattern based on landscape ecological principle and planning evaluation; the latter aims at some landscape type within the city, including protection planning of environmental sensitive area and planning of urban spatial environment<sup>[7]</sup>.

In addition, ecological planning of urban landscape is a comprehensive method system, involving landscape ecological investigation, landscape ecological analysis, comprehensive evaluation, etc. The procedures are shown in Figure 1:



**Figure 1 : Procedure for ecological planning of urban landscape**

### **Ecological planning of urban landscape based on sustainable development idea and complexity theory**

Development of ecological planning of urban landscape should stand from the present and give consideration to long run, which is good to the sustainable development of urban. Sustainability of urban landscape is extension of harmony of human-landscape relationship on time. It should be established to meet the basic needs and continue integration of landscape ecology. It should be on the basis of sustainable development, based on sustainable use of landscape resource and improvement of ecological environment and ensure the sustainable development of social economy. We induce complexity science when urban environmental problem is solved in technology but urban planning affects urban rational decisions with uncertainty. Therefore, postmodern urban ecological planning theory forms new pattern under the influence of sustainable development theory and complexity science.

### **STUDY ON ECOLOGICAL PLANNING OF URBAN LANDSCAPE BASED ON COMPLEXITY THEORY**

Complexity theory is a new science theory system representing by chaos theory, fractal theory, theory of dissipative structure and uncertain theory. Especially, chaos theory, fractal theory and uncertainty theory has become important tools for complexity theory. This paper mainly told study on complexity of ecological planning.

#### **Studies on complexity of ecological planning of urban landscape**

Study on complexity of ecological planning of urban landscape mainly includes complexity in planning and complexity of planning. Current researches focus on complexity in planning. Researches on complexity of planning are rare. This paper took uncertainty- a branch of complexity in ecological planning of urban landscape as an example to study the uncertainty problem and method for reducing uncertainty in planning process, thus to discuss and study the theory and method for complexity of planning.

**Studies on uncertainty in ecological planning of urban landscape**

Generally, uncertainty can be defined as unsure, uncertainly-known and changeability, which wide exists in natural world and human society<sup>[8]</sup>. In view of ecological planning of urban landscape, uncertainty exists commonly, mainly representing on: uncertainty from planning itself, including inherent uncertainty of natural world and uncertainty caused by human; uncertainty in planning, including uncertainty caused in landscape ecological planning and uncertainty in decision analysis.

**Uncertainty of planning**

Inherent uncertainty in natural world includes uncertainty of natural phenomenon such as hydrology, geography, temperature, sunshine radiation, etc, especially some natural disasters such as storm, flood, etc.

Uncertainty caused by human: uncertainty of landscape ecological planning caused by population immigration, social progress and economical development. Environmental sensitive area is an important aspect of ecological planning of urban landscape<sup>[7]</sup>. Improper developing activities often lead to environmental negative effect and fragility of ecological environment.

**Uncertainty in planning**

Uncertainty of current materials includes uncertainty caused by insufficient data and uncertainty in data collection process and uncertainty caused by data analysis; uncertainty of landscape ecological index includes uncertainty caused by confirmation and quantization of index. Uncertainty of planning result includes uncertainty of landscape status and planning district as well as uncertainty in decision analysis. For example, in order to realize the purpose formulated by landscape ecological planning, we can make analysis on the comprehensive benefits produced by many schemes that can be replaced each other and select an ideal scheme. Uncertainty decision can accurately evaluate the comprehensive benefits of scheme (TABLE 1).

**TABLE 1: Benefit analysis table**

Future possible state	Scheme 1			Scheme 2				
	Economic benefit	Environmental benefit	Social benefit	Comprehensive benefit	Economic benefit	Environmental benefit	Social benefit	Comprehensive benefit
S1	3	5	2	10	6	3	3	12
S2	6	3	3	12	3	5	2	10

S1 and S2, two kinds of situations that may appear in future development of city, were supposed here. Suppose comprehensive benefit is equal to the sum of economic benefit, environment benefit and social benefit. As shown in the table, there are two kinds of uncertainty. One is uncertainty in decision process. Scheme 2 will be selected under S1 state and scheme 1 will be selected under S2 state. However, due to the uncertainty of future state, selection of scheme can not be judged. The other is the uncertainty of future benefit after implementation of scheme. Suppose scheme 1 has been selected. Then the comprehensive benefit is uncertain judged from TABLE 1. The comprehensive benefit is 10 in S1, 12 in S2. If future state is S1, then scheme 2 is better than scheme 1. In addition, benefits in various subsystems are also uncertain. In S1, economic benefit is 3 and environmental benefit is 5. In S2, they are 6 and 3, respectively.

**ANALYSIS METHOD FOR UNCERTAINTY IN ECOLOGICAL PLANNING OF URBAN LANDSCAPE**

So far, analysis method for uncertainty in ecological planning of urban landscape mainly includes sensitivity analysis<sup>[9]</sup>, transfer function method, cybernetic method, stochastic mathematical methods and fuzzy mathematical method in mathematical model, etc.

### Sensitivity analysis

Systematic analysis usually relied on mathematical model. However, uncertainty also exists in model. Therefore, facticity and reliability need to be further discussed. Sensitivity analysis can estimate the uncertainty scope and reliability degree by input parameters. However, its drawback is the excessive reliability on mathematical model. Therefore, F. Vester nad A.V. Hesler, the famous ecological cybernetics expert from Germany, proposed a qualitative “sensitivity model” method. They integrated system science thought, ecological control method and urban planning together. With the help of system dynamics, variances needed in modeling was obtained from subsystems in urban ecological system. Differential equation was applied to simulate the structure, function and dynamic characteristics of urban ecological system, thus to provide relative solution for urban development. In addition, Lv Yonglong and Wang Songru improved the model and applied method that combined quantitative and qualitative analysis, which can provide new idea for urban development.

### Transfer function method

That is, use the size of uncertainty of initial variances to gradually analyze the uncertainty of calculation result according to error transfer theory<sup>[10]</sup>. The main theory is variance calculation theory. For example, we predict the concentration of some pollutant in ecological system of urban landscape. Suppose prediction pattern is:

$$I = F(x_i, t, a_j) (i = 1, 2, 3, j = 1, 2, \dots, n). \quad (1)$$

Among which, I is predicted value, F is function, xi is space coordinates of pollutant, t is time parameter and aj is relative parameter vector.

Then according to error transfer formula:

$$\sigma_i^2 = \left[ \frac{\partial F}{\partial x_i} \sigma_{x_i} \right]^2 + \left[ \frac{\partial F}{\partial t} \sigma_t \right]^2 + \left[ \frac{\partial F}{\partial a_j} \sigma_{a_j} \right]^2 + R \quad (2)$$

$$R = \frac{\partial F}{\partial x_i} \frac{\partial F}{\partial t} \rho_{x_i t} \sigma_{x_i} \sigma_t + \frac{\partial F}{\partial x_i} \frac{\partial F}{\partial a_j} \rho_{x_i a_j} \sigma_{x_i} \sigma_{a_j} + \frac{\partial F}{\partial a_j} \frac{\partial F}{\partial t} \rho_{a_j t} \sigma_{a_j} \sigma_t$$

In the formula:

Taking into account the mutual independence between  $x_i = (1, 2, 3)$ ,  $t$ ,  $k_j (j = 1, 2, \dots, n)$ , error transfer formula of independence variance is:

$$\sigma_i^2 = \left[ \frac{\partial F}{\partial x_i} \sigma_{x_i} \right]^2 + \left[ \frac{\partial F}{\partial t} \sigma_t \right]^2 + \left[ \frac{\partial F}{\partial a_j} \sigma_{a_j} \right]^2 \quad (3)$$

Value of  $\frac{\partial F}{\partial x_i}, \frac{\partial F}{\partial t}, \frac{\partial F}{\partial k_j}$  are termed as error transfer coefficient of xi, t and aj, respectively.  $\frac{\partial F}{\partial x_i} \sigma_{x_i}, \frac{\partial F}{\partial t} \sigma_t, \frac{\partial F}{\partial k_j} \sigma_{k_j}$  are the effect of error of first quantity on I, respectively. Then the standard deviation of I is:

$$\sigma_i = \sqrt{\left[ \frac{\partial F}{\partial x_i} \sigma_{x_i} \right]^2 + \left[ \frac{\partial F}{\partial t} \sigma_t \right]^2 + \left[ \frac{\partial F}{\partial a_j} \sigma_{a_j} \right]^2} \quad (4)$$

Thus, the total uncertainty of confidence limit can be derived from the standard deviation of I:

$$U_{\alpha} = K_{\alpha} \sigma_I \quad (5)$$

$U_{\alpha}$  is the total uncertainty under confidence level of  $1 - \alpha$ ;  $\alpha$  is the confidence level;  $K_{\alpha}$  is the confidence factor.

As a result, reliability of index predicted can be analyzed.

### Cybernetic method

Application of cybernetics can provide reference for uncertainty problem. Fuzzy control, stochastic control and neural network in control theory solve the uncertainty problem in ecological system of urban landscape. Cybernetics has achieved initial study in ecology and ekistics. Niu Xin and Wu Guan<sup>[11]</sup> provided an analysis framework for operating mechanism of regulation of land ecosystem and provided theoretical reference for the maintenance and control of land ecosystem by land and resources management departments in the perspective of cybernetics. Li Pengyu, Yuan Yanhua, et al<sup>[12]</sup> discussed the application of theory and method for ecological restoration with method of ecological cybernetics and example of urban-rural integration zone in Nanjing.

### Uncertainty analysis method

Stochastic mathematical method can conveniently deal with the uncertainty problem in complex model. In ecosystem planning of urban landscape, threshold of comprehensive index system can be regarded as other cities status value and uncertainty function that originates from extrapolation. Luo Min<sup>[13]</sup> et al discussed a research on a kind of predicting gushed water using a kind of stochastic mathematical method. The uncertainty problem is extrapolating solubility of rock or earth's surface catchment into ecosystem, and extrapolating some element as a source or originated from extrapolating. Application of fuzzy mathematical method represents on fuzzy comprehensive evaluation, fuzzy decision analysis and fuzzy planning. Uncertainty in ecological planning, that is fuzzy, can also be described by fuzzy mathematical model.

## FRAMEWORK OF ENTERPRISE INTEGRATED SYSTEM BASED ON ACTIVITY — BASED ACCOUNTING

Through the former understanding, we realize that planning of landscape ecology is various. The uncertainty factors include natural factor and social factor. Some need to be quantitatively solved by natural science. Some are closely related to social science and need to be qualitatively and quantitatively analyzed. Thus, the bad influence of uncertainty factors on landscape planning can be reduced to the largest extent. In general, we should consider the following factors in qualitative view when analyzing uncertainty of landscape ecology: 1) we should regard landscape ecological planning as social planning rather than technical planning. It is closely related to urban land utilization and spatial extension of population. Balance state in different aspects should be realized by ensuring landscape ecological integrity as well as considering local benefits; 2) landscape ecological planning itself is macroscopic controlled planning with integration of various subjects. First, we should consider ecological, social and economical benefits in order to solve uncertainty problem. The main purpose of economic growth or local benefit of landscape are not enough; 3) landscape ecological planning should combine with ecological overall planning. Planning analysis involves types, levels and structure relation of ecology. The key is how to recognize and master urban landscape ecological planning to reduce influence to the largest extent in proper way. So far, there are two kinds of planning: flexible planning and IDEA-CID method.

Flexible planning includes flexible planning objective and flexible planning scheme. Flexible planning purpose is to make planning objective uncertain. The scheme is also uncertain under

uncertainty purpose. Flexible planning should follow two principles: 1) scope principle. Flexible planning should stipulate relative scope and bound as constraints to ensure realization of planning purpose according to the possible change range of planning; 2) space and time principle. Mastering flexible objective should ensure advancement and predictability of objective on time and overall control in macroscopic view on space. Overall, flexible planning should not only meet the requirements of landscape development in ecological level but also take into account the restriction of various uncertainty factors. Uncertainty analysis method can provide solid theoretical basis and feasible method for urban ecological planning.

IDEA-CID method (the isolation of dimensions, the elimination of alternatives and the elimination of alternatives, the continuous increase of dimensionality): IDEA-CID method is an effective method for reducing uncertainty of objective. IDEA method is to resolve screening standard, limit in a scope, select an eligible scheme and evaluate in another scope. The rest eligible scheme is the best; CID method is to extend the scope of evaluation standard and take into account further.

### **PROSPECT OF ECOLOGICAL PLANNING OF URBAN LANDSCAPE**

Ecological planning of urban landscape develops from single to complexity, optimizes from part to entirety and evolves from traditional beauty and ecological beauty. It is dynamic changes which promotes the application and development of quantitative analysis and simulation in urban landscape ecology. Meanwhile, low-carbon and economic urban landscape pattern is the main pattern, which is to reasonably plan and design land resource. Combinations of lands with various functions are used to realize short distance traveling with public transportation so as to achieve low-carbon development<sup>[14]</sup>.

### **CONCLUSION**

The significance of ecological planning of urban landscape is to create an urban ecosystem that is conforming to ecological virtuous circle, connected with external space, reasonable in internal layout and harmonious in landscape through reasonable organization of space environment. Flexible planning is proposed in order to reduce uncertainty influence in landscape ecological planning. It makes the goal of urban landscape planning and urban ecological planning uncertain. In addition, IDEA-CID method is applied to select optimal planning. Uncertainty mathematical methods such as sensitivity analysis, error transfer function method, stochastic theory and fuzzy mathematical theory can be adopted to reduce the influence of uncertainty factors.

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