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Research Article

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Preliminary plan to construct an eco-city based on chaos theory

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ABSTRACT

Key points of chaos theory: 1, systematic nonlinearity and complexity; 2, non-causality and unpredictability; 3initial sensitivity; 4, fractal and self-similarity; 5, strange attractor, analyzes and explores the chaotic significance of eco-city plan and construction, then proposes a preliminary plan.

Key words: chaos theory, eco-city, fractal, self-similarity, strange attractor

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INTRODUCTION

Butterfly effect, relativity theory and quantum mechanics are referred to as the chaos theory of the 20th century's three scientific revolutions. [1] With the establishment of chaos theory, people gradually realize that nonlinear system is the universal existence, and linear thinking and theory which were deemed to be mastered by people expertly are, in fact, special cases in nature. Chaos theory helps us to understand nonlinear complex system. Aperiodic behavior patterns are caused by the interaction between nonlinear elements in a complicated system are called chaos phenomenon.

Chaos phenomenon occurs in objects or systems which are very easy to change. Such systems begin to operate in a very easy pattern, but the pattern iterates according to certain principles and the operation result of the former stage is enlarged accordingly, so the final results turn to be very unpredictable, thus entering the chaos state. However, chaos state does not mean total disorder, because we can find certain principles of chaos phenomenon after long-term and comprehensive analysis. Because chaos theory can reveal the essence of the world vividly and efficiently, it has been widely applied to earthquake prediction, meteorology, ecology, urban plan and computers.

Urban giant system is made of many independent systems and elements. Every system can operate independently based on its own power and has self-regulation ability. Meanwhile, all systems interact with each other in a complicated way. City operation is the result of the iteration of infinite systems and complicated elements. So simple linear thinking cannot be used to restore and reconstruct the urban giant system. When we look back at history, we would know that ancient people cannot control the nature and society as well as us, but cities and villages in the past were very disciplined and eco-friendly, because they thought a lot about natural phenomenon and learned from nature. So eco-city is what a city should be and will be. Previous and current city mode built on the base of linear thinking and simplified organizing characteristics is abnormal. To recognize, analyze, study and plan the building of eco-city on the base of chaos system is vital for China's construction of eco-city.

The key points of chaos theory are as follows: 1, systematic nonlinearity and complexity; 2, non-causality and unpredictability; 3initial sensitivity; 4, fractal and self-similarity; 5, strange attractor, for the preliminary exploration of the construction and plan of eco-city.

SYSTEMATIC NONLINEARITY AND COMPLEXITY

Chaos system is the result of the cross iteration of many systems and complicated elements. The system is characterized by multi-layer, multi-angle, multi-dimension, non-linearity and complexity. So eco-city plan should

not be confined to traditional natural ecology, but should be expanded to the broad sense of ecology. Firstly, we have to know the composing elements and organizing network of eco-city system. The primary eco-city plan theory defined eco-city system as natural elements such as greening system. Later, the theory progressed to the modern ecological concept of the balance of land carrying capacity, industrial ecology and commercial ecology. With the development of science, people gradually realize that we have to expand eco-city dimension into the balance between human and ecology, and stress the individual ecological balance of life. Only when we build a complicated and balanced ecosystem of many layers, dimensions, systems and structures, can we build a complete and healthy eco-city. A simple ecological system based on material space is vulnerable to changes and cannot operate independently, so it cannot form a complete eco-city. *Athens Charter* is regarded as the milestone is urban plan, but the opinions it brings about in terms of accommodation, work, recreation and transportation are too simple, so the cities built based on the charter are all alike, and traffic-jammed, and ecological-unfriendly. The "ghost city" Erdos is a vivid example to show how extremely single development of city leads to ecological collapse. The first step to build eco-city is to study the complexity and multilayer characteristic of city, and build it from the aspect of society, culture, economy and humanity.

NON-CAUSALITY AND LIMITED PREDICTABILITY

The intrinsic complexity and randomness of chaos system are regarded as disorder in city form after being reflected. Chaos theory points out that the complexity and randomness of systems causes the unpredictability of system's long–term behaviors. Thus, the eco-city system also has long-term unpredictability. So, corresponding eco-city plan solutions are: long-term macro-control, short-term detailed plan, quantitative detection of process, the combination of top-down and bottom-up mode of planning. Long-term, extensive and detailed plan of eco-control is not practical. We can do long-term ecological plan at the macro level to set larger structure and control area for regional ecology, but the short-term plan has to have strict initial conditions and detailed control area and build strict and scientific indicators for quantitative management. Meanwhile, we have to adopt dual planning method from both top down and bottom up. Traditional urban plan is the "top down" mode, but it has many disadvantages and can only applied to the plan of physical environment but not to the planning and construction of eco-city. Ecological plan demands another aspect- the self-organization and mutual promotion based on different levels of fractal- the inner of the city to mobilize the creativity of all levels and individuals to realize the self-organization of urban ecology so as to build an eco-city.

SENSITIVE DEPENDENCE ON INITIAL CONDITIONS

Sensitive dependence on initial conditions is a typical feature of chaos system. The small difference of initial conditions can lead to great difference in the final results. The self-organization of fractals of chaos system makes the small difference at initial stage able to cause unpredictable results by enlarging the iteration function between different stages gradually, which means when the information is passed from one stage into the next, the initial randomness is enlarged infinitely.

When the sensitivity of initial conditions of the construction of eco-city is revealed, the government has to define strictly and input and monitor initial conditions in the planning and construction of eco-city, because minor changes of initial conditions can greatly influence the result of the whole system. The formulation of initial conditions includes setting and implementation. Setting means setting strict ecological standards, because only when we set scientific, comprehensive, quantitative eco-city plan standards based on local conditions can we start the construction of eco-city. Currently, many local governments set evaluation standards of eco-city, but these standards are neither scientific, specified, quantitative nor based on local conditions. So these standards cannot efficiently guide, evaluate and monitor the construction of eco-city, instead, they are mere image projects. Meanwhile the strict implementation is more important, because initial conditions can turn into totally different ones after the independent operation of designing, constructing and managing process. So the strict management of initial conditions is vital to realize the intended goals of ecological system. As a complicated system, the implementation of every detail of eco-city can have enormous influence.

FRACTAL AND SELF-SIMILARITY

Fractal means every graph in different scale is self-similar. Fractal has the following features:1, fine structure in every small scale; 2, irregularity, no matter the whole or individual part cannot be described by Euclidean geometry; 3, self-similarity; 4, the existence of simple recursive definition under most circumstances.[2] Fractal is an important concept of chaos theory. The internal order of chaos system means that chaos has inner systematic structural relations and similarity at different levels, i.e., self-similarity. [3] Different functional layers, zonal structures, network system, building density and man-earth relationship all have the feature of fractal.

Eco-city is a complex and giant system of multilayer, self-similarity and self-organization. The multi-layer fractal of ecological system ensures its stable and sustained functioning. In the multi-layer, self-similarity and self-organizing eco-city system, several systems interact. Each ecological system at each layer is a spontaneous self-organizing unit, thus having self-adjusting ability. This enables that the complex system can adjust and repair itself based on its own motivations. The disturbing and damaging effect of environment will influence the operation of some systems and layers, but the self-organization at macro-level or micro-level of systems or multi-systems will correct or repair this influence to make sure that ecological system can resist damage and change, and operate healthily. As old sayings go, "grass cannot grow without trees" "there would be no material progress without intellectual progress", so the whole eco-city can exist because it has many layers and each layer has complete ecological group. So the construction and plan of eco-city should use the principle of fractal. We should first set a goal composed of different layers and complete system, and they should interact with each other and have the characteristic of self-similarity. Secondly, we have to set strict evaluation standards to ensure that the management process has principles to follow and that ecological goals can be realized quantitatively. Thirdly, we have to give full rein to the bottom-up planning strategy to ensure that self-similarity can get into every aspect of society and become the smallest functioning cell.

STRANGE ATTRACTOR

Chaos theory studies about the orders in disorder. Order means the system would converge to certain attractor in the phase space. In the phase space composed of generalized coordinates, after a long time, the motion trial of chaos system will enter a stable and periodic orbit or become a clothoid which is always changing but has latent rules and orders. Chaos activities appear to be random, but also have the attributes of disordered whole being imported to some potential centers, so chaos activities can converge to limit set and have the regression characteristics of being able to make variables tend to return. This strange characteristic is called strange attractor. [4]

The appearance and development is the spatial aggregation at preferred locations. Geographical environment has decisive influence on a city's characteristics. However, the plan and development of eco-city is, first of all, to form growing point based on the region's core natural characteristics and high-quality resources, which is strange attractor, and then the city can develop gradually. In history, geographical, social, cultural and economic models centered around strange attractor after long-term evolution have formed relatively stable and good urban ecological systems. This kind of eco-city plan and construction based on natural characteristics are very easy to develop and can avoid the building of simple and fragile system because of limited knowledge of human beings. When the growing point begins to have ecological effect, the region can form growth pole through polarization and proliferation, thus attracting surrounding regions to follow the same example. Though plan cannot control whole process of the change of eco-city, however, it can find the intervention method and help to adjust the intervention of eco-city. For example, Barcelona of Spain conducted the "acupuncture mode" of local environment movement led by the government, which promoted whole urban ecology step by step. So the key point of eco-city plan is not to acquire details or to build precise models, but to control the "strange attractors" of system behaviors and mode change.

Chaos theory helps us to know the rich and colorful 21st century. It helps us to rediscover the seemingly similar world. We should not be afraid of disorder. Only after we accept the universal law that the world is disordered, can we see the world clearly in chaos. For the designers and developers of urban planning, they must fully respect, understand and use chaos theory in order to plan and build a real eco-city.

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