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Review of Related Studies on Eco-city Theory

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Abstract This paper reviews the birth and development of eco-city research by means of historical analysis and literature search. It elaborates the concepts, connotations and principles of scholars both at home and abroad. By comparing the research and practice differences between domestic and foreign eco-city construction, it reviews the various indicators and research progress applied in the current eco-city construction in foreign countries. It systematically sorts out the characteristics of eco-city construction practice in China and points out the main problems in the construction of China's eco-city.

Key words Eco-city, Connotation, Concept, Indicator system

1 Introduction

A city is a type of social, economic and natural complex ecosystem with human activities as the center^[1]. With the continuous economic development, more and more people flow to cities to live. According to statistics, in 2010, the world urban population has exceeded 50%; it is predicted that by 2050, the world urban population will account for 66.4% of the total population, while China's urban population will reach 75.8% of China's total population^[2]. Urbanization has become a direct engine driving global environmental change and economic transformation^[3]. However, with the rapid economic development and population growth, urbanization has also brought about a series of social, economic and ecological problems, such as environmental pollution, biodiversity loss, ecological damage, heat island effect, traffic congestion, disparity between the rich and the poor and increased crime rate, etc., and all of these lead to the concern of the whole society^[4-5]. Traditional urban planning focuses on planning and economic efficiency of urban material space function and architectural landscape. At present, people become increasingly aware that this system can no longer adapt to the new development of the city. At the same time of seeking economic development, people are also thinking about how to improve the ecological environment, ensure ecological security, to achieve sustainable urban development. Through introducing ecological principles and technical methods, urban planning guides and improves the traditional planning. In this situation, the eco-city becomes a hotspot of research. By urban planning means, it is expected to coordinate urban spatial layout and development strategies, so as to promote urban ecological development in a healthy and reasonable manner^[6]. In recent several decades, the theory of ecology has greatly developed. Many cases of eco-city practice have accumulated rich practical experience for the construction of eco-cities, making the development of eco-cities become mature and mature.

Based on the relevant research of eco-city, we sorted out the

development of eco-city, elaborated its concept and connotation, reviewed the principles, construction and evaluation index system of eco-city, and analyzed and discussed problems in the research of other scholars about construction practice of eco-city in recent years, elaborated the problems faced by the eco-city, and finally came up with recommendations for the eco-city construction.

2 Emergence and development of eco-city

The proposal of the eco-city concept is not long, but its academic ideas existed since the beginning of the city. Plato put forward the idea of "ideal country". Marcus Vitruvius Pollio proposed integrating the natural conditions into architectural design in his *Ten Books on Architecture*. Some urban planning ideas in the 18th-19th century already contained certain connotations of an eco-city. At the end of the 19th century, the planning practice of ecologists and planners represented by Marsh marked that the ecological planning came into being. For the first time, it proposed rationally planning human activities to coordinate with nature rather than destroy nature. Later, the University of Chicago's human ecology school further emphasized that the development should be coordinated with nature in urban and regional planning. After entering the 20th century, there have been two urban ecological climaxes that have greatly promoted the development of eco-city research. Mumford's natural view in urban planning and concerns about the development of urban cars have sounded the alarm of human-nature imbalance brought about by urban development^[7].

In 1971, the Man and Biosphere Programme (MAB) initiated by UNESCO first proposed the concept of "eco-city". In the report, it stressed that eco-city planning is the best human activity integrating technology and nature created from both natural and social aspects, inducing human creativity and productivity, providing high levels of material and lifestyle^[8]. Due to the urgency of human environmental issues and the wide recognition of the international community, the effective promotion of the Man and the Biosphere Programme and the advocacy of interdisciplinary cooperation, since the 1980s, eco-city has rapidly become a research

hotspot in the international academic circle, and eco-city planning and construction practices have been carried out in related countries and the first international eco-city conference was held in 1990. Since then, eco-cities have been widely concerned and accepted by all countries in the world, and eco-city construction has also moved to the practical stage.

3 Concept, connotation, theoretical basis and principles of eco-city

3.1 Concept The human environmental issue has received the wide attention of the international community. But as to the definition of eco-city, scholars have different opinions, and there is still no unified idea about the definition^[9]. In the opinion of Yanitsky, eco-city is an ideal urban model, it is a full integration of technology and nature, and people's creativity and productivity are brought into full play, the physical and mental health and environmental quality of residents are protected to the maximum extent, and material, energy and information are efficiently utilized, it is an ideal environment for ecological benign cycle. Register gives a highly general definition of eco-city, he defined the eco-city as an ecologically sound city, compact, vigorous, energy-efficient urban community harmoniously coexisting with nature^[10]. In the opinion of Downtown, eco-city is a city that has achieved an ecological balance between people and between man and nature, and Downtown pointed out that the key to the construction of an eco-city lies in creating a vigorous living environment, building a healthy economy that is consistent with ecological principles, promoting social equity and improving social welfare^[11].

In the early 20th century, China lags behind the western countries in the research and practice of eco-city. After more than half a century of stagnation, both the theory and practice of China's modern eco-city started to catch up. Since the 1980s, with the development of China's social economy, the increasingly prominent ecological environment issues have provided extensive research materials for eco-city researchers. China's research on eco-cities has made rapid progress and made significant achievements and domestic scholars have their own understanding of eco-cities. For example, Wang Rusong summarized Yanitsky's eco-city idea as "an ecological city is a human settlement established on the principle of ecology, with harmonious development of society, economy and nature, efficient use of materials, energy and information, and ecological benign development^[12]". As stated by Huang Guangyu, eco-city is the form of human settlements that are socially harmonious, economically efficient, and ecologically benign, with nature, city, and human beings integrated into an organic whole, forming a mutually beneficial symbiotic structure^[13]. In 2001, on the basis of summarizing the domestic and international studies about eco-city theory, and combining the latest ecological economic theory, Huang Zhaoyi and Yang Dongyuan put forward a relatively complete definition of eco-city, that is, "eco-city is the sustainable subsystem of share of fair-bearing system sharing in global or regional ecosystems", it is a complex system of natural

harmony, social equity and economic efficiency based on ecological principles, is an ideal human settlement environment with natural and artificial coordination and harmony between people with its own humanistic characteristics^[14].

In the development of the eco-city concept, due to the different emphasis and the improvement of the level of understanding, the concept of eco-city is also enriched and improved. Combining the views of many scholars, we can summarize that eco-city is a brand new mode based on certain theory of ecology, taking promotion of the harmony between urban social and economic development by effective use of environment resources, to realize sustainable development of production and lifestyle^[15].

3.2 Connotation The concept of eco-city reflects people's introspection on urban environmental issues, and scholars from different schools have different understanding of the connotation of eco-city^[16-17]. According to the theory of sustainable development, an eco-city is an ecosystem under the guidance of the theory of sustainable development to achieve sustainable development of social and economic development. Ecological footprint holders regard the eco-city as a sustainable subsystem in global or regional ecosystem to share their fair carrying capacity. The health theorists consider the eco-city as a city that pursues the health of the urban ecosystem. According to the urban complex ecosystem theory, the eco-city is a complex ecosystem consisting of three subsystems: society, economy, and nature. Yanitsky believed that eco-city is an ideal urban model, it is a full integration of technology and nature, and people's creativity and productivity are brought into full play, the physical and mental health and environmental quality of residents are protected to the maximum extent, and material, energy and information are efficiently utilized, it is an ideal environment for ecological benign cycle. American scholar Roseland held that the eco-city concept includes sustainable urban development, healthy communities, community economic development, high technology, bio-regionalism, indigenous world outlook, and social ecology. Huang Guangyu, an expert on urban planning in China, considered that an eco-city is a complex ecosystem integrating society, economy, and nature built on the basis of ecological principles, and it is a human settlement with sustainable development, residents' satisfaction, economic efficiency and ecological benign cycle. From the perspective of time and space and functional level, Yang Tong elaborated the concept of eco-city and proposed that the construction of eco-city should be based on the principle of ecology, and it is a sustainable city based on the integration of society, economy, and nature^[18].

According to the understanding of the connotation of eco-city of different scholars, we can summarize the distinctive features of an eco-city. (i) Harmony. A healthy eco-city has a reasonable ecological structure, pursuing the health and harmony of the urban ecosystem. (ii) Sustainability. It includes natural, social and economic sustainable development, in which natural sustainable development is the foundation. (iii) High efficiency. In an eco-city, the knowledge economy minimizes the consumption of natural

resources, and the growth of non-material wealth becomes the main point of economic growth. (iv) Systematicness. Eco-city is a social-natural complex ecosystem based on ecological principles. Each subsystem develops in a balanced manner under the overall coordination of the eco-city system. (v) Regionality. An eco-city is an urban-rural complex based on a certain region, and an isolated city cannot realize ecologicalization. (vi) Diversity. Eco-cities have changed the simplification and specialization of traditional industrial cities. Its diversity includes not only biodiversity, but also cultural diversity, landscape diversity, and functional diversity^[19–20].

3.3 Theoretical basis The time since the proposal of eco-city theory is not long. Many theories are still in the process of development. At present, it is generally believed that it is based on the following theories: (i) urban ecosystem theory; (ii) sustainable development strategy; (iii) regional integrity and coordinated development theory; (iv) urban comprehensive development theory; (v) circular economy theory^[21]. Urban ecology is a cross discipline of ecological science, environmental science, urban science and geographic science, taking cities with intensive human activities as objects and urban ecosystem as the core, to study its ecological mechanism of structure, function, balance and regulation control, and apply the method to the planning, construction and management of eco-city, to find countermeasures and paths for the sustainable development of urban environment, economy and the improvement of residents' quality of life^[22–24].

3.4 Principles for eco-city construction The introduction of eco-city concept is the product of human beings transforming from industrial civilization to ecological civilization. Once the concept of eco-city is introduced, it has been widely concerned by both domestic and foreign scholars, and the theory and practice of eco-city has been greatly developed.

In 1984, the MAB provided five principles for eco-city planning, namely, ecological protection strategies (including nature conservation, flora and fauna and resource conservation and pollution prevention); ecological infrastructure (enduring support capacity of natural landscapes and hinterland to cities); living standards of residents; protection of culture and history; integration of nature into cities^[25]. These five principles summarize the main content of eco-city planning and become the basis for the development of eco-city theory. In 1996, based on the five principles of eco-city construction, Register put forward a more complete ten principles of eco-city, including urban land development, transportation mode, natural environment, resource utilization technology, production and consumption patterns, ecological awareness and social equity and management^[26]. With these principles, the eco-city system becomes richer, and has a strong operation and direct guiding significance for practice. In 1997, the Australian Urban Ecology Association (UEA) proposed the idea of eco-city development: restore the degraded land; coordinate urban development and biological region and implement balanced development; achieve balance between urban development and land carrying ca-

capacity; stop the urban spread; optimize energy structure; provide healthy and safe community services, and encourage community participation in urban development; improve social equity; protect historical and cultural heritage; cultivate rich cultural landscapes; rectify damage to the biosphere^[27].

Since the 1980s, many domestic scholars have conducted research on eco-cities. In 1984, Ma Shijun and Wang Rusong stated that the eco-city is a typical socio-economic-natural complex ecosystem^[28]. On this basis, Wang Rusong carried out an in-depth study on urban issues and eco-cities, put forward that eco-cities should meet the principles of human ecology, the efficiency of economic ecology, and the principles of natural ecology^[29]. Shen Qingji held that the eco-city system that conforms to the ecological rules should be an urban ecosystem with reasonable structure, efficient function, coordinated relationship and dynamic balance^[30]. In the opinion of Song Yongchang, urban ecological planning should be guided by ecological principles, using environmental science and systematic science methods to plan urban complex ecosystems, coordinate various ecological relationships within the system, improve system structure and function, and ensure natural balance and resource protection, and promote the coordinated development of man and nature^[31]. Ye Limei proposed five principles for eco-city planning, construction and operation: low-carbon operation, low impact construction, location based on ecological service capacity, urban greening with ecological function as the first, green space construction combined with public activity space construction, and resource recycling^[32].

All of these principles emphasize the transformation of the improper current situation of the urban system, put forward many measures for the specific problems of the city, and have a strong guiding significance for the practice of eco-cities.

4 Practice of eco-city construction and establishment of indicator system

At present, the eco-city construction is in a rapid development period, and governments of different countries and regions are actively participating in the construction. Although there is still no widely recognized eco-city model, extensive practical activities continue to improve the establishment of indicators for eco-city construction, and will further promote the development of eco-cities.

The United States is currently the most important developed country in the world, and its research and practice of eco-city construction are both very active. The construction of the Treasure Island eco-city in the United States was based on the expansion of the existing urban area, and the construction of the city mainly employed the PPP model^[33]. This project planned to build a new commercial and retail area that can accommodate 8 000 residents, approximately 240 000 ft² conforming to ND Gold standard, and build approximately 300 acres of open space, including 22 acres of organic farms, parks and wetlands for leisure and recreation. In terms of policy, it planned to build multi-purpose public transportation facilities, encourage cycling and walking, and will collect

fees for congestion periods. In addition, it also included a socio-economic sustainable development index.

In 1997, Boston launched an indicator system establishment project that selected the existing wetland area instead of the lost wetland area as the evaluation indicator. For economic development, the project not only included the currently widely accepted evaluation indicators, such as employment rate and new job opportunities, or annual profit and products, but also incorporated the educational level into the evaluation indicators. Boston's indicator system included the total per capita income, housing satisfaction, health care system, and number of children's controllable diseases. In the field of public security, the indicator system included the crime rate and social trust degree. In the field of social development, the indicator system included the proportion of housing loans to income, the number of voters, the degree of participation in volunteer activities, the number of rescued people who found work, the unemployment rate, the vacancy rate of public officials, and the number of wanderers^[34].

Compared with the United States, the United Kingdom not only considered ecological factors when planning and building eco-cities, but also set forth requirements of solving housing problems for eco-city projects. Its eco-town program, as a test platform for eco-city construction, was used to achieve low carbon construction, provide 30% housing and 40% environmentally friendly infrastructure, and properly manage waste. In terms of development indicators, the program emphasizes the ability to meet the environmental standards required in other regions, family life meets low carbon standards, has good facilities in waste management, and can apply advanced treatment technologies to meet housing needs and provide compact green space, so as to organically combine the interior of the city, and give priority to the use of natural land with poor conditions rather than excellent land^[35].

Other areas of Europe also carried out extensive practices in the construction of eco-cities. In the context of the European Eco-City project, many cities have applied technological improvements and energy-saving products, such as Helsingborg in Sweden and Trondheim in Norway. These practices have achieved good results, providing an important reference for the next step of research and practice^[36]. Eero Paloheimo *et al.* analyzed the current situation of carbon emissions at the national level in Finland from five aspects: energy, transportation, agriculture and forestry, industry, and construction. In terms of consumption at the national and city levels, they believed that the influencing factors include income, place of residence, age, educational level, gender and family size, the consumption includes food, consumer goods, households, travel, and services^[37]. On the basis of the study of Andalusia in Spain, Jaime Solís-Guzmán *et al.* established an ecological footprint indicator for monitoring residential buildings. They calculated the total ecological footprint on the basis of calculating the ecological footprint of energy consumption, water use, food consumption, building materials consumption, waste consumption, and construction land consumption^[38].

In Asia, many countries have also started the eco-city construction in recent years. Japan's eco-city construction indicators mainly focus on two aspects, one is the utilization of renewable resources and the allocation of energy recycling facilities, and the other is the allocation of urban green space. Japan's practice in eco-town construction has made significant achievements in many industrial parks. The utilization of renewable resources and the use of supporting facilities have been incorporated into the indicator system in many eco-industrial parks^[39]. A most representative example of eco-city construction in Korea is the planning and construction of Seoul. In the planning process, Seoul has taken into account the natural environmental factors such as biodiversity and water resources^[40]. Malaysia's indicator system includes two aspects, namely the clean production and the working environment. In these indicators, some reflect clean production such as raw materials, energy, water resources, waste emissions, biodiversity, products and services, environmental effects, and complaints; some reflect the labor environment such as employment volume and age structure, employee safety and health, educational level and professional skill level^[41].

With the economic development, the practice of eco-cities in China has also become more and more, and many scholars have proposed an indicator system suitable for the construction of China's eco-cities. Based on the detailed analysis of the theory and connotation of eco-city, Wu Qiong *et al.* established the eco-city evaluation indicator system for Yangzhou with the aid of the qualitative and quantitative information obtained through expert consultation. This indicator system includes three subsystems (social, economic and natural in the urban complex ecosystem) and reflects the connotation of the eco-city and measure the status, dynamics and strength of various subsystems of the eco-city. In order to combine all levels of indicators, they proposed a method for evaluating the indicators of fully arranged polygons, to evaluate the effectiveness of eco-city construction at different planning stages^[42]. Through broadly summarizing the indicator systems used by foreign eco-cities, Mi Kai summarized 69 indicators and divided them into three categories: ecological environment, economic development and social progress^[43]. Using the expert scoring method, based on the ecological city of Sino-Singapore Tianjin Eco-City and Caofeidian International Eco-city, Wu Yingjie selected and established China's eco-city evaluation indicator system, including five threshold conditions and 32 indicators (three target hierarchies and seven path hierarchies)^[44], and analyzed the eco-city indicators adopted by many countries and found that the eco-city embodies the philosophy of "serving people and people-oriented". The purpose and starting point of eco-city construction is to make people live better. Therefore, the eco-city indicator is based on people's safe living and high living standards, which are reflected in employment, income, medical security, convenient transportation and complete living facilities. On this basis, it is expected to further strengthen the management of polluted environment and landscape ecological construction. In recent

years, low-carbon living, low-carbon industries, and low-carbon services become the main contents of eco-city construction. These expand the demands for urban leisure, entertainment, and fitness facilities to meet the needs of human beings in harmony with nature. From the adjustment of the eco-city indicators of various countries, it can be seen that the eco-city indicator system is a gradual, dynamic process of adapting to the process of human progress. Besides, with the elapse of time, many indicators are increasingly being applied to practice, but some are enhanced and others are weakened^[45]. The dynamic adjustment of development indicators in the urban development process will turn eco-city construction into an organic dynamic process.

5 Existing problems in eco-city construction of China

At present, the eco-city construction has become a hot spot in urban construction. Although China has made some achievements in eco-city construction, there are some issues worth paying attention. Chu Zhujie classified the various problems of China's eco-city construction into three aspects: hardware, software and mindware, and proposed specific and feasible countermeasures^[46]. On the basis of systematically reviewing the national macro-environmental policies since 1989, Jiang Yanling *et al.* summarized the basic characteristics of China's eco-city construction practice, and pointed out the main problems in the eco-city construction: (i) the development orientation of China's eco-city construction is excessive; (ii) promptly adjusting the objectives and functional orientation of the original eco-city construction under the new policies; (iii) large investment in various eco-city construction, long construction period, and lack of evaluation method for the construction effect^[47]. In the opinion of Gao Jing, many city governments have misunderstandings about the concept of eco-city. Some of them are simply pursuing the beautification of the natural environment and considering the eco-city construction only from the perspective of natural environment, and some eco-city constructions ignore the overall concept of close connection between urban and regional areas and the protection of the surrounding ecological system, and simply pursue the efficiency, economy and low pollution within the scope of small systems^[48].

6 Conclusions

As a new concept of urban development, eco-city concept has less than 40 years since it has been proposed. Considering the complexity of the human-land system, the internal mechanism, function and structure of the urban system, and the hard work of the population control, resources and environmental problems, this concept will constantly be developed and deepened in terms of concept, connotation, theory and mode with the development of economy, science and technology and social progress. Foreign scholars focus on the practicality and operability of eco-city theory, stress the specific schemes of eco-cities in accordance with actual situations, and linking theory with practice, so that they could better solve problems in eco-city planning and construction. By

comparison, domestic scholars focus on the integration of Chinese traditional culture, and mainly study the eco-city theory from the perspective of ecology and planning, and generally undertake the eco-city planning from the establishment of objectives and targets, so the objective is definite. However, both the domestic and foreign scholars are limited in traditional scientific study method in traditional value, and stress the micro level of some parts or certain problem of cities, lack the systematic study and overall grasp at the macro level, and connotation and extension are not clear and mainly remain on the description and lack in-depth analysis. In summary, the integration of ecology and urban theory is an important foundation for eco-city research. It is recommended to strengthen the integration and cross application of urban planning, ecology, geography, sociology, economics, architecture, landscape architecture, environmental science, systems science, philosophy, and aesthetics, and all other related disciplines in the eco-city research and practice.

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