

ORIGINAL RESEARCH ARTICLE

Theoretical research on urban spatial structure from the perspective of ecology

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ABSTRACT

Since ancient times, exploring a reasonable relationship between urban space and nature has been the tireless pursuit of mankind. Since the 21st century, ecological thought has been deeply rooted in the hearts of the people. Today, when the ecological city is gradually recognized by people and recognized as the ideal development model of the city, emphasizing the urban spatial model integrated with nature and building a scientific and reasonable urban spatial structure system has gradually become the research hotspot of urban scholars and builders at home and abroad. From the theoretical basis of urban spatial structure research from the perspective of ecology, the origin of academic thought has a long history, but it lacks a systematic established model, so it is very necessary to summarize it.

Keywords: ecology; eco city; urban spatial structure

1. Introduction

Urban spatial structure is one of the core contents of urban geography and urban planning. With the rise of urban development concepts such as “ecological city”, China’s urban construction has entered a golden period of prosperity and development. Urban spatial structure is a specific structural form reflected by various constituent elements and many functions of a city according to a certain spatial order in the city. They are not randomly distributed in the city. The urban spatial structure affects the operation efficiency of the city to a great extent. Exploring this spatial order and the resulting spatial structure model has important theoretical and practical significance in urban

geography.

2. Urban spatial structure under the influence of “primitive ecological view” (before the 18th century)

From primitive society to quite a long time later, man and nature maintained a harmonious and friendly relationship. During this period, the urban and rural spatial structure is mainly affected by the natural environmental conditions, which is manifested in the pursuit of advantages and avoiding disadvantages of the ecological environment and the concept of spatial composition from the aesthetic perspective.

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2.1. The “unity of heaven and man” model and “Feng Shui model” of ancient Chinese urban space

The theoretical research on urban spatial structure in ancient China can be traced back to the spring and Autumn period and the Warring States period. Shang proposed that “urban land should be coordinated with the surrounding natural environment to keep the balance between land and population”, and put forward the understanding with ecological thought on the issue of urban spatial structure for the first time. During this period, China’s urban space paid attention to the integration with the natural environment and strive for the organic combination of city and garden. This intuitive oriental wisdom has been affecting the urban construction of China’s feudal society for more than 2,000 years.

The ancient Chinese “geomantic omen model” was based on the five behaviors of Yin and Yang, advocated that “people should live mainly in the earth, mountains and rivers”, emphasized the organic integration of urban space and natural environment, and advocated that urban construction should “taste water with soil”^[1]. As the core of Feng Shui model, the overall urban spatial structure of “left green dragon, right white tiger, front rosetree and rear Xuanwu” has always affected the relationship between cities, villages and natural environment. The ideal state of geomantic omen model is that the city is surrounded by mountains and water, which is located in a wide terrain in the middle, surrounded by water on both sides, and surrounded by low mountain protection on the left and right of the city, forming a relatively closed and ventilated space connected by mountains and waters.

2.2. “Materialization” model of ancient western urban spatial structure

The research on urban spatial structure under the concept of ecology abroad can be traced back to the idea of “Utopia” by Plato, an ancient Greek philosopher. The idea of urban construction in this period was mainly influenced by artistic aesthetics.

For example, the West bodham model of Miletus in ancient Greece pursues the harmony and order beauty between geometric images and numbers. The ancient Roman architect Vitruvius summarized the experience of building cities in ancient Rome and Greece, advocated designing cities according to urban environmental conditions, integrated the understanding of life and health into the choice of nature and architectural design, and fully reflected the idea of adjusting measures to local conditions in the layout of urban spatial structure. During the Renaissance, Alberti, an Italian architect, inherited and carried forward the thought of Vitruvius and advocated that the urban layout should meet the needs of the city and form the theory of “ideal city”. The transformation of the palace of Versailles in Paris in the 16th–17th century adopted the form of radial symmetry of the axis, which reflected the pursuit of architectural art and aesthetics and became the object of competitive imitation of urban design at that time.

In the later urban planning practice, a series of classical urban planning structure models focusing on urban shape reconstruction and advocating macro and magnificent urban structure have emerged. The most typical ones are the reconstruction plan of Paris presided over by Osman and the spatial development plan of cities such as San Francisco and Chicago presided over by Benham. The idea of urban construction in this period was mainly influenced by artistic aesthetics, which was obviously impractical to solve the environmental and social problems of the metropolis at that time.

3. Urban spatial structure under the influence of “natural determinism” (from the second half of the 18th century to the beginning of the 20th century)

The modern industrial revolution not only created great wealth for the city, but also brought disastrous damage to the city. The excessive concentration of population destroyed the family centered structural layout of feudal cities, and profound changes have taken place in the urban

spatial structure. In order to solve the urban problems, people explore the pastoral urban space in pursuit of integration with nature, which reflects the early awakening of ecological thought. For example, Thomas Moore proposed “Utopia” to solve the separation and opposition between capitalist cities and villages, as well as the problems of private ownership and land speculation. Almost at the same time, the utopian socialist companella put forward the “Sun City” scheme, describing a new ideal society without exploitation and property, and clearly proposed for the first time that the urban spatial structure is composed of seven concentric circles. During the period from the formation of capitalism to the development of capitalism in the 18th–19th century, the contradictions in cities became more prominent. At this time, utopian socialists put forward some super class subjective Utopians. Such as Owen’s “new Concorde village” and Fourier’s “Francie” These early theories had obvious “natural determinism” thought, but they provided ideological origin for the later theories such as “garden city” and “satellite town”, and enriched the research in the field of urban spatial structure.

3.1. Ecological thought of urban spatial structure in North America

Influenced by the expansion of European colonists in North America, American cities showed a checkerboard spatial pattern. Under the influence of economic determinism, urban construction in this period appeared overcrowding, traffic chaos, widening the gap between the rich and the poor and so on. In the second half of the 19th century, urban reformers began to think about how to reshape the integration of city and nature.

In the mid-19th century, ecologists represented by marsh launched the movement of building urban park green space system in the United States, advocating the formation of symbiotic relationship between man, nature and other organisms; in 1851, New York began to create the first public park, from the construction of urban park to the use of greening system to divide the city, which is of pioneering

significance in the transformation of urban spatial structure. The 19th century planner olmster made an important contribution in practice. In 1878, in order to improve the urban environment of Boston metropolitan area, Olmsted built an ecological space network within nearly 600 square kilometers, and used five coastal river corridors to connect the suburban green space system, which greatly enriched the urban space form. Influenced by Olmsted, the urban planning of Washington and Seattle follow the natural terrain of the city and form the natural framework of the city based on the natural background of urban rivers, valleys, ridges, wetlands and so on. By the end of the 19th century, some bold planners and urban builders had found that urban planning as a means of political control could no longer solve the current urban problems, so they turned to new theoretical ideas. During this period, the thinking on urban spatial structure has shifted from local adjustment to overall reconstruction.

3.2. Main theories of ecological urban spatial structure in Europe

Soria I Mata’s “belt city”

In the 1980s, the designer Soria Yi Mata put forward the theory of “belt city”, which believed that the expansion of traditional urban space from the core to the surrounding layer was the root of the disorderly spread of the city, and advocated to fundamentally solve the urban problems and change the urban spatial structure. Mata stressed that the city should develop orderly along a main line, with a width of about 40 m and unlimited length. One or more tram lines should be arranged along the spine. The total width of urban construction land is about 500 m, and a 20 m wide transverse road should be arranged every 300 m to connect the land on both sides of the trunk road and form a series of urban units. Each urban unit is divided into small pieces of land by greening, with parks and green spaces on both sides of the periphery. It embodies the main idea of “belt city”. Let urban residents “return to nature”^[2].

Howard's "pastoral city"

The urban transformation movement carried out at the end of the 19th century did not fundamentally change the traditional urban spatial structure. In 1898, Howard, a British sociologist, pointed out that "the city should be combined with the countryside". This combination of urban and rural areas is called "pastoral city"^[3]. The concept of "garden city" is mainly reflected in the following two aspects: the first is the idea of growth limit. When the city reaches a certain scale, another city should accept its excessive growth, that is, build a new city in the "rural" area not far from the central city. Second, the idea of organic combination of urban agglomeration. In order to improve the quality of life of urban residents, it is far from enough to rely on the development of the city itself. It should be solved in the form of broader regional urban alliance, and ensure that the quality of life of each rural city reaches the same level as that of the central city.

4. Theoretical research on urban spatial structure under the influence of "narrow ecological philosophy" (early 20th century to late 1960s)

At the beginning of the 20th century, the development of the ecological theory of urban spatial structure was the first climax. The urban spatial theory of this period began to use ecological ideas. The most typical is that the Chicago school took the lead in establishing urban ecology at the beginning of the 20th century and studied the urban population and land use problems in Chicago with the principle and viewpoint of plant community^[4]. However, it is still influenced by the "natural environment orientation", showing a narrow ecological view, which has certain limitations in theory and practice.

4.1. Ideological evolution of ecological urban spatial structure in Europe

Geddes's "composite city"

Gaidis, a British biologist, is similar to Mumford's idea in promoting the integration of urban and rural areas. He believes that urban and rural areas are an inseparable unity and emphasizes the ecological barrier function of rural natural environment. It is advocated to use "urban areas" instead of urban planning, because urban areas fully integrate the concepts of cities and surrounding villages. Finally, Geddes foresaw the future urban development model: cities will eventually form the form of urban groups, even "world cities"^[5].

Eliel Saarinen's "organic evacuation theory"

In 1918, the Finnish architect Eliel Saarinen put forward the theory of organic evacuation in order to solve various disadvantages caused by excessive concentration of urban population^[6]. Saarinen advocates centralized layout of daily life and work, and infrequent occasional activities are scattered to the periphery of the city. Regions should be separated by protective green belts. Such urban spatial layout mode not only meets the needs of human work and communication, but also meets the needs of people to get close to nature.

Le Corbusier's "bright city"

It is different from Howard's contradiction of avoiding big cities "Guangming city" advocates a new way to transform the city: to solve the problem of urban population congestion by increasing the density. Corbusier believes that skyscrapers are a good form to solve the over concentration of population and the shortage of urban land, and can also improve the efficiency of urban internal operation. High density can bring more green space. By orderly guiding the urban density distribution, employment and living in the city show a reasonable spatial distribution state^[7].

4.2. Ideological evolution of ecological urban spatial structure in North America

Wright's "wide Mu city"

American architect Wright put forward the idea of "Wide Mu City" for urban space expansion in

1932. In Guangmu City, families keep a certain distance and are connected by roads. It is suggested to shape the city with a low-density spatial form, and the whole city is distributed on the natural farmland network. Wright believes that the private ownership of land is the root cause of social injustice. In order to achieve true democracy, each resident owns at least one hectare of land, so that people have half the time in factories and the other half to enjoy nature. It is undeniable that Wright's broad Mu city was put forward under the background of the American automobile era, and its theoretical model inevitably has certain limitations.

Mumford's "organic integration of urban and rural areas"

In the way of thinking of decentralization, Mumford is consistent with Wright, but embodies the principle of maintaining appropriate concentration in orderly decentralization. He believes that the concentrated development of population in big cities or mega cities will eventually lead to environmental pollution, residential crowding and subsequent social problems. The key to solving the problem lies in relieving the population of big cities, building new urban centers, forming a regional unity in a larger scope and maintaining the overall coordination of the region.

"Community Movement" in the United States

Influenced by the British theory of garden city, a "Community Movement" has been launched in the United States, which has overturned the previous community planning method of setting roads in advance and then filling houses into them, and instead built a community space system surrounded by buildings and with open green space. In the planning of Redborn Avenue square, architect Stein designed a pedestrian road system separated from the motorway, which is arranged in a curve through the public green space between houses, and the houses are arranged in groups to form a "pocket shape". Perry, the architect, put forward the theory of neighborhood unit, advocating expanding the neighborhood and forming a neighborhood unit with

the service area of a primary school, so as to make the residents have a kind sense of belonging. The urban construction ideas of "redborn system" and "neighborhood unit" are changes to the traditional urban spatial structure and have an important impact on the later residential area planning^[8].

5. "Humanism" turn and theoretical research on urban spatial structure (1960-1980)

Since the 1960s, with the recovery of the world economy and the continuous outbreak of environmental and energy crises, people began to reflect on their original lifestyles and values. During this period, the research on the theory of urban spatial structure has the most profound influence on the modern urban planning theory. It advocates that the urban public space should be coordinated with the surrounding space, and there should be sufficient recreational and leisure green space in the city. During this period, the concept of urban construction changed from simple "natural ecology" to "historical and cultural ecology", showing a humanistic tendency, which is reflected in the urban spatial structure and presents the characteristics of regionalization and ecology. Represented by Carson's silent spring and the limit of growth of the Rome club, it further aroused people's awareness of ecology.

5.1. Theoretical research on urban spatial structure in the embryonic stage of ecology

"Human settlement" by Ousadias Mchager's "design combines nature"

In 1963, Ousadias created the theory of "human settlement". Ousadias advocates that urban designers and planners should have certain foresight to keep the growth of the city in a single direction, to avoid the consumption of surrounding villages and natural resources. As for the distance of 2 km from pedestrian to urban area, it should be calculated according to the design standard of 2 km for pedestrian to urban area. Ousadias gave guiding

opinions on the model of urban spatial structure to solve the damage of modern urban ecological environment, which is of far-reaching significance to the later research on human settlements.

American ecologist Michael Hager's research on urban spatial structure and environmental problems emphasizes that the urban artificial environment and natural environment are regarded. In his book *Design Combined With Nature*^[9], Michael Hager believes that the selection of open space within the scope of urban land should be based on the natural evolution process of land, and the land left by natural selection is the ecological land in large urban areas, which is emphasized that urban development activities should avoid damage to the ecosystem. The proposal of mchager's urban design concept has created an ecological prelude to the study of urban spatial structure.

5.2. Biosphere consciousness—The practice climax of the green revolution

In 1971, marked by the convening of the man and biosphere program (mab)conference, the urban spatial structure showed obvious biosphere characteristics; the Machu Picchu charter in 1977 advocated the spatial re unification of architecture, city and landscaping, and promoted the coordination between urban space and built environment. In 1978, Simmonds, an American landscape architecture expert, advocated maintaining the continuity of urban natural space in his book—*Landscape Environmental Planning Guide*. After that, Simmons improved mchager's ecological planning method and introduced the concept of visual aesthetics, which enriched the theoretical research of landscape ecology.

5.3. Research on urban spatial structure under the impact of new technological revolution

Vision of future urban spatial structure in Europe

In the 1960s, due to the development of modern high-tech technology, urbanists all over the world

began to think about using technology to transform urban space. They believed that if advanced technology was combined with powerful design concepts, it could bring new order to modern society, and put forward various ideas of future cities. European scholars mainly start with the relationship between urban space and nature and try not to damage the ecological environment. For example, in 1964, British architect cook envisaged "inserting the city". In addition, architects simulate the principle of natural ecology and propose giant structures to form a "centralized bionic city". It is worth mentioning that the "bionic city" envisaged by Italian architect solelli is to build a tree like natural form and simulate the urban spatial structure with the plant ecological image. The constituent elements of the city, such as residential area, industrial area, commercial area, public square and garden green space, are orderly superimposed in the city according to the natural ecological principle of plants. In 1965, solelli conceived a circular "miniature city", which tightly combined land, resources and energy in the urban space to form a giant skyscraper like ecological city. Solelli hopes to save resources and energy through the "miniaturization effect" of the city, occupy as little ecological land as possible, and the urban spatial form is like a compact and efficient "integrated city" like large scale integrated circuits.

Japan's "metabolism" theory

Because the purely optimistic "technology domination theory" can not solve the urban problems, the urban construction movement in Japan during this period once again reflected the essential characteristics of Utopia, but had a significant impact on the urban landscape of Tokyo. Finally, the complex appearance of urban spatial structure reflected different urban design ideas including two prototypes of "giant structure" and "collective form".

In the 1960s, the Tokyo World Design Conference produced "New Chendai Xie 1960 Proposals for New Urbanism", calling for a complete transformation of modern cities and bringing a new order to the city. During this period, Japan's urban space design concept was mainly influenced by two

factions represented by Kurokawa Kisho and Kiyomizu Kiyomizu, the theoretical research on the “megastructure” that regards the city as a biological organism, and the theoretical research on the “megastructure” of the city as a biological organism. The theoretical study of “group modeling”. Kiyomizu Kiyomi’s “tower shaped city” and “sea city” became the precedents for later metabolism projects. He believes that vertical megastructures can be freed from the traditional city composed of streets and blocks, and the rest of the land is reserved for ecological natural space, making the city an efficient city built for work and life. The idea of “city on the sea” tries to go beyond what he called “Continental Civilization”, using the form of building a floating city on the sea, replacing Le Corbusier’s “sunshine, air and green” with his own “sunshine, air and water”, so that people can get rid of the competition and aggression for land, and create a new form of ecological space. In his “Space City”, Kurokawa Kisho suggested that Tokyo should be rearranged in the form of a cross regiment and stretched out from the existing city center. Masahiro Otaka and Fumihiko Maki are not satisfied with a completely theoretical virtual plan, they hope to create a new relationship between individual elements and the overall space, that is, “group modeling”, which is different from the traditional way of combining architectural spaces, that is, when a certain When elements are separated from the whole or new elements are added, the whole can still maintain a harmonious and stable state.

6. Theoretical research on urban spatial structure under the influence of contemporary “generalized ecological philosophy” (since 1980s)

In the 1980s, the ecological concept has gradually penetrated into the hearts of the people, and the idea of human settlement has also penetrated from simple environmental protection to the fields of society, ecology and culture. Some developed countries have entered the advanced stage of

urbanization and are moving towards the “ecological era”, and the global ecological environment concept has gradually formed. During this period, people’s attention to urban space has changed from simple material space planning to “broad ecological philosophy” of coordinated economic and social development.

6.1. Regional ecology—Further international attention to the ecology of urban spatial structure

Since the 1980s, the world has begun to find a way of coordinated development aimed at the high integration of human settlement environment and natural environment, with the research of “ecological city” as a typical example. The Australian urban ecology association, the European Union and the five International Eco City Conferences since the 1990s have made meaningful discussions on the methods and technologies of eco city construction and the sustainable use of urban land in theory and practice.

Richard register is the most typical eco city research in the world. In 1987, in his book ecological city Berkeley^[10]. Reggiest described in detail how the American city Berkeley evolved into a space with full integration of urban and rural areas, and put forward 10 design principles of “ecological structure revolution” in 1990. In 2002, reggiest comprehensively introduced the construction modes, methods and concepts of ecological city or quasi ecological city in the world, put forward a new perspective of urban and township construction, and outlined a beautiful blueprint for ecological city construction.

6.2. Theoretical research on the spatial structure of domestic ecological city since 1980s

Domestic research on eco city space issues began in the 1980s, reflecting domestic scholars’ inheritance of oriental classical culture and reference to international excellent results. The research on domestic eco city is represented by Ma and Wang.

Wang first proposed the concept of “society-economic-natural complex ecosystem” in the 1980s, marking a new breakthrough in the theoretical research of eco city^[11]. In 1990, Professor Qian put forward the theory of “landscape city”, advocating the transformation of cities with Chinese classical afforestation culture^[12]. Huang and others believe that eco city is the unity of natural, social and economic functions, which expands the research of urban spatial structure in the field of ecology^[13]. Starting with urban ecology, Shen put forward the theoretical framework of the basic principle of Urban Space Ecology^[14]. Yao put forward the layout ideas of constructing regional overall space of ecological city based on the comparative study of the urban construction of Cologne and Nanjing^[15]. Gu put forward the corresponding optimization model of ecological city spatial structure in combination with practice^[16]. Zhou summarized and studied the ecological oriented urban spatial structure, and systematically expounded the research contents and characteristics of each stage^[17]. Qiu conducted a systematic study on the principles, modes and methods of spatial construction of eco city^[18,19].

Since the 1980s, the planning and architecture circles have made important achievements in the research on the ecology of urban spatial structure, represented by Huang and Yu. Huang creatively put forward the spatial structure model of “green heart ring” ecological city in Leshan regional planning in 1993, established the framework of regional environmental circle of “city in landscape and mountain forest in city”, and embodied the oriental philosophy of urban-rural integration. Yu believes that urban ecological infrastructure is the guarantee for cities and residents to continuously obtain natural ecological services, and proposes to establish an urban ecological safety network to ensure the naturalness and ecology of urban living environment and improve residents’ quality of life^[20].

Since the beginning of the 21st century, under the guidance of the concept of “ecological civilization”, urban space attaches importance to the regional ecological environment. Chengdu,

Zhangjiagang, Yangzhou and Changsha all aim to build an ecological city. Hainan Province, Shaanxi, Heilongjiang and other provinces also put forward the goal of building an ecological province. The construction of these eco cities or quasi eco cities may be different from the connotation of eco cities in the real sense, but in different aspects, it reflects people’s desire to pursue the ideal living mode and build an urban spatial structure harmonious with nature, indicating that China has embarked on a bright journey of exploring eco cities.

Since ancient times, ecological thought has always run through the formation and development of urban spatial structure, and has experienced the changes of “primitive ecological view”, “natural determinism”, “environmental orientation”, “narrow ecological philosophy”, “broad ecological view”. This evolution is not accidental regression and passive adaptation. It is the infiltration of human settlement thought from the simple view of natural environment to society, economy, culture and other aspects. It has gradually formed a diversified and broad view of human settlement environment ecology, and has become the spiritual main line that can not be ignored affecting the urban spatial structure, which is mainly reflected in:

1. The urban spatial structure must meet the coordination between man and nature and between people, and realize social and economic development on the premise of sustainable utilization of resources and environmental protection, that is, meet the spatial concept of sustainable development.
2. The coordination between urban space and natural environment is the most typical function of urban ecological system.
3. The planning of urban spatial structure system should select human settlements according to the ecological security space left by nature, to realize the real “harmony between man and land”.
4. Emphasize the restriction of natural environment in the process of urban space

development and embody the concept of development limit.

In short, the research on urban spatial structure from the perspective of ecology is still in the stage of theoretical exploration, and the practice of urban construction at home and abroad is also slightly weak. Moreover, there is no systematic standard in China, and the spatial structure model for planning and construction is not clear; in terms of the study area, it is dominated by local urban areas or new towns, and there is a lack of research on the overall structure of cities or regions. Therefore, from the perspective of future ecology, the integration of urban residential environment and natural space in structure, function and form will become a hot spot in the field of ecological research of urban spatial structure.

Conflict of interest

The authors declare no conflict of interest.

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