

THE IMPACT OF ENVIRONMENTAL AND ECOLOGICAL CONSTRUCTION ON THE  
SUSTAINABLE DEVELOPMENT OF CITIES: A CASE STUDY OF NANJING, JIANGSU  
PROVINCE, CHINA

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The Impact of Environmental and Ecological Construction on the Sustainable Development of  
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## A CAUTION TO THE READER

This HBEM thesis has been through a semi-formal process of review and comment by at least two faculty members. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional and scientific forestry.

The reader should be aware that opinions and conclusions expressed in this document are those of the student and do not necessarily reflect the opinions of the thesis supervisor, the faculty or Lakehead University.

## ABSTRACT

Today, urban development faces an ecological crisis. As a famous historical and cultural city in China, the contradiction between the morphological development of Nanjing and the ecological environment is becoming increasingly acute, and the city's ecological regulation function tends to be fragile. Because cities are not only the birthplace of human technological progress and social and economic development but also an important source of human-environmental problems and environmental crises, the problem of the urban ecological environment has aroused the widespread concern of governments and scientists of various countries. In this context, the sustainable development of urban morphology with Nanjing as an empirical study is undoubtedly of great significance to the sustainable development of cities in China and the world. It also provides a certain reference and ideas for the development of modern cities.

In terms of ecological environment research in Chinese cities, single-element research has developed rapidly and in-depth, such as urban climate, urban geomorphology, urban hydrology, and urban environmental pollution. The above elements are all published in monographs, but systematic and comprehensive urban ecological environment research is rare. This means that studying urban ecological environmental problems, exploring effective treatment measures for urban environmental pollution, and coordinating the contradiction between social-economic development and urban ecological environment have become major issues waiting to be resolved in modern urban ecological environment research.

This thesis systematically summarizes the concepts and characteristics of sustainable urban development, and combines the natural and social environment to systematically analyze the ecological process and the laws of the evolution of Nanjing's urban form. I then use different measurement methods to calculate the compactness of Nanjing's urban form to grasp its spatial form's expansion trend dynamically. At the same time, I will go back to compare and study the pros and cons of several typical development models to explore the rational choice of sustainable development of Nanjing city. In addition, this thesis attempts to initially establish an index system for the sustainability evaluation of urban morphology, and uses mathematical statistics to perform calculations and analysis to make a comprehensive evaluation of the sustainable development capability of the urban morphology of Nanjing.

Key words: City, ecology, eco-city, environment, sustainable development

## CONTENTS

LIBRARY RIGHTS STATEMENT.....	iii
A CAUTION TO THE READER.....	iv
ABSTRACT.....	v
CONTENTS.....	vi
ACKNOWLEDGEMENTS.....	vii
INTRODUCTION AND OBJECTIVES.....	8
LITERATURE REVIEW.....	12
MATERIALS AND METHODS.....	28
RESULTS.....	30
DISCUSSION.....	38
CONCLUSION.....	58
LITERATURE CITED.....	63

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## INTRODUCTION AND OBJECTIVES

### 1. Research Background

With the acceleration of urbanization worldwide and the intensification of urban environmental problems, people have increasingly realized the importance of strengthening the ecological construction of urban greening and improving the quality of the urban ecological environment. Many countries have begun to position urban environmental and ecological construction as an essential part of sustainable urban development. A good environment is the foundation of social and economic development in rapid social and economic development. If we want to achieve sustainable social and economic development, we must thoroughly solve the problem of environmental destruction so that environmental problems will no longer be a factor that plagues sustainable social and economic growth.

Investigating the root cause of ecological and environmental problems is, to some extent, a development problem. Economic development will inevitably bring about some ecological and environmental problems. In particular, China, as the world's largest developing country, has achieved accelerating economic growth, but ecological damage and environmental pollution have also become prominent. In the 20th century, China followed a development model similar to developed countries, but the consequence was that the deterioration and speed of the ecological environment far exceeded the speed of economic development, and the government had to start paying attention to this issue. However, is it necessary to continuously squeeze ecological resources to cause its deterioration in pursuit of economic growth? Or will the protection of the ecological environment necessarily hinder economic



development? This is an important topic that everyone in China and the world has been studying.

## 2. Research Significance

Urbanization promotes the prosperity of society, economy, and culture, but the rapid depletion of natural resources also accompanies it. The continuous deterioration of the natural ecological environment and the quality of the urban environment, as well as the unbalanced rapid growth of population, have become a major obstacle to the sustainable development of cities. Nevertheless, sustainable development is the only way to urbanization in China. Its core is to meet the needs of contemporary people without compromising the ability of future generations to meet their own needs. Countries have widely accepted this concept all over the world. In the process of rapid urbanization in China, how to apply the concept of sustainable development to build and manage cities and strengthen the improvement of urban ecological environment quality is not only a key task faced by governments at all levels, but also an important content of environmental science and engineering research. It has important theoretical and practical significance to carry out the evaluation research on the sustainable improvement of the urban ecological environment.

### 2.1 Theoretical significance

The protection of the ecological environment is vital to national development, and sustainable development can only be achieved if the ecological environment is guaranteed. It was not until the beginning of this century that Nanjing actually implemented the official

national policy of the Chinese government on ecological environment construction by the end of the last century. This thesis takes the sustainable development of the ecological environment in Nanjing as the research goal, trying to study the mutual influence between it and sustainable development theoretically. In addition, this thesis also studies the urban water environment and urban forest construction in Nanjing and analyzes the impact in different time periods (long-term and short-term) to further improve the research in the field of ecological environment construction and sustainable development.

## 2.2 Practical significance

Eco-environmental issues are related to the sustainable development of the entire human society. Therefore, these issues can increase the awareness of government departments and various large and small enterprises on protecting the ecological environment and encourage them to actively participate in research and implementation of policies. In addition, the urban water environment is an important issue that restricts urban economic development and affects the urban natural environment. The main body of the implementation of the social water cycle is the water industry, which takes cities as the object and engages in the sustainable development, utilization, and protection of water to meet the water quantity and quality required by the sustainable development of the social economy. At the same time, urban greening can also improve the quality of the city's ecological environment. But, unfortunately, in China's urban greening work, there is currently a phenomenon of one-sided emphasis on the effect of green space, blindly pursuing area and ignoring the ecological process, greatly reducing the ecological function of urban forests. Urban water environment

issues are closely related to the sustainable development of cities, and urban greening and forest construction can also promote the construction of sustainable development. By comparing and analyzing the status quo of Nanjing's ecological environment and the actual situation of urban development, not only can we discover the current problems in Nanjing and promote the sustainable development of the city, but also provide a reference for the sustainable development of large cities in other surrounding areas.

## LITERATURE REVIEW

The preliminary discussion on the urban form can be traced back to ancient times. Both the Hippodamus model in ancient Greece and Miletus, a seaport city, have evident artificial traces. They are all embodied in a complete and strong composition form, establishing a new urban order and urban conception. These have a far-reaching impact on the later sustainable development planning of urban morphology in the West (Brotchie 1985). The state management system of "Rite of Zhou - The Artificers' Record" in ancient China also embodies the idea of sustainable urban planning that has urban order and satisfies the will of the ruling class (Brotchie 1985).

After that, the research on urban morphology has entered a new stage. In the long-term development, this type of research has continued to deepen and set off a wave of research in many fields such as urban science and architecture. In order to have a deeper and more precise understanding of the development status of the sustainable development theory of urban morphology, the following is a review of the relevant theories and practices in countries outside China and in China.

### 1. Progress in theoretical research and practice in other countries

#### 1.1 Theoretical Research Progress

In the "Man and the Biosphere (MAB)" program initiated by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in the 1970s, the eco-city, a brand-new urban concept and development model, was first proposed (Ma 2005). In 1987,

Soviet ecologist Yanitsky explained the design and implementation stages of eco-city as shown in Table 1. Rusong Wang summed up Yanitsky's thinking as "a kind of coordinated development of society, economy, and nature-based on ecological principles. It can make efficient use of matter, energy, and information. This is an ecologically virtuous circle of human settlements, in other words, an efficient and harmonious human habitat" (Wang 1988).

Table 1. Yanitsky's 'eco-city' design and implementation matrix changes over time.

The level of knowledge and action	Basic Research (I)	Applied Research (II)	Urban Design (III)	Construction process (IV)	The formation of urban organic organizational structure (V)
Historical and cultural level	√				√
Social function level		√			√
Temporal and spatial level			√	√	

In 1996, the "Urban Ecology" organization led by Register (1996) put forward ten principles for the establishment of a more complete urban ecological environment:

- 1) Modify the priority of land use development, give priority to the development of compact, diverse, green, safe, pleasant, and vibrant mixed land use communities, which are close to bus stations and transportation facilities;
- 2) Modify the priority of transportation construction, put walking, bicycle, carriage and public transportation mode in priority over the car model, and emphasize the nearest

travel;

3) Repair the damaged urban natural environment, especially rivers, seashores, ridgelines, and wetlands;

4) Build a decent, low-cost, safe, convenient, multi-ethnic, and economical mixed residential area;

5) Cultivate social justice and improve the lives and social conditions of women, colored ethnic groups, and the disabled;

6) Support localized agriculture, support urban greening projects, and realize the westernization of communities;

7) Promote recycling, adopt new and excellent technology and resource protection technology, and reduce the discharge of pollutants and dangerous goods at the same time;

8) Work with the business community to support economic activities with good ecological benefits while suppressing the discharge of polluting waste and the production and use of hazardous and toxic materials;

9) Promote a consciously simplified lifestyle and oppose excessive consumption of resources and commodities;

10) Improve public awareness of the local environment and biological regions through publicity activities and educational projects that increase the public's awareness of sustainable ecological development.

The principles of eco-city development proposed by the Urban Ecology Association of Australia (UEA) are: Restoration of degraded land; coordinated and balanced development of urban development and biological regions; achieve the balance between urban development

and land carrying capacity; end urban sprawl; optimized energy structure, commit to using renewable energy, such as solar and wind energy, and reduce fossil fuels consumption; promote economic development; provide healthy and safe community services; encourage community participation in urban development; improve social equity; protect historical and cultural heritage; cultivate colorful and rich cultural landscapes; correct damage to the biosphere (Huang 2001).

The key principles of the sustainable development of human settlements proposed by the European Union are: resource consumption budget; energy conservation and improvement of energy efficiency; development of renewable energy technologies; long-term use of building structures; residential and working places close to each other; efficient public transportation system; reduction of waste generation and recycling; use of organic waste to make compost; implementation of a circular urban metabolism system; and local production of food. Eco-design experts also consider these to be the basic concepts of urban eco-environmental construction (Huang 2001).

The Australian Urban Ecology Association and the European Union's urban ecological environment construction principles emphasize the modification of the unreasonable content of the existing urban system, and the specific measures proposed are aimed at the unsustainable characteristics of urban problems. Although these principles are not systematic, their guiding significance for practice is very significant.

## 1.2 Practice in the construction of urban ecological environment in countries other than China

### 1) Japan's progress in the construction of eco-city (Li 2003)

Japan put forward the concept of eco-city as early as the 1980s. Especially in large cities with high population density such as Tokyo and Osaka, there are not only waste disposal problems but also environmental problems that directly endanger human health, such as air pollution, water pollution, and soil pollution. These problems are mainly caused by the unreasonable layout of urban land use and energy utilization. In the past 20 years of practice, Japan has developed many methods and technologies for building an eco-city, which mainly can be divided into two: rational use of energy, adjustment of land use layout, and completely recycled housing.

### 2) Urban Ecology and Environmental Construction in Curitiba, Brazil (Li 2003)

Curitiba in southern Brazil is the ecological capital of Brazil and is considered the closest city in the world to an ecological city. Its primary experience lies in bus-oriented urban development planning, which integrates urban design, planning, and management. Through the pursuit of highly systematic, gradual, and thoughtful urban planning and design, the integration of land use and public transportation has been realized, and outstanding achievements have been made. At the same time, it also pays attention to social welfare projects and provides comprehensive environmental education to citizens.

### 3) Healthy Eco-city Planning in the Netherlands (Li 2003)

In 1990, the "Long-term Environmental Policy Conference" in the Netherlands proposed five gradual stages in the formulation of healthy eco-city planning policies:

- environmental pollution as a negative effect
- environmental pollution as a cost factor
- environment as a limiting condition



- environment as a policy guiding factor
- environment as a goal

## 2. Progress in China's theoretical research and practice

### 2.1 Theoretical Research Progress

Famous Chinese ecologists Shijun Ma and Rusong Wang (Ma 1984) put forward the theory of "society-economy-natural complex ecosystem" and clearly pointed out that cities are typical social-economic-natural complex ecosystems. On this basis, Rusong Wang conducted in-depth research on urban issues and ecological cities. Through experiments and research, they speculate that the ecological nature of urban problems is shown in Table 2. The construction of an urban ecological environment must meet the following standards:

Table 2. The ecological essence of urban problems.

Problem	Principle	Countermeasure	Methodology	Target
Inefficient use of resources	Regeneration and competition	Technological transformation	Ecological Technology	High efficiency
Unreasonable system relationship	Symbiosis and co-evolution	Relationship adjustment	Ecological planning	Harmonious relationship
Low self-regulation	Self-learning	Behavior Induction	Ecological Management	Strong vitality

Satisfaction principles of human ecology include satisfying human's physiological and

psychological needs, satisfying real and future needs, and satisfying human evolution needs.

The high-efficiency principle of economic ecology includes the effective use of resources; the principle of minimum manual maintenance: the city is self-sustaining to a large extent, with minimal external input energy; the overlapping effect of the space-time niche: the multiple utilization value of the urban material environment; optimization of social, economic and environmental benefits.

The principle of harmony in the natural ecology, in other words, is the principle of symbiosis: including the symbiosis between man and other living things or man and nature; the principle of self-purification; the principle of continuity.

Eco-city is a sustainable development constructed by comprehensively studying the social-economic-natural complex ecosystem based on the principles of ecology, and applying a series of modern scientific and technological means such as ecological engineering, social engineering, and systems engineering. According to Jun Hu, the construction of the urban ecological environment needs to emphasize the expansion of natural ecological capacity (such as increasing the open space of the city and increasing the rate of green space) and adjusting the economic and ecological structure (such as the development of clean production, the tertiary industry, and the technological transformation of polluting industries), a series of planning methods such as controlling the scale of social ecology (such as determining the reasonable scale of urban entrances and carrying out the reasonable distribution of the population) and improving the self-organization of the system (such as establishing an effective environmental protection and sanitation facility system) to promote the economic, social and environmental development of the city's coordinated development. Establishing an

ecological city is one of the fundamental ways to solve the problems of modern cities.

The above literature review shows that the content of theoretical research on urban ecological environment construction in various disciplines in China is relatively affluent. Unfortunately, the Chinese ecology community has not been able to unite with the planning academia and other disciplines to carry out a more influential and in-depth urban ecological environment research program. This makes the existing research and practice of China's urban ecological environment construction unable to produce more positive significance for urban planning and sustainable urban development.

## 2.2 China's Practice in the Construction of Urban Ecological Environment

As early as 1988, Nanjing City, Jiangsu Province, first proposed the development goal of building an eco-city nationwide. Then, in 1989, it carried out a pilot project of eco-city planning and construction, which can achieve the first step in China's eco-city construction. At the current stage, Hainan, Jilin, Heilongjiang, Zhejiang, Shandong, and Fujian have carried out the construction of the urban ecological environment. Many cities such as Shenzhen, Shanghai, and Harbin are planning the construction of the urban ecological environment. This reflects the concern and attention of Chinese cities from the government to the people on ecological and environmental issues and the urgent desire to improve the quality of urban life. It means that Chinese cities are embarking on the path of ecological construction.

In August 2002, the Fifth International Eco-City Conference was held in Shenzhen, China. The conference produced the "Eco-City Construction Shenzhen Declaration" on urban ecological environment construction's basic goals and principles. In the same year, the

Ministry of Environmental Protection also issued the "Eco-Counties, Eco-Cities, and Eco-Province Construction Indicators." These have greatly promoted the development of the theory and practice of China's urban ecological environment construction.

### 3. Research status

#### 3.1 Research status in other countries

The concept of SEA (Strategic Environmental Assessment) was originally proposed by Lee N. Wood and Walsh F. (Lee 1992) in the United Kingdom. Now widely accepted is the definition given by the scholar Riki Therival of the Centre for Environmental Impact Assessment at the University of Manchester: Strategic Environmental Assessment refers to a systematic and comprehensive evaluation process of the environmental impact of Policy, Plan, Program and their alternatives, including a written report submitted based on the evaluation results and the evaluation results used in comprehensive decision-making (Therivel 1992). It analyzes and evaluates the environmental impact of social and economic activities triggered by the strategy, and proposes corresponding environmental protection countermeasures or revised strategies and adjustment suggestions to avoid or minimize the environmental impact caused by decision-making errors, which can promote social, economic, and social sustainable development of the environmental system. SEA is gradually being accepted by more countries and has become one of the essential support tools for sustainable development strategy decision-making. Among them, Buckley lists seven main types of SEA:

- (1) Environmental assessment of the policies or policy changes currently implemented by the government;
- (2) Evaluation of elements related to specific environmental issues, such as biodiversity

conservation and reduction of greenhouse gas emissions. The most significant advantage of this type of SEA is that it comprehensively and uniformly considers environmental issues common to different sectors (Buckley 1998);

- (3) Regional or national environmental assessment and planning;
- (4) Evaluation of environmental problems caused by changes in social and economic factors;
- (5) Environmental assessment of scientific and technological progress;
- (6) Environmental assessment of a certain industrial sector of the national economy and its development direction;
- (7) Research on the environmental impact assessment framework system of similar development projects.

Buckley pointed out that the role of SEA should be reflected in its impact on strategic decision-making, and the way to improve the effectiveness of SEA is to incorporate it into the current conceptual framework of policy and planning decision-making processes. The core content of this conceptual framework is to implement SEA in the entire process of policy and plan formulation and implementation. The key to measuring the success of SEA lies in the quality of the final decision and the degree of SEA's influence on decision-making. Thus, SEA will promote the achievement of sustainable development goals through its influence on decision-making methods.

The development of SEA can be traced back to the National Environmental Policy Act (NEPA) of the United States passed in 1969. Article 102 of the third chapter of the law stipulates that any legislative proposal that has an important impact on the classified environment, as well as

important actions determined by policies and federal agencies, must be subject to environmental impact assessment (Ding 2002). The Netherlands established the statutory SEA system in 1987. Then in 1990, the Canadian Cabinet instructed all ministries to pay attention to the environment at the strategic level of policy, planning, and planning, which represented that SEA gradually attracted attention. In February 2000, South Africa issued the "South Africa Strategic Environmental Assessment", the main content of which is the SEA Guidelines for Planning and Planning (Guideline Document 2000). Japan's SEA made relevant provisions on the environmental impact assessment of harbor plans in Article 19 of the 1993 Environmental Basic Law. It is a SEA for the establishment of harbors and the planning stage of filling projects.

### 3.2 Current Status of Research in China

In recent years, due to the rapid growth of China's economy, it has inevitably consumed a large amount of natural resources. Thus, the development model of high investment, high consumption, and high emissions has severely damaged China's ecological balance. Over the past decade or so, the field and scope of new urbanization construction have become larger and larger, and the contradiction between the sustained development of the national economy and the deterioration of the social ecological environment has become more and more prominent. Therefore, many experts and scholars have conducted research on this issue. As China's urbanization process is later than other Western countries, the research on urban ecological environment problems in China is slightly lagging behind. In the 1960s, China's research on environmental science had just begun. Since the 1970s, China's ecological

environment research has finally entered a new stage. The first is the UNESCO "Man and the Biosphere Project" with China's participation; second, in 1987, the International Symposium on "Urban and Suburban Ecological Research and Its Application in Urban Planning and Development" was held in Beijing. The success of the conference marked that China's research on the urban ecological environment has entered a new stage.

After the 1980s, it was a period of vigorous development of Chinese urban ecological environment theory. With the acceleration of China's urbanization process, domestic academic research on ecological and environmental issues has been developed by leaps and bounds, and the theories and methods of research have also been greatly innovated. For example, the well-known scholar Shijun Ma put forward a unique ecological system thinking in the context of studying China's specific national conditions, that is, to realize the complex development of society, economy and nature by dealing with the relationship between human beings and the environment (Ma 1984). Rusong Wang used the principles of ecosystem optimization, cybernetic methods, and pan-target planning methods to study urban ecology, and constructed an urban ecosystem system from multiple perspectives such as nature, society, economic structure, and production (Wang 1984). After entering the 1990s, Chinese academia paid attention to the construction of ecological cities as a new research point and conducted in-depth research from multiple angles. This includes the evaluation criteria of the eco-city, the principles of creation, and the definition of basic connotations, which promote the theoretical innovation of research work. Since then, various disciplines have carried out multi-angle and in-depth research work on the urban ecological environment from their own fields, which has greatly promoted the development of China's urban ecological environment

theory.

In terms of environmental and ecological protection and urban macroeconomics, the earliest research was the proportion of investment in constructing the ecological environment in the GDP. These investments are mainly used for environmental protection infrastructure construction and pollution control technology and equipment investment. Economists represented by Yining Li define the source channel of investment in ecological environment construction as the reason that will impact the economy. When environmental protection investment reaches a certain proportion, its impact on the economy will appear, but As for what kind of influence it is, it needs to be analyzed in detail (Li 1984). Jie Su used co-integration theory to conduct empirical research on China's environmental governance investment and GDP data from 1990 to 2007, and the results show that there is a long-term stable equilibrium relationship and a short-term volatility relationship between the two (Su 2009).

In terms of theoretical research, Jun Lu believes that the indicator system for planning environmental impact assessment should include five systems: natural environment indicators, ecological environment indicators, resource utilization indicators, energy utilization indicators, and socio-economic indicators (Lu 2006); Huashan Xiao conducted research on planning environmental impact assessment methods (Xiao 2003); Jihua Wang established the IMOPREES planning environment model through research and successfully applied it to the planning impact assessment of Nanjing (Wang 2004); Chunzhi Chang used the selected environmental factors to construct and evaluate the environmental carrying capacity index system, which was able to achieve the consistency between the sub-item evaluation and the



comprehensive evaluation (Chang 2007); In the book "Strategic Environmental Assessment", Tan Zhu used a chapter to discuss the scope and classification characteristics of planning environmental impact assessment, evaluation procedures, evaluation content, monitoring and follow-up evaluation, public participation, and evaluation methods (Zhu 2005); Jincheng Shang has conducted in-depth explorations on the theoretical research and practice of planning environmental impact assessment (Shang 2003); Lei Wang proposed implementing the concept of sustainable development and circular economy in planning environmental impact assessment and using circular economy theory and methods to guide planning environmental impact assessment (Wang 2006).

The above scholars have different research perspectives, research methods, and research fields. However, this does not mean that their views will be very different. On the contrary, from the above literature review, we can conclude that there is a certain interactive relationship between the urban environmental and ecological construction and the sustainable development of the city, no matter what time span, time period, or different region is viewed.

#### 4. Conclusion of Literature Review

##### 4.1 Review of Research in Countries Outside China

The above has summarized and summarized the research on urban morphology from the perspectives of various related fields and different scholars in countries outside China, from which we can understand the research methods and research results of various urban morphology outside China. This empirical study of this thesis can provide theoretical and methodological reference and enlightenment.

## 4.2 Review of Research in China

In terms of the evolutionary law of urban morphology, scholars have summarized a series of key points after research, such as: function, elements, and structure of the environment; the alternating law of "diffusion" and "clustering" phenomena; unbalanced development and evolution of self-organization; and the fractal and the law of evolution. The exploration of these morphological evolution phenomena is of great significance to the construction and development of contemporary cities.

The urban ecological environment is a complex and diverse overall and comprehensive ecosystem for the urban ecological environment. Therefore, we must take measures to achieve the sustainable development of the urban ecological environment based on a high degree of harmony and coordination between the various parts of this system. The urban ecological environment system emphasizes that the comprehensive development of society and economy must maintain the long-term use of resources and the environment. This also requires us to strengthen the construction of the urban ecological environment and strengthen the construction of urban ecological environment self-regulation capacity to promote the comprehensive and coordinated development of the urban ecological environment composite system. At present, Chinese scholars have begun to pay attention to the critical impact of ecologicalization and informatization on the development of urban morphology.

## 4.3 General Research Review

Looking at the above extensive research results on urban morphology, experts and

scholars from all over the world have conducted different degrees of discussion on various aspects of urban morphology from different disciplines. As a result, we can have an intuitive and perceptual understanding of the urban form and observe its essence through the phenomenon. Today, with the deepening of sustainable development and ecological planning, the urban form is extending in a more diversified direction.

## MATERIALS AND METHODS

The research method of this paper is to use empirical research to conduct in-depth analysis, summary, and exploration of the laws and patterns of urban morphological development under a systematic theoretical framework. There are both intuitive discourses and causal explanations, and on this basis, the enlightening prediction of the future development of Nanjing's urban form has important methodological significance. The subject research of this article involves a wide range and complex content, mainly using the following four types of research methods:

(1) Literature research.

Combining and summarizing the relevant research on the sustainable development of cities in academic circles lays the foundation for making relevant suggestions to promote the sustainable development of cities. Objective 1 is to collect basic data and new theoretical results and practical experience of urban morphology research in China and other countries; objective 2 is to consult relevant literature and history materials, dissertations, various academic journals and magazines, environmental quality bulletins, and relevant textual materials of the Nanjing City Planning Department.

(2) Case analysis.

Objective 3 is to analyze domestic cases of promoting sustainable urban development in recent years to explore these specific practical experiences and improvement measures.

(3) Remote research.

Objective 4 is to conduct remote network surveys of Nanjing, especially the key areas

involved in the research content, to obtain basic information and intuitive feelings of urban spatial morphology; conduct research and consultation with relevant planning management and planning and design departments of Nanjing, collect graphics and data information, and collect interviews with relevant experts and citizens on the Internet to summarize the content and enrich the information.

(4) Comparative analysis of combining theory with practice.

Through the research on the scientific concept of development and the summary of the current theoretical research on promoting the sustainable development of Chinese cities, I use the case study method to explore how to promote the sustainable development of Nanjing. Through the comparative study of charts and data, using the methods of hypothesis and deduction, the future urban form of Nanjing based on ecological principles is proposed.

## RESULTS

### 1. Basic overview of Nanjing City

As the provincial capital of Jiangsu Province and a national sub-provincial city, Nanjing has always been one of the core cities in the Yangtze River Delta region. Nanjing is one of the first national historical and cultural cities in China and has long been southern China's political, economic, and cultural center. The total area of the city is 6587 square kilometers. In 2021, the total registered population of the city will reach 8.3 million, of which the registered population will be about 6.7 million, and the registered urban population will be about 6.8 million. The city's urbanization rate will reach 83% (Zhou 2020).

### 2. State of Natural Resources in Nanjing City

#### (1) Water Resources

Nanjing is located in the middle and lower reaches of the Yangtze River. The city's waters include the branches of the Yangtze River, Qinhuai River, Chuhe River, and other water systems. It belongs to the eastern coastal area and has many rivers. Nanjing's climatic conditions are relatively complex, and it belongs to the northern subtropical zone and the climate transition zone between northern and southern China. The city's average annual precipitation is 1,100 mm, the average annual water resource is 2.6 billion cubic meters, and the per capita water resources are 475 cubic meters; other water resources, such as surface water totaling 1.9 billion cubic meters, and groundwater totaling 690 million cubic meters m (Zhou 2020).

## (2) Land Resources

Nanjing covers an area of 6,587.02 square kilometers, ranking last in Jiangsu Province in terms of area per capita. In 2020, the city's arable land area is 2,371.7 square kilometers, and the per capita arable land area is 0.4 mu, which is slightly lower than the national per capita arable land area (Zhou 2020).

## (3) Mineral Resources

So far, nearly 60 kinds of mineral resources have been surveyed in Nanjing. The total resources of more than a dozen common metal minerals such as aluminum, iron, and silver are ranked first in Jiangsu Province, and even some of these resource reserves are among the best in the country. The city's average annual output of iron ore accounts for about 39% of the total iron ore output in Jiangsu Province, and strontium ore is not only high in output but also of superior quality, ranking first among countries in East Asia (Zhou 2020).

## (4) Ecological Resources

Nanjing has a subtropical climate and is rich in various plants, with many varieties and large yields. So far, the city's ecological garden coverage rate is about 27%, of which the green coverage rate in built-up areas accounts for about 47%, and the per capita green space occupies an area of about 14 square meters. Nanjing is rich in natural ecological resources, with more than 100 kinds of rare animals and plants, such as national and provincial protected animals and scarce Chinese herbal medicines (Zhou 2020).

# 3. State of energy and environment in Nanjing City

## (1) Water Environment

In 2020, the total sewage discharge in Nanjing was 232 million tons. Among them, the discharge of industrial sewage was 108 million tons, an increase of 8% year-on-year; the discharge of urban domestic wastewater was 115 million tons, an increase of about 5% year-on-year; the discharge of rural domestic wastewater was 48 million tons, an increase of less than 1% year-on-year (Zhou 2020 ).

## (2) Air Environment

The city's total exhaust gas emissions were 878.213 billion cubic meters, and sulfur dioxide emissions were 101,500 tons. Among them, industrial sulfur dioxide emissions were 100,500 tons, accounting for 99.01% of all sulfur dioxide emissions; soot emissions were 84,100 tons, of which industrial soot emissions were 72,500 tons, accounting for 86.21 percent of all soot emissions (Zhou 2020).

## (3) Industrial Solid Waste

The city's total industrial solid waste discharge was 14.7536 million tons. Among them, the discharge of hazardous solid waste is 493,400 tons, accounting for 3.34% of the city's industrial solid waste discharge; the comprehensive utilization volume is 13.2119 million tons, the waste treatment volume is 1.352 million tons, and the comprehensive utilization rate is 89.55% (Zhou 2020).

## 4. Analysis of ecological environment in Nanjing City

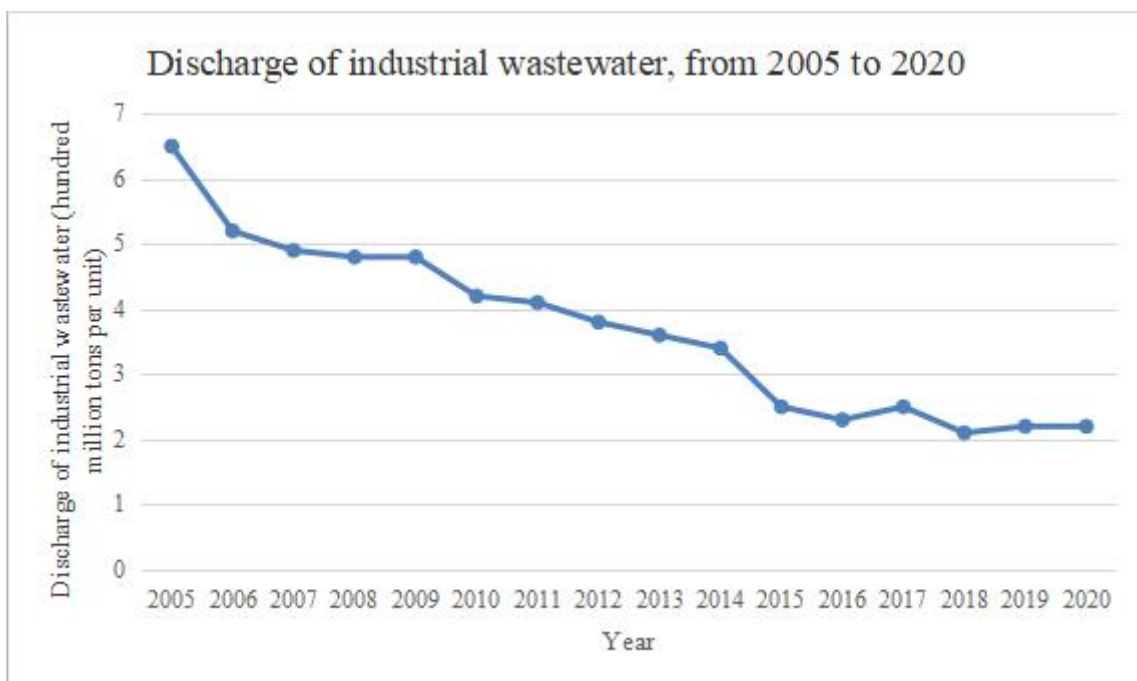
Nanjing has made great efforts in ecological construction and environmental protection over the years, investing a lot of human resources, material resources, and funds. Generally speaking, the efforts made are not in vain, and the results have been quite fruitful. However,



due to various reasons such as unstable investment channels and low investment efficiency, irregular capital acquisition and use procedures, immaturity of technological means, and unreasonable industrial environment as a whole, the ecological environment level has only been partially improved. Therefore, it has not yet entered a stable stage, and the situation is still relatively severe.

#### 4.1 The total discharge of industrial waste is monotonous

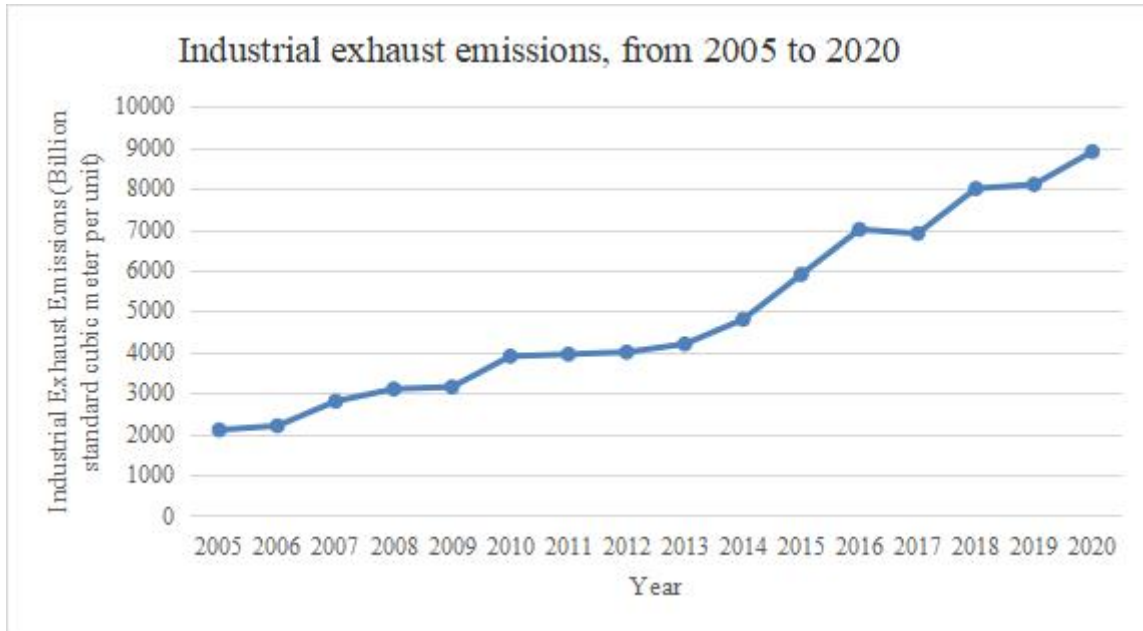
Since the beginning of this century, the total discharge of the three major industrial wastes in Nanjing has shown a trend of increase and decrease. Among them, the discharge of wastewater has been decreasing for many years, and the annual reduction rate is not obvious; the discharge of industrial waste gas is increasing continuously and rising in a straight line; the discharge of industrial solid waste maintains a certain rate of increase in the early stage, but the increase or decrease in the later period is uncertain.



Source: Nanjing Statistical Yearbook

Figure 1. Industrial wastewater discharge in Nanjing from 2005 to 2020

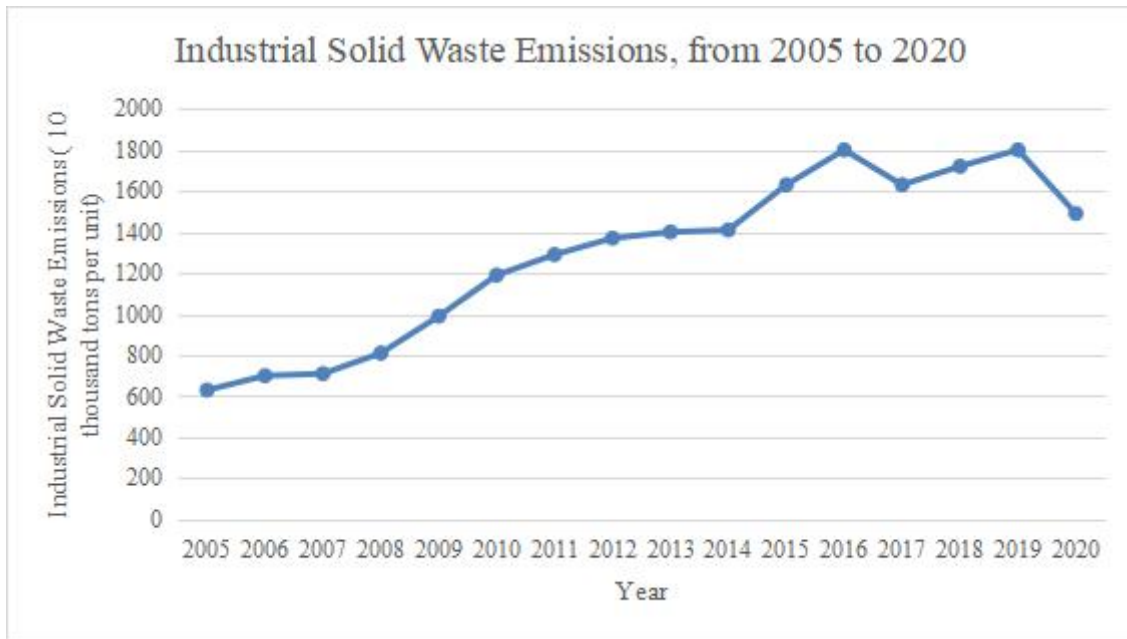
As shown in Figure 1, the discharge of industrial wastewater in Nanjing showed a rapid downward trend from 2005 to 2015 and fluctuated and slowly decreased from 2016 to 2020.



Source: Nanjing Statistical Yearbook

Figure 2. Industrial waste gas emissions in Nanjing from 2005 to 2020

In Figure 2, except for the decline in Nanjing's industrial waste gas emissions from 2016 to 2017, the overall performance increases.



Source: Nanjing Statistical Yearbook

Figure 3. Industrial solid waste discharge in Nanjing from 2005 to 2020

In Figure 3, from 2005 to 2007, the discharge of industrial solid waste in Nanjing was stable, increased continuously from 2007 to 2015, and decreased in 2017, but the added value reached its peak in 2017 and then began to decrease slowly. Based on the above analysis, it can be seen that although the discharge situation of the three types of industrial wastes in the city has improved, the effect is not so noticeable, and the pressure on the ecological environment has not eased.

#### 4.2 Relative scarcity of water resources

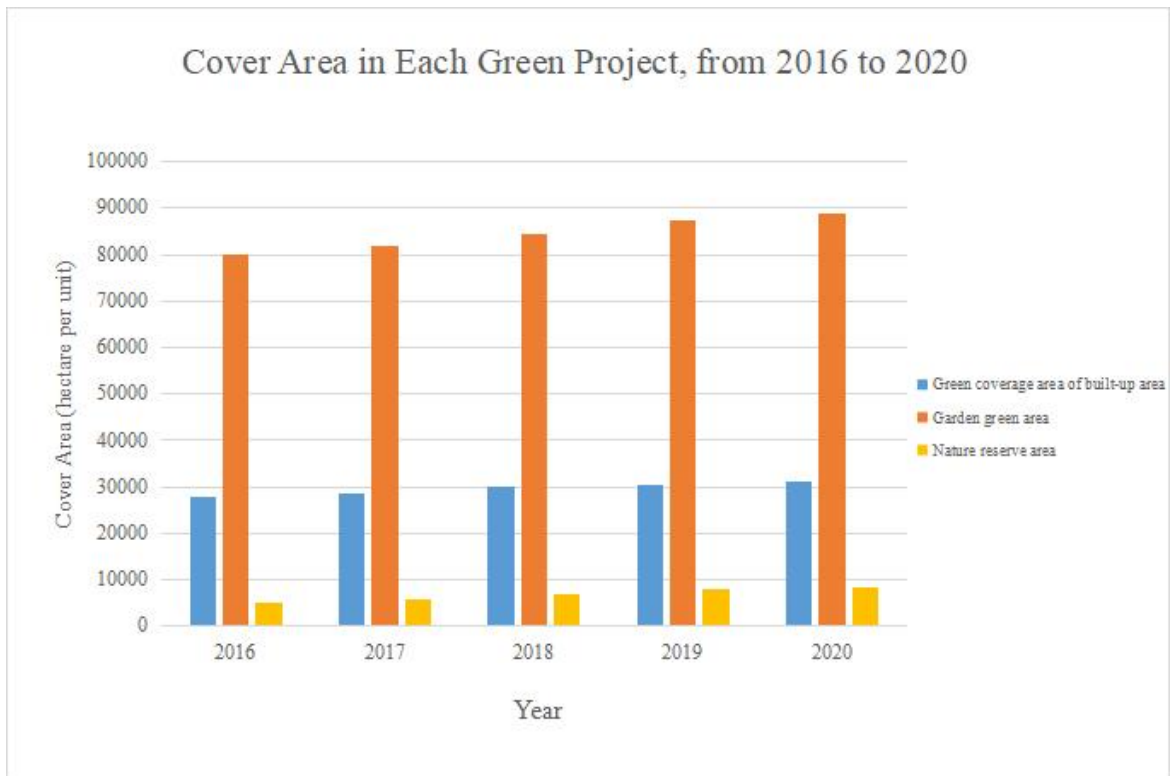
Nanjing's water surface rate accounts for 11.4% of the city's total area, and the city's water resources are in a situation where the total amount is large, but the per capita occupancy is small (Fang 2021). It can be said that both freshwater resources, surface, and groundwater resources are relatively insufficient to meet the needs of the city's production and life. The

lack of water resources and water pollution have prompted Nanjing to actively develop water sources and strengthen the prevention and control of water pollution. However, it is the governance work that needs to be further strengthened.

#### 4.3 Green coverage has not increased significantly

Since the construction of an ecological city in Nanjing, the level of green coverage in the city has increased year by year. At present, Nanjing's urban green coverage area is 33,588 hectares, and the green coverage rate of built-up areas is as high as 44.47%; the area of green garden space is 88,910 hectares; the park area is 7,122 hectares, the per capita park area is 15.5 square meters, and the number of parks is 127; The protected area coverage rate is 25.7% (Fang 2021). From the country's overall situation, the greening index of Nanjing is relatively high, and it has shown a steady growth trend in recent years.

As shown in Figure 4, the following figure selects three indicators of green coverage area, garden green area, and nature reserve area in the built-up area and selects the data for the five years from 2016 to 2020. It can be seen from Figure 4 that the green coverage area in Nanjing has increased, but the upward trend is not apparent.



Source: Nanjing Statistical Yearbook & Jiangsu Statistical Yearbook

Figure 4. Main indicators of green coverage area

## DISCUSSION

### 1. Discussion on the Concept of Urban Ecological Environment

#### (1) Discussion on the concept of city

Cities are the products of human social, economic, and cultural development. In the research of this paper, the author defines a city as human material, spiritual environment, and wealth that has been processed by human creative labor and has higher "value", which is more in line with human beings. It is one of the places for social activities that it needs and one of the progressive ways of life for human beings, and it is also a new type of ecosystem in which human beings have an absolute advantage.

People, living and non-living things, and space (environment) are the three essential elements that make up a city (Zhou 2020). The fundamental nature of cities is people-centric for the following reasons:

- a. Every city is built by people, and every city in history is the crystallization of human labor;
- b. Every city is managed by people, and the environmental problems of the city are also created by people;
- c. Every city serves the people.

As a comprehensive natural complex ecosystem, the city has gradually formed its unique urban environment in the process of development. Therefore, advocating people-oriented is the starting point and endpoint of all urban work, and urban planning and construction should focus on people. Economic development is not only to provide people with increasingly rich

material products but also to improve people's quality of life.

## (2) Discussion on the Concept of Ecology

Ecology can be understood as the living state of living things, which includes the living and developing conditions of living things in a certain natural environment, as well as the physiological conditions of living things, such as characteristics and habits. Fundamentally, the term ecology has its origins in ancient Greece, when it mainly meant home and our environment (Lee 1992). After thousands of years of development, the meaning of ecology has far exceeded its original meaning. It no longer only refers to the relationship between a creature and the environment or between humans and the environment but also to the harmony of a complex relationship.

British botanist Tansley first proposed the concept of the ecosystem in 1935. Based on his predecessors and his own research on forest dynamics, he introduced the "system" in physics into ecology and proposed that the entire ecosystem includes biological complexes and the environment, a complex of natural factors ( Lee 1992). We cannot separate living things from their specific natural environment, living things and the environment form a natural system. It is this kind of system that makes up the basic units on the Earth's surface, and they come in all sizes and kinds, and that's the ecosystem.

## (3) Discussion on the Concept of Environment

The meaning of environment is vibrant, such as social environment, traffic environment, and network environment. The word environment in English is derived from the verb

"environ", which is of Latin origin and means to surround, surround (Buckley 1998).

According to the research of this paper, the "environment" mainly includes three aspects: nature, ecology, and society. For the survival and development of human beings, the natural environment is a necessary basic condition, which is the sum of various natural factors that people need for survival and development. From the perspective of the relationship between organisms and their living environment, we can define the ecological environment as the sum of those environmental elements (ecological factors) that directly impact and affect biological life activities. Light, heat, water, air, and soil are all ecological factors. The ecological environment is the sum of all ecological factors in the living area of organisms or their groups, and it is the combined effect of various ecological factors on organisms. The social environment refers to transforming natural conditions through long-term purposeful social labor based on the natural environment to build a new material production system.

#### (4) Urban Ecological Environment

The urban ecological environment is a whole that constitutes human beings and the urban environment. It is a process in which people's lives and the environment influence and restrict each other. In this coordinated environment, a state of equilibrium is achieved at a certain moment. The city's ecological environment can be understood as human beings transforming the environment to suit human development to survive. In other words, it is based on the living environment, using the characteristics of the environment to improve the environment. We can usually divide it into the natural environment and social environment. The social environment generally refers to the environment of coordinated development of the social



economy and urban population. The natural environment is mainly divided into several parts, mainly soil, geographical features, flora and fauna, and local climatic influences. In the process of city formation, the ecological environment plays an indispensable role.

## 2. The relationship between urban ecological environment and rapid urban development

### (1) Utilization of resources

In order to ensure the sustainable development of the city, we should learn to reuse resources, recycle some reusable resources, and continuously utilize and reduce them. This can use the principle of dynamic balance in the ecological environment to reduce the emission of pollutants to a minimum scientifically and effectively, using a scientific and effective method to reduce the amount of waste in daily life in the city, the wastewater of factories, and the gas emissions after fuel combustion, and recycle the resources that can be reused twice. Its essence is the secondary utilization of resources, which is also an important measure to alleviate the continued deterioration of the urban ecological environment and achieve sustainable development.

### (2) How to realize sustainable development of urban ecological environment

Keeping the city's ecological environment in a sustainable state is one of the guarantees for a country to realize a social economy. China is still a developing country. Therefore, to ensure the harmonious development of society and economy is to enable people to have a better living environment and also to satisfy people's yearning and pursuit for a better life. China's goal is to narrow the gap with developed countries continuously, and protecting the

urban ecological environment is essential for improving these efforts. While striving to develop the social economy and the national economy, the problem of the ecological environment cannot be ignored. The concept of sustainable development of the social economy is realized by coordinating the ecological environment of the city and the economy of the society. From the perspective of protecting the physical and mental health of human beings, it is of great practical significance for the sustainable development of society and economy to increase the protection of the urban ecological environment, to achieve the rational development and use of resources, and to strive to achieve urban ecological and environmental protection.

### (3) The development direction of urban ecological environment

Paying attention to the sustainable development of society and economy provides a planning direction for the urban ecological environment. The principle of protection of the urban ecological environment is mainly to pay attention to the overall interests of social development. In order to reflect fairness and inclusiveness in this process, urban ecological protection should pay attention to multiple aspects of social life, such as economy and culture. Ecological and environmental protection planning should consider the sustainability of development. Suppose in the process of economic development, only short-term benefits are emphasized, and the adverse effects of the urban ecological environment and long-term human development are not considered and studied from a long-term perspective. In that case, this economic model is not suitable. The living environment of human beings is also a part of the natural environment. If we want to develop urban civilization, we must respect nature. The

relevant protection plan for the urban ecological environment is to carry out protection planning for the relevant measures taken for the urban ecological environment in urban economic development. The purpose is to maintain the stability of the urban ecological environment and realize the sustainable development policy of the city. Urban ecological environmental protection can connect urban environmental planning with the overall urban planning, mainly emphasizing the integrity and coordination of the planning, and the main goal is to pursue the improvement of the social economy and the sustainable development of the urban ecological environment.

### 3. Analysis on the Current Situation Governance of Nanjing's Urban Ecological Environment

#### (1) Air pollution control

Nanjing insists on starting from the people and is guided by the scientific concept of development. In order to achieve the goal of optimizing urban air quality, Nanjing has adopted various measures to achieve comprehensive control of environmental pollution and continuously improve the pertinence and scientificity of the solutions from the source of pollution. Under various measures, the politics of air pollution has achieved good results. In the first half of 2017, the concentration of major air pollutants in Nanjing has been greatly improved compared with the same period of previous years, and the average concentration of inhalable particulate matter has dropped somewhat. Weather with excellent air quality across the city has also been added.

Through the online survey, we learned that the Nanjing Environmental Protection Bureau has set up a special leading group to improve urban air quality. According to the national

environmental protection model city standard, the following contents are clearly included (Fang 2021):

- a. The Nanjing Environmental Protection Bureau has set up 59 environmental protection goals, including the comprehensive improvement of the atmospheric environment, sorted out the relevant requirements for the comprehensive improvement of the urban and rural environment, refined 59 environmental protection projects, and established a long-term assessment mechanism and measures. Efforts to achieve comprehensive improvement of the atmospheric environment;
- b. The Nanjing government carried out particular control actions and allocated special funds to solve air pollution problems such as coal combustion and dust. Joint law enforcement to implement key crackdowns on illegal industrial polluting enterprises and various types of enterprises with serious pollution. And improve the construction of energy infrastructure, vigorously promote the development of new energy performance, implement stricter restrictions and requirements, and strictly manage the burning pollution of urban straw;
- c. The Nanjing Environmental Protection Bureau has strengthened the supervision and inspection of air quality in the city's environment, improved the daily supervision and emergency response mechanism of the atmospheric environment, and released air quality-related information in a timely manner.

## (2) Water pollution control

- a. Governance of small watersheds and realize management system innovation

Nanjing City has achieved innovation in the management system in the governance of small watersheds, adhered to the principle of combining source control and end-point pollution control, adopted a combination of non-engineering measures and engineering measures, and actively promoted the governance of 21 medium and small rivers such as the Baitiao River. According to the official information released by the Nanjing Environmental Protection Bureau, Nanjing completed non-engineering measures on schedule in 12 target responsible districts and counties. A total of 212 industrial enterprises, 237 farms, 56 farmhouses, and 89 concentrated residential areas were rectified throughout the year. There were 149 regular public toilets, 143,000 square meters of shanty towns along the river were demolished, 13 non-designated slaughterhouses were banned, 290,000 cubic meters of sediment in the canals were cleared, and 18,700 cubic meters of solid waste was removed (Zhou 2020). In terms of engineering measures, Nanjing built 17 terminal sewage treatment facilities in 12 relevant districts and counties, built 24 sewage intercepting weirs, restored 13 kilometers of ecological river embankments, and completed sewage interception and renovation of 40 lower estuaries in the central city and 477 households of rainwater. The sewage diversion project will increase the sewage treatment capacity by 31,800 tons per day (Zhou 2020). The development of small watershed management work has effectively improved the water quality of medium and small rivers. Nanjing increases the quality of water pollution in small river basins, bans illegal enterprises that cause water pollution in accordance with the law, innovates management mechanisms, actively promotes the management of small river channels, and strengthens the awareness of environmental protection and government responsibility.

b. Strengthen investment in comprehensive management of water environment

As a pilot area for comprehensive reform of urban and rural areas in China, continuous improvement of the rural environment is the key, and rural water environment governance is even more important. According to the characteristics of the primary pollutants in the rural environment, Nanjing City has strengthened the comprehensive improvement of the rural water environment through the following measures. Combined with the characteristics of the rural environment, the city has built and renovated the sewage treatment facilities of 69 designated slaughterhouses, promoting the discharge of wastewater from designated slaughterhouses. The city has completed the comprehensive renovation of 58 farmhouses along 24 small watersheds, 11 were closed and relocated, and 47 reached the emission standard. Invested 5.28 million yuan to complete the sewage remediation of 393 star-rated farmhouses and achieved discharge standards (Zhou 2020). At present, the city has actually started the construction of 57 township sewage treatment plants and supporting pipe networks. Among them, the main construction of 28 sewage treatment stations undertaken by Nanjing Xingrong Company will be completed by the end of the year, and the new sewage treatment capacity will be 97,000 tons per day. The 21 self-built townships will complete the main project by the end of the year, with an additional sewage treatment capacity of 73,000 tons per day (Zhou 2020).

Through the implementation of a series of water control projects, Nanjing reduced chemical oxygen demand by 2,200 tons and ammonia nitrogen by 510 tons during the year, effectively curbing water pollution. So far, the sewage treatment rate in the central urban area of Nanjing has reached more than 87% (Zhou 2020).

### (3) Solid waste pollution control

In order to implement the relevant regulations and requirements of the Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste, Nanjing Environmental Protection Bureau has further strengthened public supervision over the prevention and control of environmental pollution by solid waste. On April 13, 2018, the Nanjing Municipal Environmental Protection Bureau issued the "2017 Nanjing Municipal Solid Waste Pollution Prevention and Control Information Announcement" to comprehensively establish a domestic waste pollution prevention and control system. According to the official website of the Nanjing Environmental Protection Bureau, the urban management department has actively promoted the centralized collection and disposal of domestic waste in 64 towns and villages. Among them, 9,132 garbage transfer rooms were built, 27,112 trash cans were set up, 490 garbage transfer vehicles were purchased, 12,733 cleaning personnel were recruited, and a harmless disposal system for centralized collection and transportation of rural domestic garbage was fully established (Zhou 2020).

At present, the daily output of rural garbage in Nanjing is 34,554 tons, and the garbage disposal volume is 2,860 tons, ensuring that the urban and rural domestic garbage collection and harmless disposal rate reaches 88.1% (Zhou 2020). The city's 2017 annual industrial solid waste, hazardous waste, rural solid waste, medical waste, urban domestic waste, and other relevant information were announced. In 2017, there were 931 enterprises producing industrial solid waste in the city, with a total output of 5,344,614 tons, of which 5,013,446 tons were comprehensively utilized, 330,904 tons were disposed of, and 264 tons were stored.

There were 356 industrial enterprises producing hazardous waste, with a total output of 132,404 tons, of which 19,583 tons were comprehensively utilized, 112,532 tons were disposed of, and 289 tons were stored (Zhou 2020).

4. An empirical analysis of the relationship between ecological environment level and economic growth in Nanjing

(1) Variable selection and sample data description

By summarizing a large number of academic researches and achievements of many experts over the years, and according to the actual local situation in Nanjing, this paper selects ten representative sub-indicators related to the ecological environment level. According to the official website of the Nanjing Environmental Protection Bureau, the entropy method is used to process the index. Finally, the overall index of the ecological environment level is obtained, and the GDP of Nanjing is also selected as the index of economic growth. It should be noted that the selection years for both indicators are from 2006 to 2020. The ten sub-indicators selected to represent the ecological environment level are mainly divided into two parts, the first part is used to represent the ecological construction level of Nanjing City, and the second part is used to represent the environmental governance level of Nanjing City. The explanation of specific sub-indicators is shown in Table 3:

Table 3. Decomposition and explanation of main indicators of ecological environment level

	Index	Unit	Remark
Ecological Construction Level	Green coverage rate of built-up area $X_1$	%	Measure the percentage of green coverage area in the built-up area of the city in the built-up area
	Public green space per	%	Measure the ratio of urban



	capita $X_2$		public green space to urban non-agricultural population
	Coverage of nature reserves $X_3$	%	Measures the ratio of the area of regional nature reserves to the total area of the region
	Water quality compliance rate of water source $X_4$	%	Measure the quality of the water environment in the region
	Excellent air quality rate $X_5$	%	Measure the status of regional atmospheric environment quality
Environmental Governance Level	Environmental investment as a percentage of GDP $X_6$	%	Measure the financial support for regional environmental governance
	Wastewater discharge compliance rate $X_7$	%	Measure the ratio of regional wastewater (industrial wastewater and domestic sewage) to the specified discharge standard
	Exhaust emission compliance rate $X_8$	%	Measure the ratio of regional exhaust gas to the specified emission standards
	Comprehensive utilization rate of solid waste $X_9$	%	Measure ability to handle and recycle solid waste
	Harmless disposal rate of domestic waste $X_{10}$	%	To measure the ability of environmental protection and low carbon treatment of domestic waste

The time span of the sample data selected in this article is from 2006 to 2020. The selection of data mainly refers to the data of the 15-year statistical yearbook displayed on the official websites of Nanjing and Jiangsu Provincial Environmental Protection Bureau, and the auxiliary reference sources are also some provincial and municipal statistical bulletins on the ecological environment. In addition, in order to eliminate price factors and inflation factors, the official website of the Nanjing Environmental Protection Bureau adjusted the directly obtained data with the Consumer Price Index (CPI). In this way, the actual data of Nanjing's ecological environment level and economic growth are obtained. Considering the possible

heteroscedasticity problem, this can not only linearize it to make the model more accurate but also will not affect the cointegration relationship between the two variables. The official website of the Nanjing Environmental Protection Bureau records the transformed data as LNEEL (level of ecological environment) and LNGDP (economic growth).

## (2) Empirical Analysis

### a. Entropy method

According to the official website of the Nanjing Environmental Protection Bureau, the entropy method is a model that assigns weights to variable indicators. Therefore, the data calculated by the entropy method is objective, and information entropy is its main tool to solve problems (Su 2009). Information measures the degree of order in the system, while entropy is an indicator of the degree of disorder or chaos in the system, so Nanjing Environmental Protection Bureau will use its value to judge the degree of variation of an indicator. The principle between the entropy value of a specific index of the system and the degree of variation is as follows: the degree of variation is inversely proportional to the information entropy, proportional to the amount of information, and proportional to the weight (Su 2009). Here is a brief introduction to the steps of the entropy method to determine the weight:

### b.

$$e_j = -K \sum_{i=1}^m p_{ij} \ln P_{ij}, \quad p_{ij} = v / \sum_{i=1}^m v_{ij}$$

Figure 5. Equation of the weight of each evaluation index using the entropy method

Source: Official website of Nanjing Environmental Protection Bureau

In figure 5,  $p_{ij}$  represents the contribution of the  $i$ -th individual data to the  $j$ -th indicator,  $K = 1/1nm$ . If the value to be calculated is a complex system, the index action value can be transferred from the lower level to the higher level, and then the value of the index at the upper level can be calculated proportionally.

c.

$$f_{ik} = \sum_{j=1}^i W_{kj} \times V_{ij}$$

$$F_i = \sum_{K=1}^3 W_K \times f_{ik}$$

Figure 6. Equation of calculating comprehensive index by entropy method

Source: Official website of Nanjing Environmental Protection Bureau

In figure 6,  $f_{ik}$  is the neutralization index of the  $k$ th subsystem in the  $i$ th year, and  $F_i$  is the comprehensive index of the entire target system in the  $i$ th year. By decomposition the ecological environment level indicators using the entropy method on the official website of Nanjing Environmental Protection Bureau, the obtained data is obtained by using Excel to obtain table 4.

Table 4. Ecological environment level sub-indicator weight

First-level Indicator	Second-level Indicator	Unit	Weights
Ecological	Green coverage in built-up areas $X_1$	%	0.0481

Construction Level 0.5542	Public green space per capita $X_2$		0.0956
	Coverage of nature reserves $X_3$	%	0.2188
	Water quality compliance rate of water source $X_4$	%	0.0472
	Excellent air quality rate $X_5$	%	0.1445
	Environmental investment as a percentage of GDP $X_6$	%	0.1142
Environmental Governance Level 0.4558	Wastewater discharge compliance rate $X_7$	%	0.0974
	Exhaust emission compliance rate $X_8$	%	0.0598
	Comprehensive utilization rate of solid waste $X_9$	%	0.1038
	Harmless disposal rate of domestic waste $X_{10}$	%	0.0706

The ecological construction level is more important than the environmental governance level in Nanjing, accounting for 55.42%, while the environmental governance level only accounts for 44.58%. Then refer to the table, I will continue correcting on a new draft that is clearer. Since 2013, while the Nanjing Municipal Government has strengthened its environmental protection and pollution reduction and emission reduction work, the pace of building an eco-city has also continued to move forward. Focusing on constructing an ecological city, Nanjing has successively issued numerous special plans and special support for capital investment to implement the construction of an ecological city in an all-round way. All these make the proportion of ecological construction exceed that of environmental governance.

In the ecological construction process in Nanjing, the coverage rate of nature reserves accounts for the most significant proportion, followed by the rate of excellent air quality, which fully shows that Nanjing attaches great importance to the natural environment and natural resources (Zhou 2020). Nanjing has increased the development, investment, and management of nature reserves in recent years, and the government has developed some new natural scenic spots and tourist areas. At the same time, the Nanjing Municipal Government, Nanjing Meteorological Bureau, and other similar relevant departments have also strengthened the construction and management of the atmospheric environment and issued the city's major atmospheric pollutant emission reduction project plans, including vigorously restricting industrial waste gas emissions and prohibiting farmland burning straw soot emission. The implementation of this plan meets the demands of the people in the city to breathe fresh air and enjoy a high-quality life with a blue sky and white clouds.

From the perspective of environmental governance, the ratio of environmental protection investment to GDP in Nanjing and the comprehensive utilization rate of solid waste occupies a relatively large weight, which is closely related to the emphasis on environmental protection work and the progress of the environmental protection industry technology (Zhou 2020). In recent years, Nanjing has adhered to the special support of environmental protection capital investment and continued to increase capital investment in environmental protection construction. As a result, the proportion of environmental protection investment in the city's GDP has remained above 4%. Nanjing cooperates with scientific research departments, colleges, universities, and related enterprises to carry out the research and development and application of environmental protection technology, among which the solid pollution

treatment technology is second to none in the country. The main content includes the development and introduction of a large number of solid pollutant treatment equipment and the cultivation of related technical personnel, which has greatly improved the utilization rate of solid waste.

According to the weight of each sub-indicator in table 4, and then according to the data corresponding to each indicator in 2006-2020, and at the same time collect and organize the data of Nanjing's GDP in 2006-2020 in the statistical yearbook, table 5 is obtained.

Table 5. Data of Nanjing's ecological environment level and economic growth in 15 years

Years	Ecological Environment Level / EEL	Economic Growth Level GDP (Unit: RMB)
2006	1.606	20597
2007	1.145	22858
2008	1.244	27307
2009	1.234	35769
2010	1.320	40887
2011	1.409	46113
2012	1.463	53638
2013	1.483	61445
2014	1.419	67455
2015	1.507	79427
2016	1.743	96872
2017	1.759	112980
2018	1.902	98011
2019	1.917	107545
2020	1.981	118171

Source: Nanjing Statistical Yearbook & Jiangsu Statistical Yearbook

Using the two sets of data of the two variables in table 5 as the original data, after adjusting them with the consumer price index, LNEEL and LNGDP are finally obtained, which can be used in the following to carry out econometric analysis and draw conclusions.

#### d. Unit root test

In the actual operation of economic problems involving time data, we must first judge the

stationarity of the sample data. There are many ways to test data stationarity. In order to ensure the accuracy and availability of data, Nanjing Environmental Protection Bureau used the ADF test in the unit root test method to test the ecological environment level LNEEL and economic growth LNGDP in Nanjing, and obtained table 6. The unit root test is to check whether there is a unit root in the data. If there is a unit root, we can judge that the series is not stationary.

Table 6. Unit root test of ecological environment level and economic growth

Project	ADF Critical Value	P Value	Test Result
LNGDP	-3.0650	0.1583	Unstable
LNEEL	-2.7112	0.4674	Unstable
ADF-LNGDP	-2.6326	0.0224	Stable
ADF-LNEEL	-4.8416	0.0174	Stable

Source: Official website of Nanjing Environmental Protection Bureau

At the 5% significance level, the test results of the series LNEEL and LNGDP are stationary (Table 6).

#### e. Granger causality test

According to the economic theory and practical experience of the Nanjing Environmental Protection Bureau, what is the relationship between Nanjing's ecological environment level and economic growth? The Granger causality test method provides an empirical basis for exploring this problem. This test aims to determine the logical relationship (causal relationship) between variables. We often cannot clearly see the causal relationship between two or more variables in the analysis, but the causal relationship is very important for our actual analysis or analysis for other purposes. So Granger created a causality model to help solve this problem, substituting the data from table 6 into the Granger causality test method to get table 7.

Table 7. Granger causality test for LNEEL and LNGDP

Granger causality	P Value	Result
LNEEL→LNY	0.1915	Reject
LNY→LNX	0.1844	Reject
LNEEL→LNY	0.5193	Reject
LNY→LNX	0.0977	Reject
LNEEL→LNY	0.0232	Unreject
LNY→LNX	0.0545	Reject
LNEEL→LNY	0.0231	Unreject
LNY→LNX	0.0072	Unreject
LNEEL→LNY	0.0040	Unreject
LNY→LNX	0.0044	Unreject

Source: Official website of Nanjing Environmental Protection Bureau

From table 5 and table 7 we can see that, at the 5% significance level, the hypothesis that the level of ecological environment in Nanjing does not cause economic growth is rejected. Likewise, the hypothesis that economic growth does not cause ecological levels is rejected. Therefore, it can be concluded that there is a causal relationship between Nanjing's ecological environment level and economic growth.

### (3) Empirical Analysis Summary

The above analysis shows that the level of ecological environment drives economic growth through supply and demand effects, while economic growth improves the level of the ecological environment through capital investment. This theoretical relationship between the two has been confirmed in Nanjing. Due to the geographical location, historical origin, and the government's economic development policy, the economic development of Nanjing has been showing an upward trend in the past two decades, which makes Nanjing have a certain economic guarantee in terms of investment in the ecological environment construction. Since 2009, the city's ecological environment construction investment has continued to grow, with



an average increase of 21.2% (Zhou 2020). By 2017, the investment in ecological environment construction reached 26 billion yuan. In the next few years, the special funds for eco-city construction increased from 30 million yuan per year at the beginning to 45 million yuan. All these indicators show that while the economy has been developing continuously, the ecological environment level of Nanjing has indeed been improved. On the other hand, the funds invested in the construction of the ecological environment have not been left idle through the development of the ecological environment industry, such as the construction of environmental protection infrastructure, the construction of ecological gardens, and the construction of ecological farms. The development of these industries has largely driven the economic development of Nanjing.

## CONCLUSION

According to the research results of this paper, the construction of Nanjing's ecological environment and economic growth are mutually reinforcing. That is to say, if we want to maintain long-term coordination and stability between the two, it is definitely not enough to start from one of them. Only when the two are adjusted simultaneously can the relationship between the two be balanced as a whole and ultimately optimized and coordinated in the dynamic development process.

### 1. Promote sustainable economic and ecological development

#### (1) Practice the value concept of protecting the ecological environment

As a social value, the concept of natural ecology has gradually become the mainstream value advocated by society in our daily production and life. From the perspective of macro strategy, rich ecological resources and a good natural environment guarantee social economic construction and promote the growth of social material wealth. For Nanjing City, in addition to regulations and systems related to ecological environmental protection, relevant departments should advocate the concept of ecological environmental protection and lead the city's people to practice ecological environmental protection activities actively. Specific measures such as holding large-scale public welfare publicity seminars throughout the city and carrying out volunteer activities for students to participate in environmental protection. From the perspective of micro-individuals, everyone lives in the living environment given to us by the natural ecology, and the maintenance of the ecological environment will even change our production and lifestyle. Therefore, every citizen should establish a correct view

of nature and ecology, keep in mind the principle of low carbon in their daily life, protect the environment and save resources, and truly implant the concept of eco-friendliness in their hearts.

(2) Change the way of development and achieving a circular economy

The essence of a circular economy is actually the re-realization process from the beginning of material production to the end of product consumption. In the whole process, resources are not wasted but are continuously recycled. This idea is in line with the conservation of matter in the world we live in. law. The circular economy mode is different from the rough economic development mode in the past, but a development mode of refined production and consumption. In recent years, the circular economy concept has penetrated into people's hearts widely, and its practice exists in all aspects of our production and life. In the process of economic transformation, Nanjing has introduced a large number of high-tech industries and developed green environmental protection industries. As a result, the circular economy development model has achieved some results. However, the industrial structure of Nanjing is relatively complex, especially the industrial structure. Although most polluting enterprises and heavy industries in the original urban area have been relocated, part of the main urban area still exists. These enterprises still continue the original production process, and circular production is just a slogan, so there is a threat to the urban environment and the health of citizens.

(3) Cultivate a good atmosphere for ecological and environmental protection in the whole society

Since the existence of human civilization, human development has always been a process

of constantly adapting to the natural environment, changing the natural environment, and even fighting against the natural environment. Only when we fully know and understand nature can we have a correct moral view of it. We can combine science and technology, humanities and social sciences, culture and art, let them give full play to the advantages and charm of integration, cultivate an excellent eco-friendly and natural harmonious atmosphere in the whole society, and finally achieve ecological environment and material production and sustainable development of consumption.

#### (4) Reorganize the industrial structure and develop technology economy

With the development of science and technology in the 21st century, the industrial social structure is also changing quietly. Some traditional industries are increasingly unable to adapt to the development and changes in the wave of science and technology. At this time, it is necessary to eliminate some industries with high investment and high energy consumption that cause damage to the ecological environment. These industries not only have little effect on the long-term development of the economy but also cause pollution and damage to the ecological environment. Transforming traditional industries through technological innovation, developing emerging technology-based industries, and re-optimizing the configuration of the entire industrial structure can achieve economic development and drive the improvement of the ecological environment. Nanjing should eliminate some backward industries based on its own conditions, and at the same time, develop a number of new industries through technological innovation, use new equipment to produce new products, and finally achieve zero emissions to the environment to achieve sustainable development.

## 2. Guide the development of ecological environment industry and drive economic growth

From the empirical analysis in the discussion, we know that from a long-term perspective, the improvement of Nanjing's ecological environment level has a significantly more significant role in promoting economic growth than economic growth has on the ecological environment level. The improvement of the ecological environment level is inseparable from the development of the ecological environment industry. Under the background of vigorously advocating green GDP, the ecological environment industry is the new and most potential economic growth point. The development of the eco-environmental industry drives not only the growth of economic benefits but also the improvement of social benefits, all of which are conducive to the policy of sustainable development.

### (1) Broaden the sources of industry investment funds

The development of the eco-environmental protection industry is not a matter of one individual or one organization but requires the joint efforts of all members of the whole society. The development of the eco-environmental protection industry is inseparable from capital investment, and the sources of capital should not be single but should broaden the scope of investment channels. As far as Nanjing is concerned, the city's financial institutions can relax the loan conditions for the ecological and environmental protection industry and lower the industry access threshold. In addition, the government can introduce and implement preferential policies for related ecological and environmental protection industries to reduce taxes to encourage the development of this industry.

### (2) Strengthen industry technological innovation

As capital and technology-intensive industry, the ecological and environmental protection

industry has higher requirements for technological innovation. Nanjing's strengthening of technological innovation in the ecological and environmental protection industry can be implemented to develop new environmental protection processes and introduce foreign advanced equipment while focusing on the independent development of technology paths and technical exchanges within the industry.

### (3) Improve the legal system of the industry

The development of the industry is inseparable from the protection of the law. The particularity of the ecological and environmental protection industry makes it more necessary to support the law. On the basis of existing industry laws and regulations, Nanjing City should focus on formulating and improving system norms for outstanding problems, focusing on solving problems related to people's livelihood and ecological environment, and forming legal norms or rules and regulations.

### (4) Cultivate industry professionals

Human resources are an indispensable resource for the development of all walks of life. The core driving force for the industry's sustainable development comes from excellent human resources. Therefore, cultivating talents in various fields of the ecological and environmental protection industry is a top priority. The current situation in Nanjing is that the overall employment in the ecological and environmental protection industry is small, the field of employment is not comprehensive, and there are few professional and technical talents. Therefore, the focus in the future is to improve the labor skills of practitioners through various training methods, adjust employment positions in various fields and continuously increase the total number of talents in the industry.

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