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**RESEARCH OF CITY'S SUSTAINABLE DEVELOPMENT BASED ON
SYMBIOSIS THEORY — A CASE STUDY OF SHANGHAI**

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АНОТАЦІЯ

Шанхай займає ключове місце в економічному будівництві Китаю. Це одна з найважливіших старих промислових баз Китаю, а також найбільший порт, економічний, торговий центр, науково-технічний, фінансовий, інформаційний і культурний центр. Після реформ і звільнення Шанхай зробив великий внесок у розвиток економіки Китаю в багатьох аспектах. Однак через швидку урбанізацію, необґрунтоване міське планування, промислове забруднення, споживання ресурсів, соціальну нерівність і недостатнє управління виникла низка міських дисбалансів, таких як важка ситуація з зайнятістю, житлові проблеми, затори на дорогах і збільшення забруднення повітря. Як результат, сталий розвиток розглядається як першочергове завдання для міської влади.

У магістерській роботі розглянуто Шанхай як дослідницький кейс на основі теорії симбіозу з природничих наук для створення системи міського симбіозу Шанхаю, що складається з підсистеми населення, економічної, соціальної, екологічної, ресурсної та технологічної підсистеми. Для оцінки сталого розвитку міста розроблено систему індексів оцінювання. Вибравши дев'ять репрезентативних наборів даних з 2011 по 2019 роки для кількісного аналізу, у дослідженні всебічно оцінюється сталий розвиток Шанхаю на рівні сталого розвитку міст, а також надаються відповідні контрзаходи та пропозиції.

В роботі аналіз головних компонент використовується для отримання кількох груп даних, які мають найбільший вплив на кожну підсистему, а потім розраховується комплексний рівень сталого розвитку кожної підсистеми. Комплексний рівень сталого розвитку міста Шанхая обраховується через коефіцієнти сталого розвитку підсистем шляхом проведення процедури аналітичної ієрархії. Обробка даних здійснюється за допомогою SPSS25. Використовуючи пропонований метод, комплексний рівень сталого розвитку в Шанхаї з 2011 по 2019 рік узгоджується з фактичним розвитком Шанхаю.

Ключові слова: сталий розвиток, Шанхай, міська система, теорія симбіозу, аналіз головних компонент, аналітичний ієрархічний процес.

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INTRODUCTION

With the acceleration of urbanization that has occurred during the past century, the increasing demand for built-up areas has led to increasingly serious conflicts between various types of land use and biodiversity hotspots with built-up land in rapid urbanizing areas [1, 2, 3]. With the continuous city sprawling, land use faces large challenges. Sustainable management is a good way to reduce those conflicts and guarantee for regional sustainable development [4, 5]. Land space is an important space carrier for human survival, social and economic activities, and ecological civilization construction [6]. Since the reform and opening-up, China's urbanization process has been advancing rapidly, which has led to a dramatic evolution of the land spatial pattern [7]. Chinese cities have grown rapidly and experienced drastic spatial restructuring in the last three decades [4, 8, 9]. The blistering speed and the massive scope of urban spatial reconfiguration are unprecedented. Rapid urban expansion and the dramatic changes in urban landscapes in China have had considerable impacts on the economy and environment. Environmental degradation and economic inequality are major concerns which have attracted the attention of researchers since the early 1990s [10, 11].

Cities have become the major growth engine in the world and central to ensuring a sustainable future [3, 12]. Urbanization now plays a key role in economic, environmental and social sustainability, and has attracted wide attention in research [13, 14, 15]. The spatial expansion and sprawl of cities as a whole have been widely studied, particularly in European [16], Asian [17, 18, 19], and American [20] cities. The current Chinese urban system [21] is characterized by rapid urbanization [22], large-scale infrastructure development and significant regional disparities. Over the past few decades, China has experienced one of the most rapid urbanization processes in history, with millions of people migrating from rural areas in search of better job opportunities and improved living conditions. As a result, China's urban population has grown significantly, and the urban landscape has transformed dramatically. Some key features of the current Chinese urban system include: hierarchy of cities, rapid urbanization, infrastructure development, regional disparities, environmental

challenges, housing and social issues and regenerate response. How to achieve sustainable development in cities becomes an important issue for urban managers to solve urgently.

Symbiosis theory, derived from the study of relationships between different organisms in ecosystems, offers valuable insights for understanding and promoting urban sustainable development. The concept of symbiosis refers to mutually beneficial interactions between different organisms that contribute to their growth, survival, and well-being. In the context of urban development, symbiosis theory can be applied to the relationships between various elements of the urban system, including population, society, economic, science, resource and environment.

The aims of the research:

- to assess the comprehensive level of sustainable development in Shanghai from 2011 to 2019.
- to develop the Shanghai urban system which are made of population subsystem, social subsystem, economic subsystem, technology subsystem, resource subsystem and environmental subsystem based on the symbiosis theory.
- to propose measures beneficial to Shanghai's sustainable development.

Methodology. This thesis intends to take Shanghai as an example, by introducing the symbiosis theory from biology into the evaluation research of urban sustainable development. In order to comprehensively evaluate the sustainable development of Shanghai in the past 10 years, based on the symbiosis theory, an urban sustainable development evaluation composed of population subsystem, economic subsystem, social subsystem, environmental subsystem, resource subsystem and technology subsystem was established. Indicators, and the indicator data of each subsystem in Shanghai from 2011 to 2019 were selected from «the National Bureau of Statistics of China» for a comprehensive analysis, and nine sets of representative indicator data were selected for each subsystem.

It is well known that not all selected index data are suitable for evaluating the comprehensive level of a city's sustainable development. This thesis uses the principal component analysis method to obtain a number of comprehensive indicators that play

a leading role from the existing variables (in layman's terms, these comprehensive indicators are the principal components), and it can be determined that these comprehensive indicators are the principal components. The magnitude of the effect of the thing or problem. Through the study of principal components, the important information expressed by the original variables can be grasped, and the variables that need to be cared about can be reduced, so that the actual application and operation can be simplified. Due to the large amount of calculation, this thesis uses the software SPSS25 for auxiliary calculation.

The structure of the current research is consist of an introduction, four chapters, and conclusions and recommendation, in addition to translated of abstract in Chinese. The first chapter consists of three sections which are dedicated to describing the basic concepts, types and characteristics of symbiosis theory, as well as the characteristics and connotation of urban sustainable development. The second chapter is dedicated to describing the composition, elements, characteristics, and structure of the urban symbiosis system and establishing an index system for sustainable development evaluation. Chapter three is to apply the principal component analysis method to calculate the comprehensive development level of each subsystem, and then use the analytic hierarchy process to synthesize the comprehensive development level of the six subsystems. The relevant calculations are completed with the help of SPSS25 software. Moreover, in chapter four, corresponding countermeasures were proposed for the sustainable development of each subsystem in the future. Then the research is concluded by conclusions.

Research problems in this thesis are caused by complicated logistics due to the war in Ukraine. Therefore, while writing theses, the author did not visit the research site (Shanghai) and used data from the National Bureau of Statistics in China, scientific articles, data published by central and local authorities.

CHAPTER ONE THE BASIC THEORY OF URBAN SUSTAINABLE DEVELOPMENT EVALUATION RESEARCH

Symbiosis is a ubiquitous phenomenon not only in nature, but also in human society. As the most important part of human society, the existence and development of cities also need to be carried out in accordance with the law of symbiosis in nature. This chapter will briefly introduce the basic content of symbiosis theory, and explore the connotation of urban sustainable development, so as to provide the necessary theoretical basis for the analysis of the following chapters.

1.1 Basic Concepts of Symbiosis Theory

The term Symbiosis was first coined by German fungal biologist Anton De Bery in 1879[23, 24, 25]. It means that different types of organisms live together for survival needs, different types of organisms interact with each other, rely on each other through some physical connection, and finally form a co-evolution and co-existence relationship. Symbiosis is at the foundation of our being[26]. With the continuous improvement of the symbiosis theory system and the continuous development of social science, the application of symbiosis theory has been extended to many disciplines beyond natural science in recent decades. In the field of public management disciplines, symbiosis theory has also been widely used.

Generally speaking, symbiosis refers to the symbiotic relationship formed between various elements in a system in a certain environment according to a certain pattern. The various symbiotic units originally competed with each other. In order to seek survival, they adopted mutual cooperation to establish a relationship of co-existence. And in the process of development, they constantly evolve and optimize the mutual symbiosis mode in order to achieve a level of maximization of the overall effect, which cannot be achieved by any single unit itself.

Symbiosis has three basic elements, symbiotic unit (U), symbiotic environment (E), and symbiotic mode (M)[27].

The symbiotic unit (U) is the material basis of the symbiosis. In various symbionts or symbiotic relationships, the symbiotic unit is the most basic unit of energy production and exchange. The nature and characteristics of the symbiotic unit vary according to the symbiotic system in which the symbiotic unit is located. The symbiotic unit is composed of two characteristic factors, the first is the image parameter, which is a factor reflecting the external characteristics of the symbiotic unit. This is followed by qualitative parameters, which are factors that determine the intrinsic characteristics of the symbiotic unit and its changes. In the symbiotic unit of each symbiotic system, there is not only one quality parameter, but also a group of quality parameters in most cases. In this group of quality parameters, one of the quality parameters often plays a leading role, which is called the main quality parameter. The interaction between quality parameters and image parameters is complementary and reflects the interaction between symbiotic units.

The symbiotic model (M) is also called the symbiotic relationship, which means that in a symbiotic body or symbiotic relationship, different symbiotic units interact and integrate with each other through a fixed mode. Through this mode, symbiotic units exchange matter, energy and information with each other. The forms of organizational interaction are also different in different symbiotic models. There are several ways to classify symbiotic models. First of all, it can be divided into parasitic mode, beneficial symbiosis mode, asymmetric mutual benefit symbiosis mode and symmetric mutual benefit symbiosis mode from the behavior mode. Secondly, from the perspective of organization, it can be divided into point symbiosis, intermittent symbiosis, integrated symbiosis, continuous symbiosis, etc.

The symbiotic environment (E) refers to the sum of all external influencing factors other than the symbiotic unit. Symbiotic patterns are relationships between symbiotic units that need to develop in a specific environment. The symbiont and the symbiotic environment influence each other, and the symbiont affects the symbiont through the exchange of matter, information and energy. This effect can be both negative and positive. According to the results of the symbiotic environment influence, the symbiotic environment can be divided into positive environment, neutral

environment and reverse environment. Correspondingly, the impact of symbionts on the environment is also divided into three types: positive effect, neutral effect and reverse effect.

1.2 The Connotation of Urban Sustainable Development

1.2.1 Cities and their characteristics

Cities have increasing populations, highly intensive human activity, large ecological and environmental service demands, and a concentration of resource use and consumption[28, 29]. Cities are not a product of modern society, the first prototypes of cities appeared as early as 5,000 years ago. Various ancient civilizations emerged successively with various cities. For example, Chang'an was the largest city in the world at that time. When human society and civilization developed to a certain stage, cities came into being. A city is not as easy to perish as a tribe. Its organizational form is more rigorous, and it has survived for a longer time. Its scale is larger than towns and villages to accommodate more people. Within a certain spatial range, the city effectively utilizes the surrounding environment and resources, gathers a large number of people together, and carries out material production and living activities together. The gradually developed economy, science and culture attract more people to enter the city. The scale of the city gradually expanded, thus realizing the progress of mankind.

When the handicraft industry was separated from agriculture, the city began to take shape, and the real rapid development of the city originated from the industrial revolution more than 200 years ago. Since then, the population has accelerated to concentrate in cities around the world, and new cities have emerged continuously. At the same time, the scale of cities has also continued to expand, and various super cities have emerged. In 1780, the world's urban population only accounted for less than 3% of the total population, but according to the report of the United Nations Habitat, it is estimated that by 2050, the world's urbanization level will reach as high as 61%.

As a center of regional wealth, information, capital, and talents, a city has its

own development characteristics, which are mainly manifested in:

(1) A city is an aggregate of various elements, each element is gathered together in a high-density form, and the efficiency of the aggregate is much higher than that of any single element. The city gathers a large number of people, material, economic and Cultural activities, this agglomeration effect has led to the increasing scale of cities, and the emergence of super cities with a population of tens of millions such as Mexico City, New York, Tokyo and Shanghai. The high concentration of urban resources makes the economic and social benefits of cities much higher than that of rural areas. For example, in 1994, the population of Shanghai accounted for only 1.13% of the national population, and the land area accounted for only 0.06% of the national total. However, the GDP accounted for 4.38% of the national gross domestic product, and the national income accounted for The total industrial output value accounted for 5.53% of the national total output value. At the same time, the per capita GDP of Henan and Hunan, which are traditionally large agricultural provinces, are only 16% and 17% of Shanghai's respectively, which further confirms the high efficiency of cities

(2) The urban artificial environment has been fully developed. With the rapid development of productivity, the spatial layout of cities is becoming more and more suitable for the survival of modern people, and various artificial infrastructures have greatly facilitated people's work and life. This is also one of the signs that distinguish modern cities from tribes and villages. However, the spatial environment created by humans lacks a self-balancing mechanism, and cities cannot repair and balance themselves like the natural environment. Because of this, the contradiction between cities and natural ecosystems is becoming increasingly acute. If urban managers cannot resolve this contradiction, various ecological problems will inevitably occur in the city, which will affect the sustainable development of the city.

(3) The openness of the city is obvious. The degree of internationalization of modern cities is getting higher and higher. The space for urban economic activities is not limited to the interior of the city, but is expanding outward. The economic exchanges between cities are becoming more and more frequent. Multiple cities in a region have gradually formed Urban agglomerations are more closely connected with

each other. The resulting cluster benefits drive the common development of each city.

(4) The city's scientific and technological innovation capabilities have been enhanced. A large number of scientific research units and institutions are concentrated in the city. A large number of scientific research results have been developed in various fields. The city has undoubtedly accelerated the speed at which these scientific research results are transformed into products. At the same time, the city has advanced information dissemination methods, which can spread these scientific research results to the outside world, thereby promoting the development of the entire technology.

1.2.2 The connotation of urban sustainable development

Sustainable development requires that development patterns that meet the needs of the present generation do not harm the needs of future generations[30]. Moreover, sustainable development seeks a balance between the increases in society and economy and decrease in ecological and environmental marginal benefits, and ceaselessly pursues the reasonable coordinative development of economic benefits and social[31, 32]. Sustainable development is an important issue for human beings[33]. Although as early as the 1980s, the international community clearly put forward the goal of sustainable development, but the specific measures and methods of sustainable development are being explored. The scientific community has also attempted to use specific scientific methods to illustrate and achieve this goal. Urban sustainable development refers to the long-term, stable, and healthy development of a city in various aspects, such as economy, society, and environment, without causing harm to the environment or disrupting ecological balance. It is a comprehensive concept aimed at meeting the needs of current residents while protecting the interests of future generations. The connotation and significance of urban sustainable development are as follows:

1. Economic sustainability: By improving production efficiency and effectiveness, urban sustainable development aims to enhance economic growth and competitiveness. It also optimizes resource allocation, reduces waste, and decreases reliance on natural resources.

2. **Social sustainability:** This aspect focuses on the well-being of urban residents by ensuring access to basic needs such as education, healthcare, and housing. It promotes social equity, inclusiveness, and harmony, improving the quality of life and ensuring that all classes and groups share in the benefits of development.

3. **Environmental sustainability:** Urban sustainable development seeks to protect the urban environment and ecosystems, reduce pollution and waste emissions, lower energy consumption and carbon emissions, and improve resource utilization efficiency to achieve harmony between the environment and development.

4. **Institutional sustainability:** Establishing effective legal, policy, and planning systems supports the strategic goals and implementation measures of urban sustainable development, enhancing urban governance capacity and standards.

The core content of sustainable development is to realize economic development in an all-round way. This is a brand-new value concept. The basis of sustainable development is natural resources that can be recycled for a long time and a good environment. The condition for realization is to protect the environment on which we live. The ultimate goal is to improve and improve the quality of human life.

The significance of urban sustainable development includes:

1. **Protecting Earth's resources:** By improving resource utilization efficiency and reducing waste, urban sustainable development lowers the consumption of natural resources, slowing down resource depletion and preserving valuable resources for future generations.

2. **Ensuring ecological security:** Protecting urban ecosystems and biodiversity, reducing environmental pollution, and addressing climate change create a suitable living environment for humans and other species.

3. **Enhancing human well-being:** By guaranteeing basic needs and improving the quality of life, urban sustainable development ensures social equity and inclusiveness, fostering comprehensive human development and well-being.

4. **Promoting global cooperation:** Urban sustainable development is a global issue that requires the joint efforts and collaboration of countries and regions, driving global environmental governance and sustainable development.

In summary, urban sustainable development aims to achieve long-term, stable, and healthy development in various aspects such as economy, society, and environment, striving to create a prosperous, inclusive, and sustainable urban environment for all.

CHAPTER TWO URBAN SYMBIOSIS SYSTEM AND SUSTAINABLE DEVELOPMENT EVALUATION INDEX SYSTEM

From the perspective of systematics, a city is an extremely complex and huge system. The emergence, development and evolution of cities also follow the law of symbiosis. Therefore, cities can also be regarded as a symbiotic system.

2.1 Overview of Urban Symbiosis System

Since cities can be viewed as a symbiotic system, sustainable urban development refers to the realization of interdependence and mutual symbiosis between people and people, people and nature, and people and cities, with the aim of achieving comprehensive human development, the key to which is how to guide development through the use of advanced scientific and technological means. In sustainable urban development, comprehensive human development is the center, and it mainly includes population quantity, quality, social living standard and economic level. Among all the factors, environment and resources are the main factors that restrict people to achieve comprehensive development. To sum up, we regard the urban symbiosis system as a symbiotic system consisting of six subsystems: population, resources, economy, society, science and technology, and environment.

2.1.1 Composition of urban symbiosis system

The core and subject of the entire urban symbiosis system is the population subsystem. The production and reproduction activities of the population constitute the population subsystem, and human beings realize their own survival and reproduction in this process. The population subsystem mainly includes two aspects: population quantity and population quality. Population quantity refers to the total population of a city within a certain period of time. Population quality refers to the comprehensive quality and ability of the population, which is mainly reflected in physical quality, scientific and cultural quality and moral quality. The population subsystem is the most

active component in the entire urban symbiosis system, and the population subsystem is the basis of all other activities in the urban symbiosis system.

The society subsystem refers to the sum of all social life activities that the population engages in. This subsystem is mainly composed of material, cultural and political life. Material life mainly refers to a form of existence that meets the survival needs of the population, mainly including clothing, food, housing, transportation, etc. Cultural life refers to all ideological activities except for human physiological survival needs, including reading, writing, entertainment, sports and other artistic activities. Political life refers to the activities of citizens exercising their own political rights, fulfilling various political obligations and participating in bottom-up democratic supervision in daily social life.

The economy subsystem refers to the production and reproduction of material means of living in the process of urban sustainable development. The economic subsystem is the material basis of the city. It provides urban residents with various products needed for survival, such as food, clothing, transportation, etc., and is the guarantee for the improvement of the quality of life of urban residents. There are many economic factors in the city, which are closely related and restrict each other, and together constitute the economic subsystem. This system can generally be divided according to industry, divided into primary industry subsystem, secondary industry subsystem and tertiary industry subsystem. Every industry has many factors. In research, segmentation can be done according to actual needs.

The science subsystem refers to the widespread application of science and technology to all aspects of economic and social life in the process of material production and reproduction. The role of science and technology in urban sustainable development has become increasingly prominent, directly accelerating the process of urban sustainable development. The level of science and technology is an important symbol to measure the development level of a city. As the name implies, science and technology are composed of two aspects: science and technology. Science refers to the systematic knowledge system about nature and society formed by people in the course of history. Science solves theoretical problems. Technology refers to the application of

scientific research results to practical problems. In the technology subsystem under the urban sustainable development symbiosis system, the technology we refer to generally includes two aspects: natural science and social science.

Resources subsystem refers to various material resources, cultural resources and human resources used for urban construction or serving urban residents. Among them, material resources are the foundation, the most intuitive and important resources, mainly including various infrastructure resources in the city, urban housing construction, garden greening, etc., and available land resources in the city, urban water use, and energy consumed by the city. Cultural resources mainly include the historical heritage of the city, the cultural symbols of the city, the advanced models of all walks of life in the city, the corporate culture of the city and the characteristic culture of the city. These are the cultural accumulation of the city and represent the soft power of the city. To some extent, it is a symbol of a city. Human resources usually refer to urban residents who have certain work experience or work skills, and whose physical conditions are suitable for work. In the resource subsystem under the urban sustainable development symbiosis system, the resources we refer to are generally divided into natural resources and socioeconomic resources.

The environment subsystem refers to the general term of all material, energy and information elements around urban residents. It mainly includes natural environment and social environment. The natural environment includes many elements such as geology, landforms, hydrology, climate, flora and fauna, and soil. The social environment mainly includes basic elements such as economy, politics, culture, history, population, nationality, and behavior. The sum of all these elements and their interrelationships constitutes the environmental system. Each of these elements is related to and restricts each other to form an organic whole. The environment under the symbiotic system of urban sustainable development mainly refers to the production and reproduction of the environment, especially the activities of people engaged in environmental protection.

For the urban symbiotic system, the sustainable and healthy economic and social development is the driving force for its development, while the resistance to its

development mainly comes from the accelerated scarcity of resources and the continuous deterioration of the environment. The precondition for urban system to realize symbiosis is that the impetus of its development is greater than the resistance of its development. As the three elements of the urban symbiotic system, the symbiotic unit, symbiotic model and symbiotic environment of the urban symbiotic system are crucial to the formation of the urban symbiotic relationship. The three interact to form an urban symbiotic relationship. Among the three elements of the urban symbiotic system, the symbiotic model is the key, the symbiotic unit is the foundation, and the symbiotic environment is the external condition.

2.1.2 Elements of an urban symbiosis system

Like all symbiotic systems, the urban symbiotic system has three elements: the symbiotic unit (U), the symbiotic model (M) and the symbiotic environment (E), all of which are indispensable.

The symbiotic unit (U) is the most basic material basis of the symbiosis. In various symbionts or symbiotic relationships, the symbiotic unit is the most basic unit of energy production and exchange. The nature and characteristics of the symbiotic unit vary according to the symbiotic system in which the symbiotic unit is located. In the urban symbiosis system we study, the urban symbiosis unit is mainly composed of six subsystems: population, resources, economy, society, technology and environment. In the urban symbiosis system, we call the factors that reflect the external characteristics of the urban symbiosis unit as image parameters, and the factors that determine the internal nature and changes of the urban symbiosis unit are called qualitative parameters. Quality parameters play a major role in the entire urban symbiosis system.

The symbiotic model (M), also known as the symbiotic relationship, refers to the behavioral pattern of interaction and integration between the symbiotic units of a symbiont or a symbiotic relationship. It reflects the material and energy exchange relationship and information exchange relationship between the symbiotic units in the urban symbiotic system, as well as the organization and interaction forms between the symbiotic units. There are also many classification methods for the symbiosis mode of

the urban symbiosis system. First of all, it can be divided into parasitic mode, beneficial symbiosis mode, asymmetric mutual benefit symbiosis mode and symmetric mutual benefit symbiosis mode from the behavior mode. Secondly, from the perspective of organization, it can be divided into point symbiosis, intermittent symbiosis, integrated symbiosis, continuous symbiosis, etc.

The symbiotic environment (E) refers to the sum of all external influencing factors other than the symbiotic unit. The symbiotic model of the urban symbiotic system is the relationship between symbiotic units that need to be developed in a specific environment. The urban symbiosis and the urban symbiotic environment influence each other, and the urban symbiotic environment affects the urban symbiotic unit through the exchange of materials, information and energy. This effect can be both negative and positive. According to the results of the impact of the urban symbiotic environment, the urban symbiotic environment can be divided into positive environment, neutral environment and reverse environment. Correspondingly, the impact of urban symbiosis on the environment is also divided into three types: positive effect, neutral effect and negative effect. Generally speaking, the main symbiotic environment of the urban symbiotic system is the urban economic institutional environment.

For the urban symbiotic system, the sustainable and healthy economic and social development is the driving force for its development, while the resistance to its development mainly comes from the accelerated scarcity of resources and the continuous deterioration of the environment. The precondition for urban system to realize symbiosis is that the impetus of its development is greater than the resistance of its development. As the three elements of the urban symbiotic system, the symbiotic unit, symbiotic model and symbiotic environment of the urban symbiotic system are crucial to the formation of the urban symbiotic relationship. The three interact to form an urban symbiotic relationship. Among the three elements of the urban symbiotic system, the symbiotic model is the key, the symbiotic unit is the foundation, and the symbiotic environment is the external condition.

2.1.3 Characteristics of urban symbiosis system

The urban symbiosis system is a very complex large-scale system. It has the same characteristics as the general large-scale system, such as giantness, internal difference, hierarchy, correlation, and functionality. In addition, the urban symbiosis system also has some important features. feature. The urban symbiosis system is a very complex large-scale system. It has the same characteristics of internal differentiation, hierarchy, correlation and functionality as a large system in the usual sense. In addition, the urban symbiosis system also has some important characteristics.

(1) Complexity. The six subsystems of population, resources, economy, society, technology and environment together constitute the urban symbiosis system. Each subsystem is composed of a large number of elements. For example, the resource subsystem is composed of material resources and socio-economic resources. Material resources include land, water, energy and infrastructure. Social and economic resources include cultural resources and human resources. The sustainable development of cities is to seek scientific and effective ways to promote the coordinated and orderly development of urban complex systems from fuzzy to systematic.

(2) Openness. The urban symbiosis system is not a closed system. There are constant interactions and influences between the city and the external environment, as well as between various subsystems within the city. Such as exchanging matter, transferring energy, exchanging information, etc. All these indicate that the urban symbiosis system is a typical open system.

(3) Participation of people. The people in the city are the main part of the city. The sustainable development of cities emphasizes the realization of people-oriented comprehensive development. Unlike natural and man-made systems, humans participate in all aspects of urban symbiotic systems. People's value orientation, decision-making methods and development concepts greatly affect the sustainable development of cities.

(4) Spatial and geographical differences. The development of cities is affected by many factors such as geography, history, and humanities, and there are obvious

differences between cities. Taking China as an example, due to regional differences, the urban systems in the eastern, central and western regions present different characteristics. Due to the different levels, national central cities, provincial capital cities, prefecture-level cities and county-level cities also have their own characteristics.

(5) Dynamic evolution. Urban sustainable development is a process of continuous dynamic evolution. The system, structure and function of the city are constantly adjusted and moving towards a gradually optimized direction, and finally realize the transformation from unbalanced to balanced development. The subsystems of the city are also in the process of continuous optimization and adjustment to better adapt to each other's coordinated development.

2.1.4 Structure of urban symbiosis system

The urban symbiosis system is a huge system, which is composed of many elements, the composition level is very complicated, and the relationship between each element is intricate. Each of these subsystems contains many elements. For example, the economic subsystem is composed of the primary industry subsystem, the secondary industry subsystem, and the tertiary industry subsystem. The primary industry subsystem includes agricultural input, agricultural output and other factors.

Among the six subsystems, the population subsystem is the core part, which provides the other subsystems with the labor necessary for production and reproduction. At the same time, other subsystems are also providing various conditions for the population subsystem to develop. For example, the economic subsystem provides the material conditions required for the development of the population subsystem, the social subsystem meets the needs of the population subsystem in terms of spiritual civilization, and the technology subsystem provides the population subsystem with various rich scientific and cultural knowledge and corresponding technology. However, the population subsystem will also have a negative impact on other subsystems. When the population expands excessively, it will inevitably cause social security chaos, environmental pollution, and resource shortages.

2.2 Construction of sustainable development evaluation index system of urban symbiosis system

2.2.1 Principles for constructing the sustainable development evaluation index system of urban symbiosis system

To establish an index system for the sustainable development of the urban symbiotic system, certain principles must be followed, so that the established index system can objectively, scientifically, systematically and accurately reflect and evaluate the sustainable development of the urban symbiotic system. This thesis believes that four basic principles should be followed when constructing the sustainable development evaluation index system of urban symbiosis system: systemic principle, functional principle, operable principle and independent principle.

(1) Systematic principles. First of all, the urban symbiotic system is composed of many factors, and the index system should also be a whole and can reflect the characteristics and status of the urban symbiotic system from all aspects. Secondly, the urban symbiosis system has dynamic evolution, and the corresponding index system should also reflect this development trend. Thirdly, the structural level of the urban symbiosis system should be used as the basis for the index classification of the index system, so that the index system designed in this way can be hierarchical and well-organized. Finally, the various elements in the urban symbiosis system are interrelated, and the index system must also have a certain degree of correlation. Establish links between indicators, but attention should be paid to reducing the overlap and duplication of indicators.

(2) Functional principle. The purpose of constructing the index system is to evaluate the sustainable development level, development ability and coordination of the urban symbiosis system. First, the most basic function of the indicator system is the descriptive function. The descriptive indicators need to be able to fully reflect various phenomena in the urban symbiosis system and reflect the degree of realization of the sustainable development goals. Second, explanatory indicators are used to clarify the reasons for the existence of certain phenomena in the urban symbiosis system. Third,

evaluation indicators are mainly used to compare the gaps between various subjects, which requires unified standardization of evaluation indicators to facilitate application. Fourth, monitoring indicators are used to reveal the problems existing in the development of urban symbiotic systems, and such indicators must be measurable objective indicators or estimable subjective indicators. Fifth, early warning indicators need to give early warning of unsustainable dangerous trends in the sustainable development of urban symbiotic systems. In addition, urban decision makers usually like to use data indicators to guide urban planning and decision-making issues. Therefore, the indicator system is closely related to the decision-making process.

(3) The principle of operability. When establishing an indicator system, it is necessary to consider whether the indicators can be quantified and the difficulty of obtaining the indicators, and try to choose those representative comprehensive indicators, such as the data indicators released by the government statistics department. The construction of the index system should also be as simple and clear as possible. An indicator system that is too complex will make it difficult to operate and lose its proper functionality.

(4) The principle of independence. When selecting the index system of the urban symbiosis system, we should try our best to avoid the overlap between the indexes, and choose those relatively independent indexes, so as to ensure the scientificity and accuracy of the evaluation of the index system.

2.2.2 Evaluation index system for sustainable development of urban symbiosis system

When we construct the sustainable development evaluation index system of the urban symbiosis system, we must strictly follow the principles of evaluation index system construction, and take into account the independent indicators that can reflect the six subsystems of population, society, economy, resources, environment, and technology. The coordination index that reflects the interrelated and interactive symbiotic relationship between each index element should also be considered.

The so-called independent index set refers to the degree of correlation between two index elements in the index system selected by the index system is small or irrelevant. For example, the index set of the social subsystem can choose indicators such as health care level, social insurance level, per capita consumption level, Engel coefficient, and urban development balance. The so-called coordination index refers to the index used to describe the interrelationship and interaction between the elements in the index system. According to the principle of selecting indicators, the index sets selected by each subsystem are as follows.

Table 2.1 Index set of population subsystem

index of population	unit	positive(+)/negative(-)
total population	person	+
urban population	person	+
rural Population	person	+
birth rate	%	+
death rate	%	-
natural growth rate	%	-
gross dependency ratio	%	+
children dependency ratio	%	-
density of population	persons/km ²	-
sex ratio	%	-
the registered urban unemployment rate	%	-
life expectancy	years	+
illiterate rate	%	-
urbanization rate	%	+
economically active population	person	+
urban employed persons	person	+
rural employed persons	person	+

Source: the National Bureau of Statistics in China(<https://data.stats.gov.cn/english/>).

Table 2.2 Index set of society subsystem

index of society	unit	positive(+)/negative(-)
consumer price index	-	-
retail price index	-	-
the water consumption per person	m ³ /person	-
per capita disposable income of urban residents	yuan	+
per capita disposable income of rural residents	yuan	+
per capita consumption expenditure of urban residents	yuan	-
per capita consumption expenditure of rural residents	yuan	-

public transport vehicles per 10,000 people	standard units	+
per capita urban road area	m ²	+
per capita park green area	m ² /person	+
public toilets per 10,000 people	seats	+
engel coefficient of urban households	%	+
engel coefficient of rural households	%	+

Source: the National Bureau of Statistics in China(<https://data.stats.gov.cn/english/>).

Table 2.3 Index set of economy subsystem

index of economy	unit	positive(+)/negative(-)
GDP	yuan	+
primary industry	yuan	+
secondary industry	yuan	+
tertiary industry	yuan	+
fiscal budget expenditure	yuan	-
total import and export	dollar	-
added value of wholesale and retail trade	yuan	+
added value of financial industry	yuan	+
added value of the real estate industry	yuan	-
GDP per capita	yuan / person	+
tourism revenue and its proportion in GDP	yuan, %	+
investment in environmental protection and its proportion in GDP	yuan, %	+
investment in education and its proportion in GDP	yuan, %	+
agricultural input and its proportion in GDP	yuan, %	+

Source: the National Bureau of Statistics in China(<https://data.stats.gov.cn/english/>).

Table 2.4 Index set of resources subsystem

index of resources	unit	positive(+)/negative(-)
total water resources	m ³	+
forest area	hectare	+
coke production	ton	-
natural gas production	m ³	+
power generation	kWh	-
coal consumption	ton	-
crude oil consumption	ton	-
number of medical and health institutions	-	+
urban green area	hectare	+
species diversity	specie	+
biomass and rate of change	specie, %	+
resource utilization efficiency	%	+
degree of resource assurance	%	+

Source: the National Bureau of Statistics in China(<https://data.stats.gov.cn/english/>).

Table 2.5 Index set of environments subsystem

index of environment	unit	positive(+)/negative(-)
harmless disposal of domestic waste	ton	-
forest cover rate	%	+
planted forest area	hectare	+
SO2 emissions and rate of change	ton, %	-
CO2 emissions and rate of change	ton, %	-
industrial waste gas emissions and rate of change	ton, %	-
industrial wastewater discharge and change rate	ton, %	-
annual solid waste generation and rate of change	ton, %	-
daily treatment capacity of urban sewage	m ³	+
length of urban drainage pipes	km	+
road cleaning area	m ²	+
park green area	hectare	+
forest pest and rodent control rate	%	+
accumulated area of solid waste	hectare	-
city noise	dB	-
soil erosion area and change rate	hectare, %	-
desertified land area and rate of change	hectare, %	-

Source: the National Bureau of Statistics in China(<https://data.stats.gov.cn/english/>).

Table 2.6 Index set of science subsystem

index of science	unit	positive(+)/negative(-)
contribution rate of scientific and technological progress	%	+
scientific research expenditure per capita	yuan	+
technological innovation capacity	%	+
utilization rate of scientific research results	%	+
R&D expenditure to GDP ratio	%	+
number of patent applications granted	item	+
number of new product	item	+
output of mobile communication handsets	unit	+
output of microcomputers	unit	+
integrated circuit output	pieces	+
number of Domain Names	item	+
internet broadband access users	household	+
education expenses	yuan	+
number of undergraduate graduates of universities	people	+

Source: the National Bureau of Statistics in China(<https://data.stats.gov.cn/english/>).

The indicator system has 87 indicators in total, including 17 population indicators, 13 social indicators, 13 economic indicators, 13 resource indicators, 17 environmental

indicators and 14 scientific and technological indicators. In the empirical research, it can be seen that economic indicators and technological indicators are basically positive indicators, and more technological and economic indicators can be selected for evaluation and research according to the actual situation.

CHAPTER THREE RESEARCH ON THE EVALUATION OF URBAN SUSTAINABLE DEVELOPMENT IN SHANGHAI

3.1 Overview of Shanghai

This paragraph presents a comprehensive overview of the city of Shanghai, located in eastern China. The paragraph covers the geography, history, economy, culture, and urban development of the city. Shanghai has experienced tremendous economic growth over the past few decades, becoming a major center for finance, commerce, and culture in China. The city's unique culture reflects its diverse population and rich history, while its urban development has been rapid and extensive.



Fig 3.1 The map of China and Shanghai.

Shanghai is a sprawling city located at the mouth of the Yangtze River on China's eastern coast. It is the largest city in China and one of the largest cities in the world. Over the past few decades, Shanghai has experienced tremendous economic growth, becoming a major center for finance, commerce, and culture in China. The city's unique culture reflects its diverse population and rich history, while its urban development has been rapid and extensive.

Shanghai is located on the east coast of China, at the mouth of the Yangtze River. It covers an area of 6,340.5 square kilometers, including the city proper, suburbs, and

islands. The city is divided into 16 districts and one county. The Huangpu River runs through the city center, dividing the city into two parts: Puxi, to the west of the river, and Pudong, to the east of the river.

Shanghai has a rich history dating back more than 1,000 years. During the Song Dynasty (960-1279), it became a major center for trade and commerce due to its location at the mouth of the Yangtze River. In the 19th century, it became one of the Treaty Ports established by Western powers, leading to significant foreign influence on the city. In the early 20th century, it became a center for Chinese industry, with the establishment of factories and mills. After the founding of the People's Republic of China in 1949, Shanghai continued to develop as a major economic and cultural center. Shanghai's economy has grown rapidly over the past few decades, becoming one of the most important financial centers in China and the world. The city's GDP reached 3.87 trillion yuan (approximately US\$593 billion) in 2020, making it one of the richest cities in China. The city's economy is diversified, with services, manufacturing, and high-tech industries being major contributors. The city's port is the largest in China and a major center for international trade.

Shanghai has a unique culture that reflects its history and diverse population. The city is known for its art, music, and literature, as well as its traditional cuisine. The city has numerous museums and galleries, such as the Shanghai Museum, which houses a vast collection of Chinese art and artifacts. Traditional gardens, such as the Yu Garden, are also popular tourist attractions.

Shanghai's urban development has been rapid and extensive in recent decades. The city has undergone a massive transformation, with many skyscrapers and modern buildings being built. The city's skyline is dominated by landmark buildings such as the Oriental Pearl Tower and the Shanghai Tower. The city has also invested heavily in transportation infrastructure, including the Shanghai Metro, which is one of the largest rapid transit systems in the world.

Shanghai is a dynamic and rapidly developing city with a rich history, diverse culture, and strong economy. The city's urban development has been remarkable, making it a modern metropolis that attracts millions of visitors each year. With

continued investment in infrastructure and the development of new industries, Shanghai is poised to remain one of China's most important cities for years to come.

3.2 Evaluation on the comprehensive level of sustainable development of urban symbiosis system in Shanghai

Each subsystem selects 9 sets of representative data indicators every year from 2011 to 2019, so each subsystem has a total of 81 data. But not every set of data indicators will play a significant role in the sustainable development of the corresponding subsystem, so this thesis mainly uses the principal component analysis[34] method for data dimensionality reduction, feature extraction and data compression, transforming the correlated variables of the raw data into a new set of linear independent variables through an orthogonal transformation, namely principal component which play a extremely significant role effecting sustainable development of each subsystem. These principal components can preserve the variation information in the original data to the greatest extent and represent the data with as few dimensions as possible. According to the determined principal components of each subsystem, the comprehensive level of sustainable development of each subsystem is calculated. Since the sustainable development of each subsystem has different impacts on the overall sustainable development of Shanghai, this thesis takes advantage of the analytic hierarchy process[35] to determine the weight ratio of each subsystem. Finally, the evaluation function of the comprehensive level of sustainable development in Shanghai is obtained. All data processing in this thesis is done with the help of SPSS25.

SPSS[36] (Statistical Package for the Social Sciences) is a powerful statistical analysis and data management software, widely used in social sciences, market research, health sciences, policy research, and other fields. Initially released in 1968, SPSS has grown over the years to become one of the leading tools in the field of statistical analysis. The main features of SPSS include:

Data management: SPSS provides data input, cleaning, transformation, and organization features, allowing users to efficiently manage large amounts of data.

Descriptive statistics: SPSS can calculate various descriptive statistics, such as mean, standard deviation, frequency distributions, etc., to give users an intuitive understanding of their dataset.

Inferential statistics: SPSS supports various hypothesis testing, confidence interval estimation, and correlation and regression analysis methods, allowing users to infer population characteristics from sample data.

Graphs and reports: SPSS can generate various types of charts, such as bar charts, pie charts, scatter plots, etc., to visually display data distribution and relationships. Additionally, SPSS can produce formatted output reports, making it easy for users to present their analysis results to others.

SPSS has a user-friendly interface, with menus and dialog boxes to execute various statistical operations. Furthermore, SPSS provides a programming language called "syntax" that users can utilize to write scripts for more complex analysis tasks. As the software is updated with new versions, SPSS continuously adds new features and improves performance to accommodate a wide range of statistical analysis needs.

3.2.1 Evaluation method for sustainable development of urban symbiosis system based on principal component analysis

The comprehensive evaluation of sustainable development of urban symbiosis system is a multi-level and multi-indicator comprehensive evaluation problem. There are two main steps. First, the comprehensive development level of each subsystem is calculated, and then, each subsystem is synthesized[37].

(1) Dimensionless processing of indicator data $X_{ij}(i = 1, 2, 3 \dots p, j = 1, 2, 3 \dots n)$:

$$Y_{ij} = \frac{x_{ij}}{\max x_i} \quad 3.1$$

Among them, Y is the indicator data set of dimensionless X_{ij} .

(2) Construct the correlation coefficient matrix $R = (r_{ij})_{n \times m}$:

$$r_{ij} = \frac{1}{p} \sum_{x=1}^p Y_{xi} Y_{xj}, \quad i, j = 1, 2, 3 \dots n \quad 3.2$$

(3) Find the eigenvalue of $R \lambda_{i+1} \geq \lambda_i \quad i = 0, 1, 2 \dots n - 1$, and the corresponding eigenvector is:

$$\beta_i = (\beta_{i1}, \beta_{i2}, \dots, \beta_{in})^T \quad 3.3$$

(4) Calculate the contribution rate p_j of each principal component and select an appropriate amount of m principal components as needed. Where m satisfies ($m < n$) and $\sum_{i=1}^m \lambda_i / \sum_{i=1}^n \lambda_i \geq e$ the smallest positive integer, usually e takes 0.85.

$$p_j = \lambda_j / \sum_{i=1}^n \lambda_i \quad j = 1, 2, \dots, n \quad 3.4$$

(5) Calculate the score value of the sample on each principal component, namely:

$$(Z_1^i, Z_2^i, Z_3^i, \dots, Z_m^i \quad i = 1, 2, \dots, p) \quad 3.5$$

(6) Calculate the score of the i -th sample:

$$q_i = p_1 | Z_1^i | + p_2 / Z_2^i | + p_3 / Z_3^i | + \dots + p_m / Z_n^i | \quad i = 1, 2, \dots, p \quad 3.6$$

From this, the comprehensive development level of each subsystem can be calculated, and then weighted according to the weight of each subsystem to obtain the comprehensive development level of the entire urban symbiosis system.

3.2.2 Determination of evaluation index weights based on analytic hierarchy process

Analytic Hierarchy Process is a comprehensive analysis method, which combines qualitative and quantitative, and is a systematic and hierarchical analysis method. When a problem is composed of many factors, and many factors are interrelated and restrict each other, or when there is a lack of quantitative data, the AHP can be applied. For the comprehensive evaluation problem of multi-level and multi-indicator evaluation of sustainable development of urban symbiosis system, AHP is suitable for determining the weight of each index. According to the basic criterion of the relative importance judgment matrix, it is judged which is more important in pairwise comparison between two elements, the relative importance degree, and then the degree of importance is assigned. Scale of significance is shown in Fig 3.2.

Evaluation scale	Definition	Description
1	Equal Importance	Levels of contribution of the two alternatives being compared are equally important
3	Weak Importance	Experience and judgment slightly prefer one alternative
5	Essential Importance	Experience and judgment strongly prefer one alternative
7	Very Strong	An extremely strong preference for one alternative is demonstrated
9	Absolute Importance	There is sufficient evidence to affirm the absolute preference for one alternative
2,4,6,8	Intermediate values	A compromise value is needed

Fig 3.2 Scale of significance.

There are $A_1, A_2, A_3, \dots, A_n$ indexes whose values are $w_1, w_2, w_3, \dots, w_n$. Apply this scale to assign values in pairs to the indicators, and the obtained ratios can form a matrix A with n rows and n columns:

$$A = \begin{pmatrix} w_1 / w_1 & w_1 / w_2 & \cdots & w_1 / w_n \\ w_2 / w_1 & w_2 / w_2 & \cdots & w_2 / w_n \\ \cdots & \cdots & \cdots & \cdots \\ w_n / w_1 & w_n / w_2 & \cdots & w_n / w_n \end{pmatrix} \quad 3.7$$

Multiply the matrix A by the eigenvector W to the right to get:

$$W = (w_1, w_2, w_3, \dots, w_n)^T \quad 3.8$$

$$W = A \cdot \begin{pmatrix} w_1 \\ w_2 \\ \cdots \\ w_n \end{pmatrix} = nW \quad 3.9$$

Finally, a consistency check is performed. In the above formula, W is the eigenvector, n is the eigenvalue, and the matrix has the only non-zero maximum eigenvalue $\lambda = \lambda_{max}$, generally speaking, λ_{max} is not equal to n . To check its consistency, $C.I$ is introduced as an indicator.

$$C.I = \frac{\lambda_{max} - n}{n - 1} \quad 3.10$$

When $\lambda_{max} = n$, $C.I = 0$, which means it is completely consistent. The worse the consistency of the judgment matrix, the greater the value of $C.I$. As long as $C.I \leq 0.1$,

the consistency of the judgment matrix is considered acceptable.

3.2.3 An Empirical Study on the Comprehensive Level Evaluation of Sustainable Development of Urban Symbiosis System in Shanghai

This thesis chooses the period from 2011 to 2019 to conduct empirical research on the evaluation of the comprehensive level of sustainable development of Shanghai's urban symbiosis system and consults the "Shanghai Statistical Yearbook" from 2011 to 2019 to obtain basic data.

(1) The index data of each subsystem in Shanghai from 2011 to 2019 is shown in the table.

Table 3.1 Primary data of population subsystem in Shanghai (2011-2019)

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9
2011	2356	2104	252	3702	1.87	6.97	5.10	113.09	3.50
2012	2399	2142	257	3754	4.20	9.56	5.36	108.78	3.10
2013	2448	2193	255	3809	2.94	8.18	5.24	106.24	4.00
2014	2467	2203	264	3826	3.14	8.35	5.21	106.70	4.10
2015	2458	2176	282	3809	2.45	7.72	5.07	108.37	4.00
2016	2467	2196	271	3816	4.00	9.00	5.00	105.87	4.10
2017	2466	2197	269	3814	2.80	8.10	5.30	103.54	3.90
2018	2475	2206	269	3823	1.80	7.20	5.40	106.61	3.50
2019	2481	2214	267	3830	1.50	7.00	5.50	107.86	3.60

In Table 3-1, X1 is the resident population (10,000 persons), X2 is the urban population (10,000 persons), X3 is the rural population (10,000 persons), X4 is the density of population (persons/km²), X5 is the rate of natural increase (%), X6 is the birth rate (%), X7 is the mortality rate (%), X8 is the sex ratio (%), and X9 is the registered urban unemployment rate (%).

Table 3.2 Primary data of society subsystem in Shanghai (2011-2019)

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9
2011	536	37079	15737	28929	10103	11.79	4.04	7.01	2.46

2012	491	31130	17452	30256	10947	11.91	4.08	7.08	2.66
2013	514	44878	19208	32447	13016	12.11	4.11	7.10	2.58
2014	438	48841	21192	35182	14820	11.97	4.11	7.33	2.54
2015	429	52962	23205	36946	16152	12.36	4.27	7.62	2.57
2016	434	57692	25520	39857	17071	12.70	4.37	7.83	2.57
2017	433	62596	27825	42304	18090	13.94	4.51	8.19	2.57
2018	427	68034	30375	46015	19965	9.04	4.58	8.49	2.50
2019	416	73615	33195	48272	22449	9.29	4.72	8.73	2.56

In Table 3-2, X1 is the water consumption per person (m^3/person), X2 is the per capita disposable income of urban residents (yuan), X3 is the per capita disposable income of rural residents (yuan), X4 is the per capita consumption expenditure of urban residents (yuan), X5 is the per capita consumption expenditure of rural residents (yuan), X6 is the public transport vehicles per 10,000 people (standard units), X7 is the per capita urban road area (m^2), X8 is the per capita park green area (m^2/person), and X9 is the public toilets per 10,000 people (seats).

Table 3.3 Primary data of economy subsystem in Shanghai (2011-2019)

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9
2011	20009.7	126.4	8169.3	11713.9	3914.88	437548615	3061.5	2237.3	1289.2
2012	21305.6	129.3	8174.1	13002.1	4184.02	436586950	3344.3	2422.6	1501.0
2013	23204.1	131.6	8286.5	14786.0	4528.61	441268216	3593.3	2787.2	1917.4
2014	25269.8	132.0	8633.3	16504.5	4923.44	466399838	3729.4	3365.3	2121.1
2015	26887.0	125.5	8408.7	18352.8	6191.56	449240723	3892.2	4089.5	2404.2
2016	29887.0	114.3	8570.2	21202.4	6918.94	433768191	4218.5	4698.0	3102.5
2017	32925.0	110.8	9525.9	23288.3	7547.62	476196649	4562.9	5334.5	2873.2
2018	36011.8	104.8	10360.8	25546.3	8351.54	515679700	4884.8	5901.9	3185.3
2019	37987.6	107.1	10193.6	27686.9	8179.28	493905026	5023.2	6535.2	3300.7

In Table 3-3, X1 is the GDP (100 million yuan), X2 is the primary industry (100 million yuan), X3 is the secondary industry (100 million yuan), X4 is the tertiary industry (100 million yuan), X5 is the fiscal budget expenditure (100 million yuan),

X6 is the total import and export (1,000 dollars), X7 is the added value of wholesale and retail trade (100 million yuan), X8 is the added value of financial industry (100 million yuan), and X9 is the added value of the real estate industry (100 million yuan).

Table 3.4 Primary data of science subsystem in Shanghai (2011-2019)

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9
2011	47960	15726	1005.90	10162.50	1663000.00	68.13	493.5	7106255	8.42
2012	51508	17042	4086.60	9804.80	1603000.00	84.35	541.0	8365270	8.57
2013	48680	17295	4384.90	8101.30	1614000.00	78.30	511.1	9069715	8.46
2014	50488	18927	5484.80	6295.40	2192200.00	102.31	532.2	9892212	8.51
2015	60623	14378	6747.50	3652.00	2174000.00	204.80	568.8	10131153	8.54
2016	64230	15046	4801.43	3083.95	2277600.00	263.21	635.7	11218946	8.77
2017	72806	16121	4710.20	2487.31	2331900.00	240.56	681.3	12104556	8.69
2018	92460	18259	4729.04	1448.81	2334800.00	147.45	772.9	13412840	8.58
2019	100587	20836	4173.16	1121.69	2075941.16	138.88	890.1	14125408	8.56

In Table 3-4, X1 is the number of patent applications granted (items), X2 is the number of new product (items), X3 is the output of mobile communication handsets (10,000 units), X4 is the output of Microcomputers (10,000 units), X5 is the integrated circuit output (10,000 pieces), X6 is the number of Domain Names (10,000 items), X7 is the internet broadband access users (10,000 households), X8 is the education expenses (10,000 yuan), and X9 is the number of undergraduate graduates of universities (10,000 people).

Table 3.5 Primary data of resources subsystem in Shanghai (2011-2019)

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9
2011	21	6.81	640.6	3.0	949.2	6142.00	2134.69	4740	12.23
2012	34	6.81	632.6	2.9	886.2	5703.00	2210.55	4845	12.42
2013	28	6.81	540.0	2.4	958.8	5681.19	2611.76	4929	12.43
2014	47	8.90	489.0	2.1	792.3	4895.78	2242.07	4984	12.57
2015	64	8.90	534.0	1.9	793.0	4728.13	2526.11	5016	12.73
2016	61	8.90	542.9	2.0	807.3	4625.62	2474.23	5016	12.88

2017	34	8.90	556.9	1.7	859.3	4577.84	2492.77	5144	13.63
2018	39	8.90	544.9	14.5	839.7	4420.62	2309.12	5293	13.94
2019	48	8.90	549.3	12.5	822.1	4238.28	2597.22	5597	15.78

In Table 3-5, X1 is the total water resources (100 billion cubic meters), X2 is the forest area (10,000 hectares), X3 is the coke production (10,000 tons), X4 is the natural gas production (100 million cubic meters), X5 is the power generation (100 million kWh), X6 is the coal consumption (10,000 tons), X7 is the crude oil consumption (10,000 tons), X8 is the number of medical and health institutions (units), and X9 is the urban green area (10,000 hectares).

Table 3.6 Primary data of environment subsystem in Shanghai (2011-2019)

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9
2011	704.0	10.7	6.81	24.01	694.3	1.76	1.64	16769	97.9
2012	716.0	10.7	6.81	22.82	701.3	1.82	1.68	17294	98.0
2013	735.0	10.7	6.81	21.58	784.6	1.88	1.71	17385	97.7
2014	608.4	14.0	8.90	18.81	788.0	2.10	1.78	17490	98.9
2015	613.2	14.0	8.90	17.08	785.0	1.69	1.84	17366	96.5
2016	629.4	14.0	8.90	6.50	806.9	1.95	1.90	18253	97.4
2017	743.1	14.0	8.90	1.38	821.0	1.98	1.98	18852	99.6
2018	784.7	14.0	8.90	1.11	813.0	2.20	2.06	20855	95.2
2019	750.6	14.0	8.90	0.75	834.3	2.18	2.12	21190	93.7

In Table 3-6, X1 is the harmless disposal of domestic waste (10,000 tons), X2 is the forest cover rate (%), X3 is the planted forest area (10,000 hectares), X4 is the sulfur dioxide emissions (10,000 tons), X5 is the daily treatment capacity of urban sewage (10,000 cubic meters), X6 is the length of urban drainage pipes (10,000 kilometers), X7 is the park green area (10,000 hectares), X8 is the road cleaning area (10,000 square meters), and X9 is the forest pest and rodent control rate (%).

Among them, we take the social subsystem as an example to calculate.

(2) Data normalization. We used the Z-Score method in the SPSS data analysis software to perform dimensionless processing on the collected data as shown in Fig

3.3, and the results obtained are shown in Table 3-7.

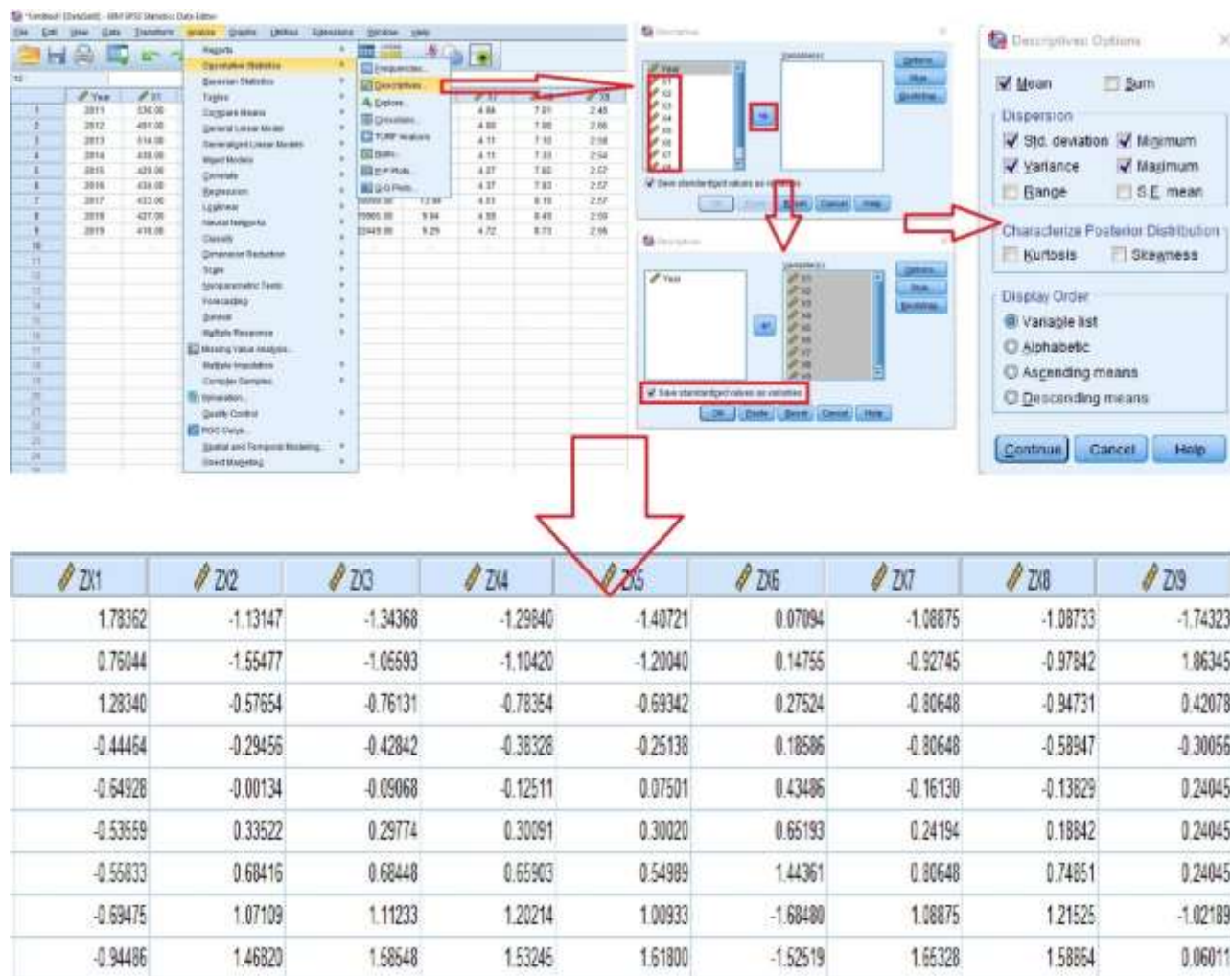


Fig 3.3 Data normalization process in SPSS25

Table 3.7 Results of date disposing for society subsystem without dimensions(2011-2019)

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9
2011	1.7836	-1.1315	-1.3437	-1.2984	-1.4072	0.0709	-1.0888	-1.0873	-1.7432
2012	0.7604	-1.5548	-1.0559	-1.1042	-1.2004	0.1476	-0.9275	-0.9784	1.8635
2013	1.2834	-0.5765	-0.7613	-0.7835	-0.6934	0.2752	-0.8065	-0.9473	0.4208
2014	-0.4446	-0.2946	-0.4284	-0.3833	-0.2514	0.1859	-0.8065	-0.5895	-0.3006
2015	-0.6493	-0.0013	-0.0907	-0.1251	0.0750	0.4349	-0.1613	-0.1383	0.2405
2016	-0.5356	0.3352	0.2977	0.3009	0.3002	0.6519	0.2419	0.1884	0.2405
2017	-0.5583	0.6842	0.6845	0.6590	0.5499	1.4436	0.8065	0.7485	0.2405
2018	-0.6948	1.0711	1.1123	1.2021	1.0093	-1.6848	1.0888	1.2153	-1.0219
2019	-0.9449	1.4682	1.5855	1.5325	1.6180	-1.5252	1.6533	1.5886	0.0601

(3) Correlation coefficient matrix. Using SPSS software, the correlation coefficient matrix of 9 social subsystem indicators in Shanghai from 2011 to 2019 can be obtained, as shown in and Fig 3.4 and Table 3-8.

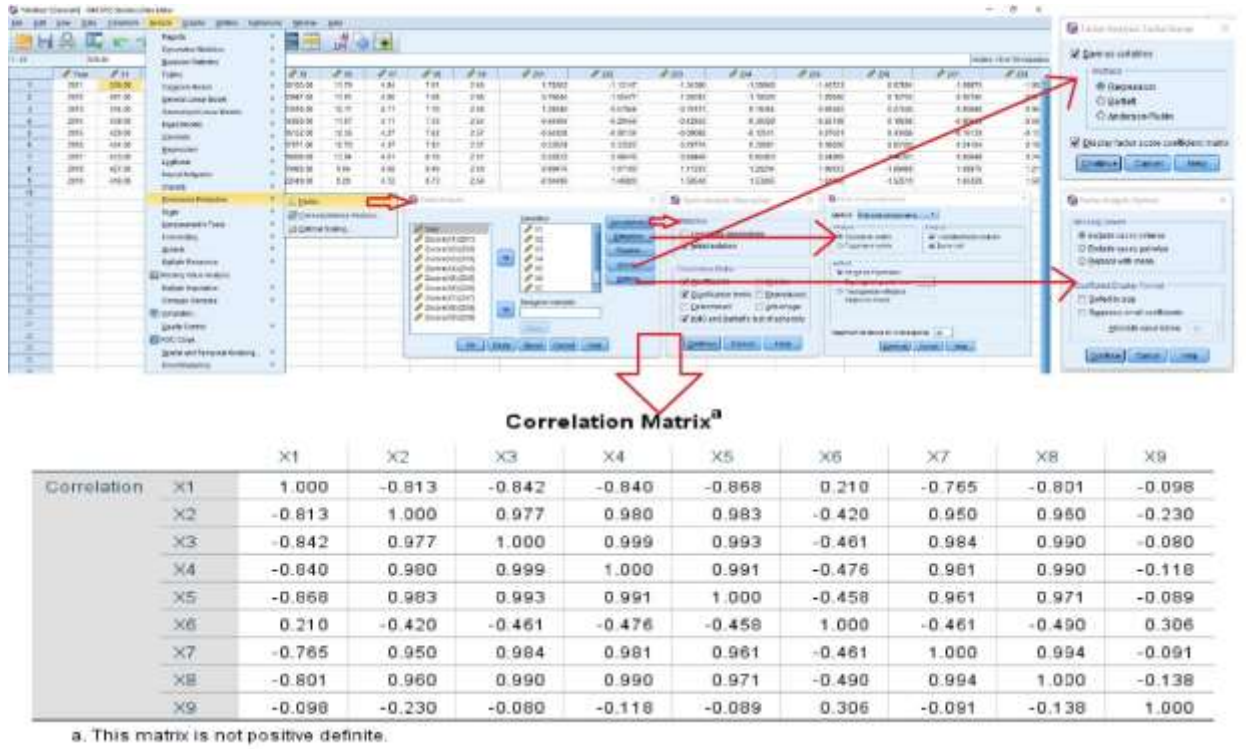


Fig 3.4 Dimension reduction process and correlation matrix in SPSS25

Table 3.8 Correlative matrix of 8 indexes of society subsystem in Shanghai(2011-2019)

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9
2011	1.0000	-0.8127	-0.8425	-0.8402	-0.8684	0.2104	-0.7647	-0.8014	-0.0981
2012	-0.8127	1.0000	0.9768	0.9800	0.9832	-0.4202	0.9504	0.9601	-0.2300
2013	-0.8425	0.9768	1.0000	0.9988	0.9926	-0.4612	0.9841	0.9899	-0.0805
2014	-0.8402	0.9800	0.9988	1.0000	0.9911	-0.4764	0.9807	0.9904	-0.1180
2015	-0.8684	0.9832	0.9926	0.9911	1.0000	-0.4576	0.9607	0.9706	-0.0890
2016	0.2104	-0.4202	-0.4612	-0.4764	-0.4576	1.0000	-0.4613	-0.4899	0.3062
2017	-0.7647	0.9504	0.9841	0.9807	0.9607	-0.4613	1.0000	0.9940	-0.0909
2018	-0.8014	0.9601	0.9899	0.9904	0.9706	-0.4899	0.9940	1.0000	-0.1379
2019	-0.0981	-0.2300	-0.0805	-0.1180	-0.0890	0.3062	-0.0909	-0.1379	1.0000

(4) Determine the number of principal components and their respective variances. We use SPSS data analysis software to calculate the cumulative contribution rate of each variance as shown in Table 3-9 and the screen plot as shown in Fig 3.5.

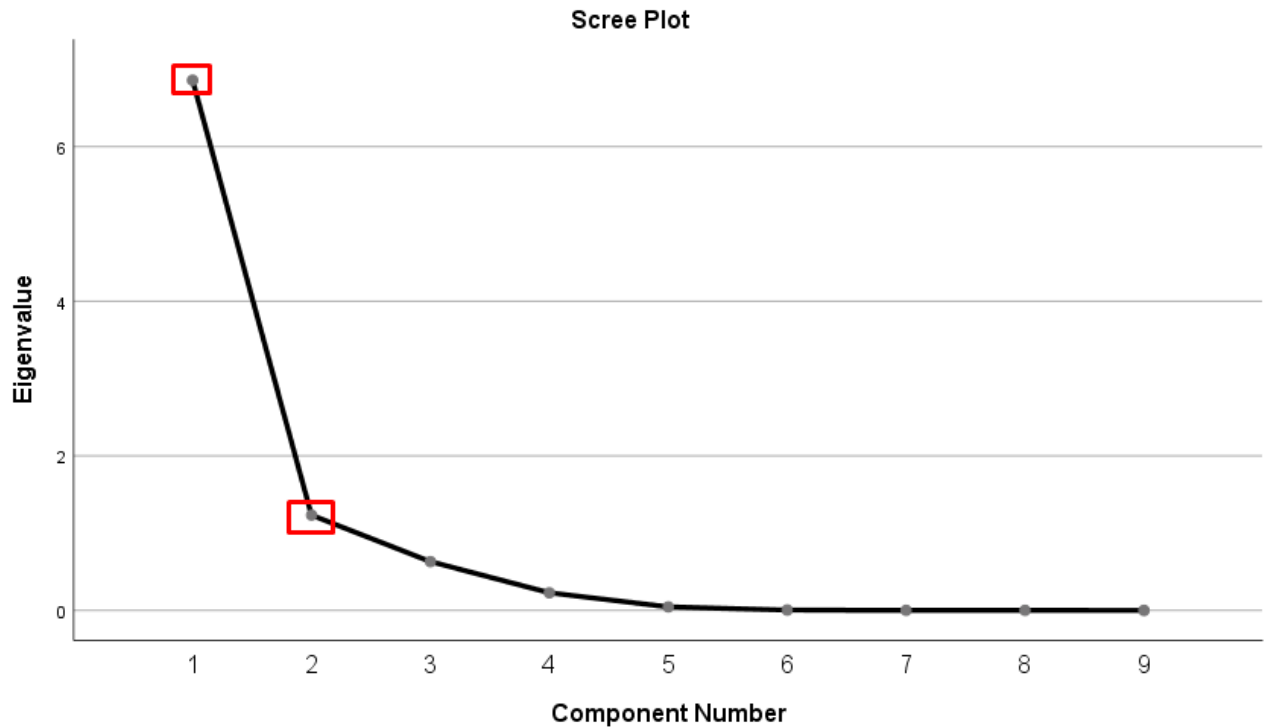


Fig 3.5 Screen plot in SPSS25

Table 3.9 Variance contribution ratio (2011-2019)

Comp- onent	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.8587	76.2083	76.2083	6.8587	76.2083	76.2083
2	1.2327	13.6971	89.9054	1.2327	13.6971	89.9054
3	0.6311	7.0119	96.9173			
4	0.2278	2.5314	99.4486			
5	0.0447	0.4968	99.9455			
6	0.0042	0.0464	99.9918			
7	0.0005	0.0058	99.9976			
8	0.0002	0.0024	100.0000			
9	0.0000	0.0000	100.0000			

From Table 3-9, we can see areat the cumulative contribution rate of the first three

principal components is 89.9054%, greater than 80%. Principal components 1 and 2 can be selected as comprehensive indicators for evaluation. The variance λ_1 of principal component 1 is 6.8587 and the variance λ_2 of principal component 2 is 1.2327.

(5) Calculate the factor scores and the scores of each principal component. We use SPSS data analysis software to directly obtain the scores of factors, as shown in Table 3-10.

Table 3-10 Component score coefficient matrix (2011-2019)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
$f1$	-0.1236	0.1428	0.1453	0.1455	0.1448	-0.0736	0.1424	0.1442	-0.0201
$f2$	-0.2694	-0.0310	0.0490	0.0207	0.0505	0.4729	0.0247	-0.0050	0.7128

The principal component score is equal to the factor score multiplied by the arithmetic square root of the corresponding variance, that is:

$$F1 = f1 \cdot \lambda_1, F2 = f2 \cdot \lambda_2 \quad 3.11$$

The score of each principal component is obtained by calculation, as shown in Table 3-11.

Table 3-11 Principal component scores (2011-2019)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
$F1$	-0.3238	0.3740	0.3805	0.3810	0.3792	-0.1927	0.3729	0.3777	-0.0527
$F2$	-0.2991	-0.0344	0.0544	0.0230	0.0561	0.5250	0.0274	-0.0056	0.7914

(6) Calculate the comprehensive evaluation value Y, that is, the comprehensive development level value. The comprehensive evaluation value Y of principal component 1 and principal component 2 is calculated according to the following formula.

$$Y = \frac{\lambda_1 F1}{\sum_{i=1}^2 \lambda_i} + \frac{\lambda_2 F2}{\sum_{i=1}^2 \lambda_i} \quad 3.12$$

According to the above formula, the comprehensive development level of

Shanghai's social subsystems from 2011 to 2019 is shown in Table 3-12.

Table 3-12 Principal component scores (2011-2019)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
<i>Y</i>	-0.5280	0.2879	0.3686	0.3425	0.3690	0.2817	0.3393	0.3154	0.6262

The same steps and methods can be used to calculate the comprehensive development level value *Y* of the six subsystems of population, economy, society, resources, environment, and technology in Shanghai from 2011 to 2019, as shown in Table 3-13.

Table 3-13 General developing value of 6 subsystem in Shanghai(2011-2019)

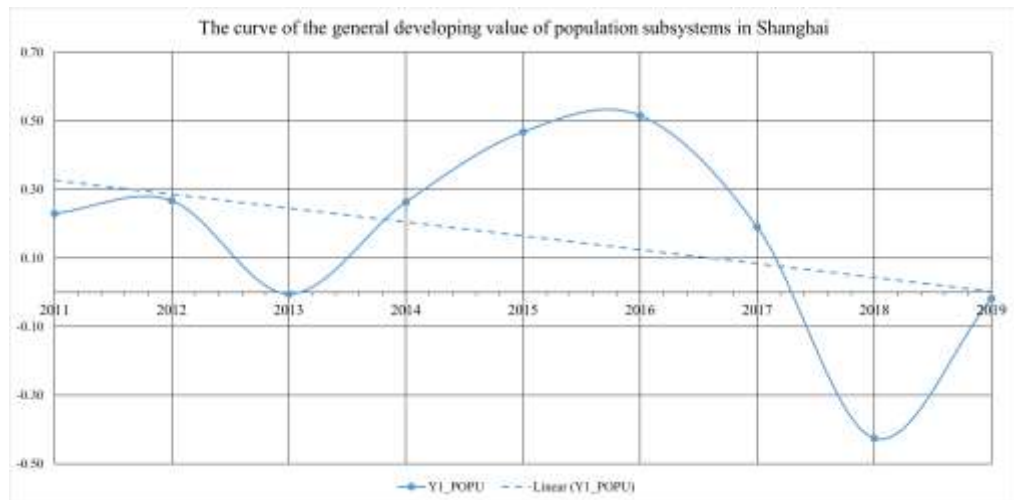
Year	Y1	Y2	Y3	Y4	Y5	Y6
2011	0.2299	-0.5280	0.9969	0.4817	-0.0730	-0.4173
2012	0.2675	0.2879	-0.9337	0.5035	0.1638	0.5762
2013	-0.0049	0.3686	0.9505	-0.0357	-0.0019	0.5762
2014	0.2631	0.3425	0.9929	-0.3034	0.5611	-0.2727
2015	0.4678	0.3690	0.9848	0.1291	-0.0247	0.4068
2016	0.5152	0.2817	0.8470	-0.0882	-0.3104	0.1409
2017	0.1905	0.3393	0.9932	0.4869	0.1823	0.2779
2018	-0.4256	0.3154	0.9916	0.4244	0.5373	0.0823
2019	-0.0182	0.6262	0.9456	-0.0350	0.5678	0.0532

In Table 3-13, Y1, Y2, Y3, Y4, Y5 and Y6 are the general developing value of population subsystem, society subsystem, economic subsystem, science subsystem, resource subsystem and environment subsystem respectively, abbreviated as POPU, SOCI, ECON, SCIE, RESO and ENVI respectively.

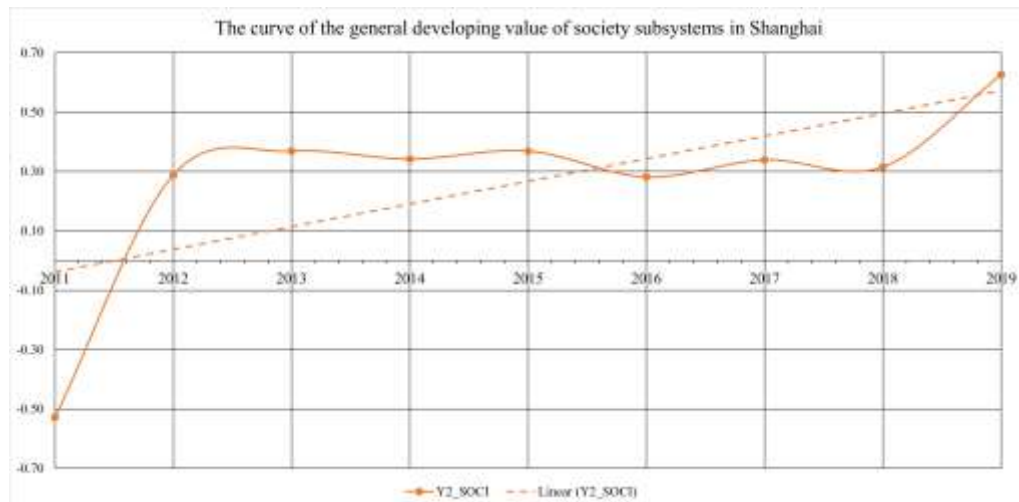
According to Fig 3.6, it can be seen that during the nine-year period from 2011 to 2019, the comprehensive level of sustainable development of each subsystem in Shanghai showed a wave-like distribution.

In order to more scientifically assess the comprehensive level of sustainable development of each subsystem in Shanghai, this thesis obtained the change trend of

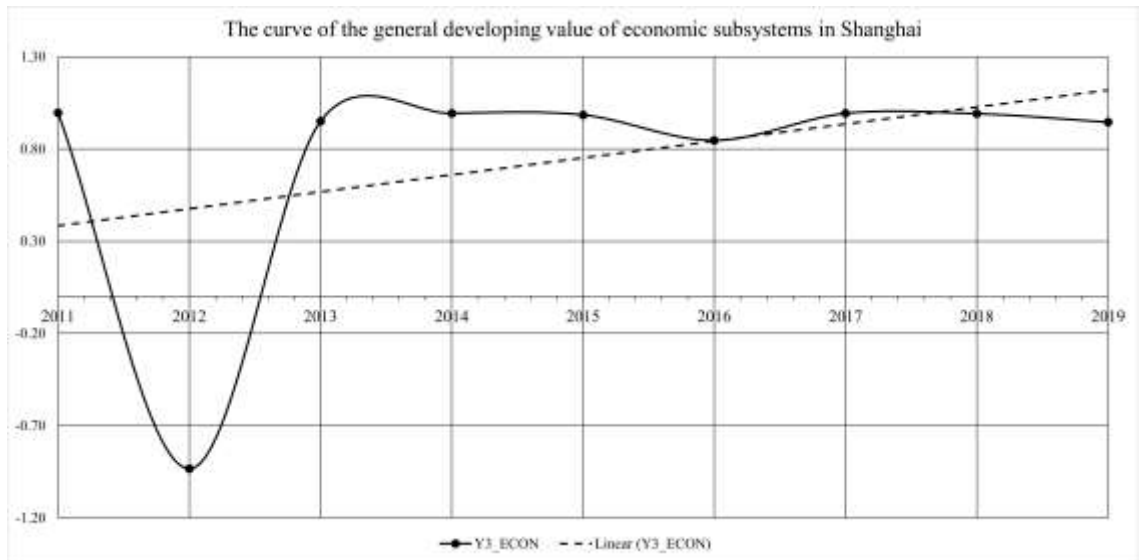
each subsystem through the straight line fitting function in Excel. From 2011 to 2019, the comprehensive level of sustainable development of the social subsystem, the economic subsystem and the resource subsystem showed an upward change as shown in Fig 3.6(b, c and e), the comprehensive level of sustainable development of the population subsystem and the social subsystem showed declining change, and the comprehensive level of sustainable development of the environmental subsystem remains basically stable.



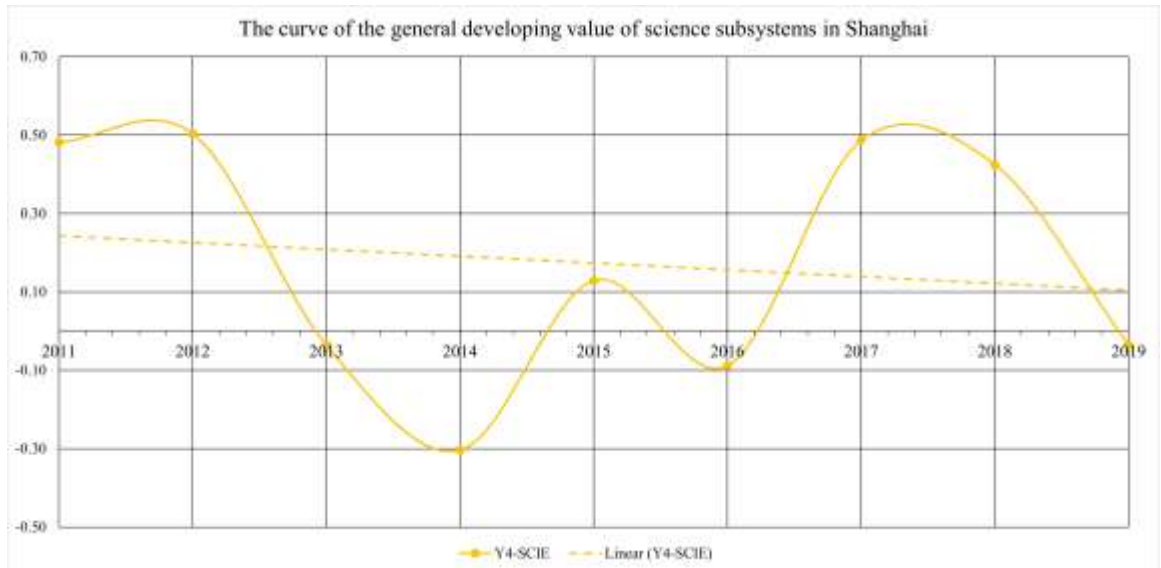
a. population system



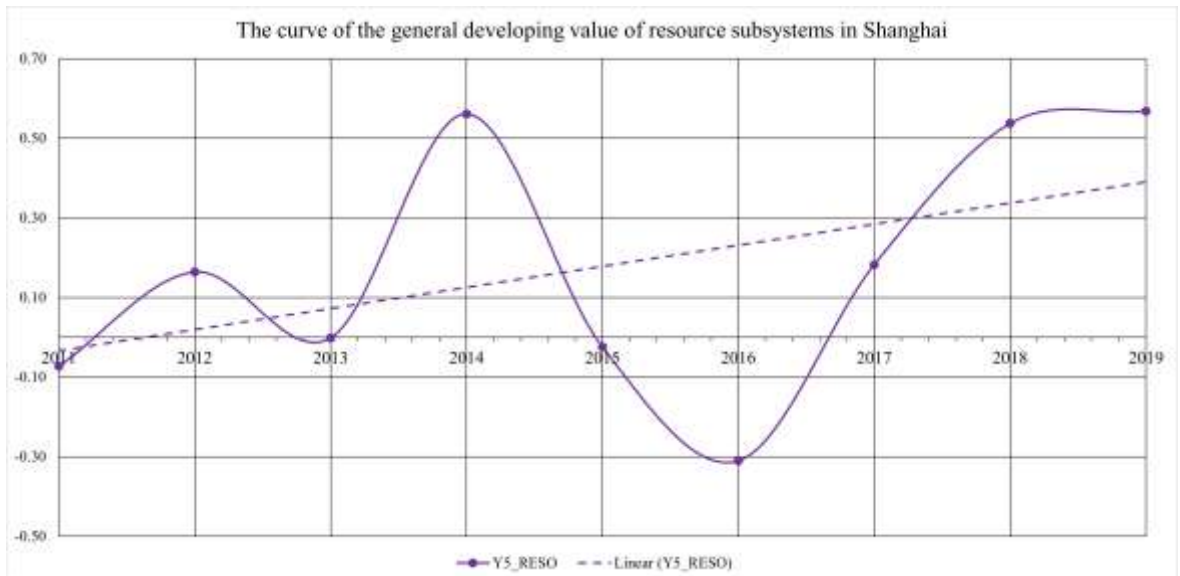
b. society system



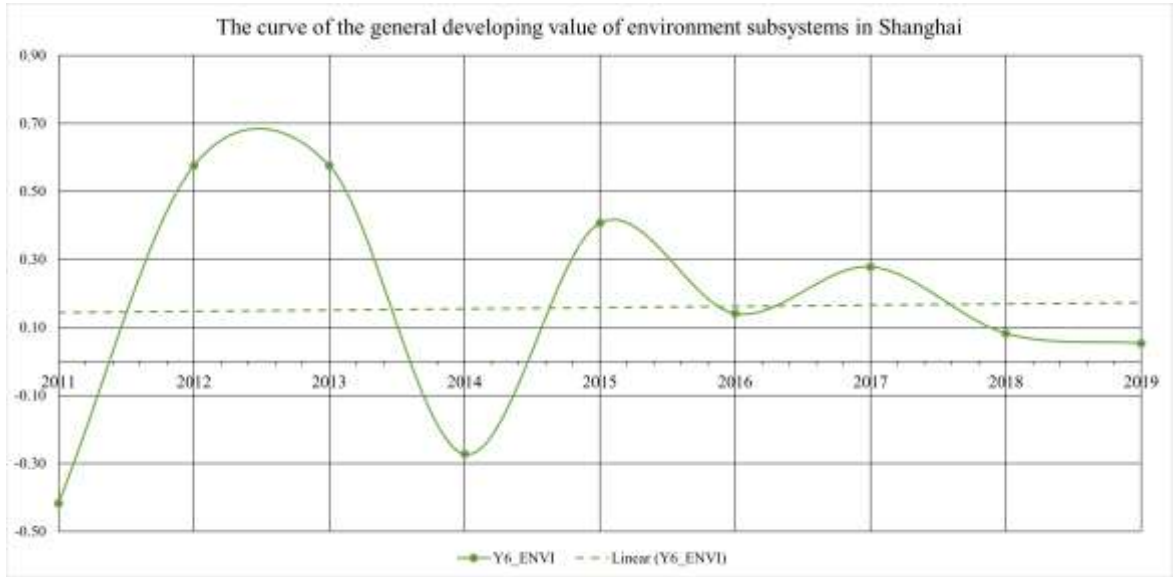
c. economic system



d. science system

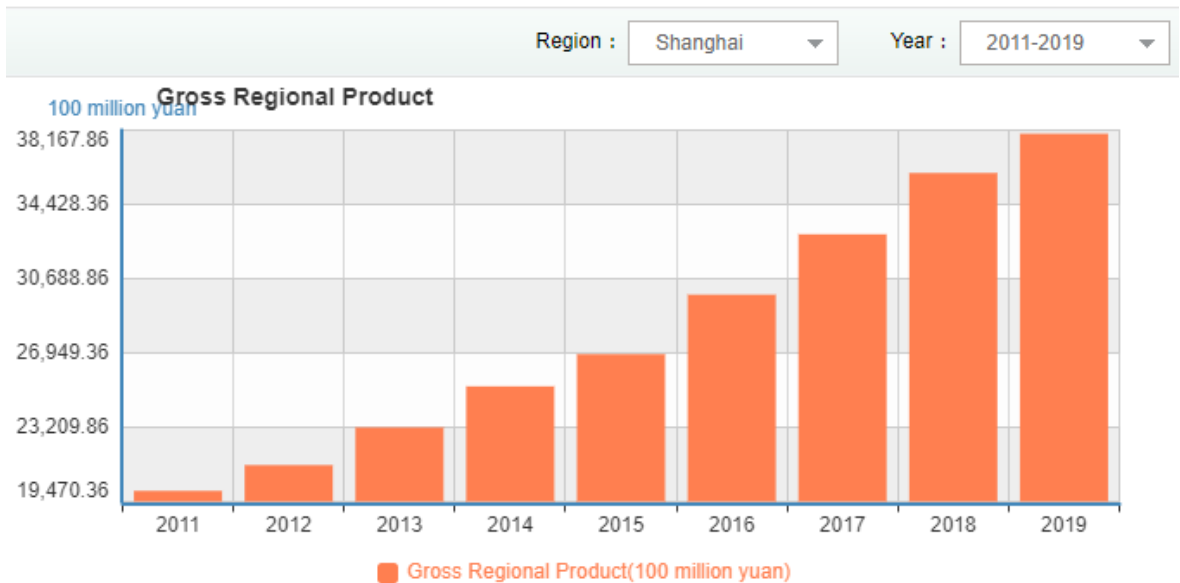


e. resource system



f. environment system

Fig 3.6 the actual curve and fitted curve of the general developing of 6 subsystems in Shanghai.



Source: the National Bureau of Statistics in China(<https://data.stats.gov.cn/english/>).

Fig 3.7 GDP in Shanghai from 2011 to 2019.

It can be seen that the economic subsystem in Shanghai's urban system plays a pivotal role. Since 2011, Shanghai's economy has been developing at a high speed, which is in line with the actual development of Shanghai's economy as shown in Fig 3.7.

3.2.4 Score of comprehensive level of sustainable development of urban symbiosis system in Shanghai

The scores of the comprehensive development level of each subsystem of the Shanghai urban symbiosis system have been determined through calculation. To obtain the overall comprehensive development level of the symbiosis system, it is possible to further weigh the scores of each subsystem by using analytic hierarchy process. Through the investigation and consultation results of many experts, and after extensively reviewing relevant materials, the relative importance judgment matrix of the six subsystems of population, economy, society, resources, environment, and technology in Shanghai's urban symbiosis system is obtained, as shown in Table 3-14 shown.

Table 3.14 Relative judging matrix of symbiotic system in Shanghai (2011-2019)

Year	Y1	Y2	Y3	Y4	Y5	Y6
Y1	1.0000	0.5000	2.0000	0.5000	0.5000	0.5000
Y2	2.0000	1.0000	3.0000	0.5000	0.5000	0.5000
Y3	0.5000	0.3333	1.0000	0.3333	0.3333	0.5000
Y4	2.0000	2.0000	3.0000	1.0000	1.0000	2.0000
Y5	2.0000	2.0000	3.0000	1.0000	1.0000	2.0000
Y6	2.0000	2.0000	2.0000	0.5000	0.5000	1.0000

It can be obtained from Table 3-14:

$$W_1 = \sqrt[6]{1 \times \frac{1}{2} \times 2 \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}} = 0.7071 \quad 3.13$$

$$W_2 = \sqrt[6]{2 \times 1 \times 3 \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}} = 0.9532 \quad 3.14$$

$$W_3 = \sqrt[6]{\frac{1}{2} \times \frac{1}{3} \times 1 \times \frac{1}{3} \times \frac{1}{3} \times \frac{1}{2}} = 0.4582 \quad 3.15$$

$$W_4 = \sqrt[6]{2 \times 2 \times 3 \times 1 \times 1 \times 2} = 1.6984 \quad 3.16$$

$$W_5 = \sqrt[6]{2 \times 2 \times 3 \times 1 \times 1 \times 2} = 1.6984 \quad 3.17$$

$$W_6 = \sqrt[6]{2 \times 2 \times 2 \times \frac{1}{2} \times \frac{1}{2} \times 1} = 1.1225 \quad 3.18$$

Next, $W_1, W_2, W_3, W_4, W_5, W_6$ are normalized, the formula is as follows:

$$\bar{W}_i = \frac{W_i}{\sum_{j=1}^6 \lambda_j} \quad i, j = 1, 2, 3, 4, 5, 6 \quad 3.19$$

Then get the following value:

$$\bar{W} = (0.1065, 0.1436, 0.0690, 0.2559, 0.2559, 0.1691)^T \quad 3.20$$

Through calculation, it can be obtained that there is a unique non-zero maximum eigenvalue $C.I = \frac{\lambda_{\max} - n}{n - 1} = \frac{6.0651 - 6}{6 - 1} = 0.017 < 0.1$, generally as long as $C.I \leq 0.1$, it is considered acceptable to judge the consistency of the matrix.

Assuming that the comprehensive level of sustainable development of the Shanghai urban symbiosis system is L , and the comprehensive development levels of the six subsystems of population, economy, society, resources, environment, and technology are $Y_1, Y_2, Y_3, Y_4, Y_5, Y_6$, then:

$$L = 0.1065 \cdot Y_1 + 0.1436 \cdot Y_2 + 0.0690 \cdot Y_3 + 0.2559 \cdot Y_4 + 0.2559 \cdot Y_5 + 0.1691 \cdot Y_6 \quad 3.21$$

Substituting the value Y of the comprehensive development level of the six subsystems of population, economy, society, resources, environment, and science and technology calculated above in the Shanghai urban system from 2011 to 2019 into the formula, we can get the urban symbiosis of Shanghai from 2011 to 2019. The comprehensive level of sustainable development of the system is L , as shown in Table 3-15.

Table 3.15 General developing value of symbiotic system in Shanghai (2011-2019)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
L	0.0515	0.2736	0.2058	0.1655	0.2663	0.0756	0.3558	0.3284	0.2986

Based on this data, we can draw the change trend chart of the comprehensive level of sustainable development of the urban symbiosis system in Shanghai from 2011 to 2019, as shown in Fig 3.7.

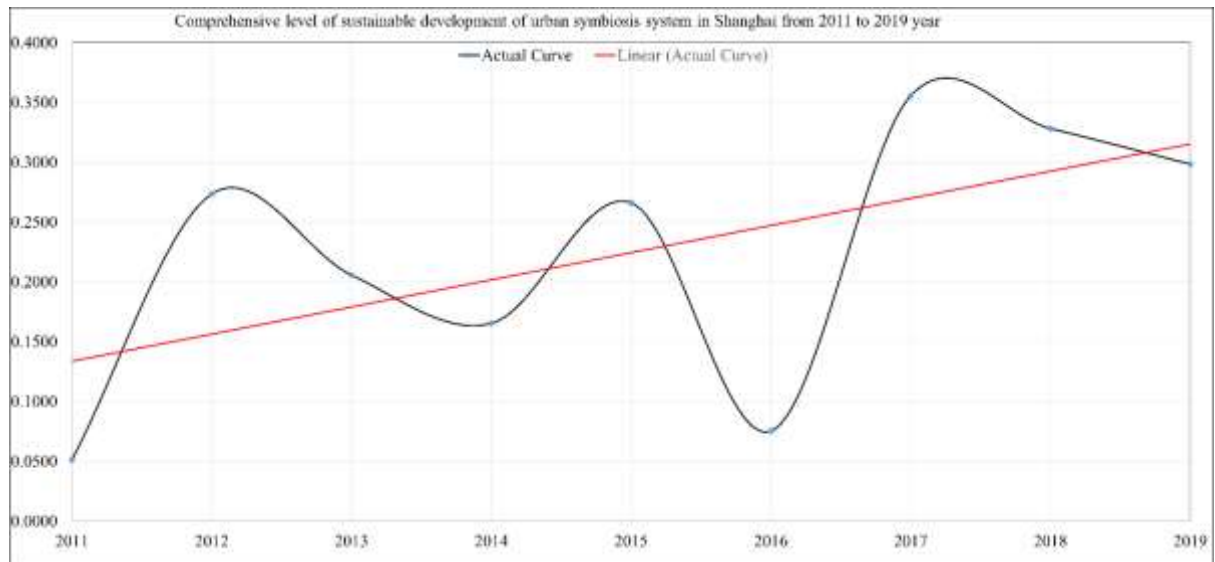


Fig 3.8 General developing level of urban symbiotic system in Shanghai.

From Fig 3.8, it can be seen that the comprehensive level of sustainable development of the urban symbiosis system in Shanghai is on the rise from 2011 to 2019, and the comprehensive level of sustainable development of the urban symbiosis system shows a good development trend.

Since the planning and construction of Shanghai, it has achieved world-renowned achievements. The six subsystems of population, society, economy, resources, environment, and technology have all made great progress. But there are still some problems in the process of sustainable development. From the perspective of symbiosis theory, it is mainly reflected in the fact that urban residents and managers generally lack the concept of harmonious symbiosis, the symbiosis model of the urban symbiosis system does not adapt to the current sustainable development process, and the units of the urban symbiosis system have certain defects.

CHAPTER FOUR COUNTERMEASURES FOR SUSTAINABLE DEVELOPMENT OF SHANGHAI

Shanghai, a global metropolis situated on the eastern coast of China, is the country's most populous city with over 24 million residents. Spanning an area of 6,341 square kilometers, it serves as an important economic, financial, trade, and shipping hub. Shanghai's strategic location at the mouth of the Yangtze River has made it a prominent port and center for commerce for centuries. Shanghai, as one of the world's largest and most populous cities, faces significant challenges in sustainable development. To achieve long-term sustainability, the city needs to address issues related to urbanization, energy consumption, environmental degradation, and social equity.

Based on the specific analysis of the problems faced by the sustainable development of cities above, in this thesis countermeasures are put forward from the perspectives of population, economy, society, resources, environment and technology.

4.1 Countermeasures for the sustainable development of the population subsystem

With the rapid expansion of population, the relationship between population and urban development is becoming more and more tense. In order to solve this contradiction, megacities have always regarded comprehensive population regulation and strict control of population size as the primary task of urban population management.

Some cities regulate population by decomposing population indicators step by step, and some cities control population growth through occupational restrictions, house purchase restrictions, or restrictions on various related certificates. Although these measures can achieve the effect of restricting population entry in a short period of time, in the long run, this anti-market mechanism cannot solve the problem of urban population explosion. The contradictions between the rural areas and urban areas make

the life and development needs of the majority of migrant workers in the city unsatisfactory. This method does not really recognize the internal causes of various conflicts in the urban population problem. To solve the urban population problem, it is necessary for the city to improve the population management level from itself, rather than simply restricting population entry mechanically.

A more people-oriented concept and method that city managers can adopt when conducting population management. In the past, city managers had misunderstood the relationship between it and the urban population. There should be an equal relationship between the two rather than a subordinate relationship. For a city, population is the main builder and foundation of urban development. The government must provide the most basic public services for all the population. The population mentioned here does not only refer to the local household registration population, but also includes the urban floating population. The government must better provide residents with various benefits, strive to create a service-oriented government, better fulfill the powers entrusted by the people, and meet the needs of the people's survival and development. For megacities, the population growth brought by the local population is limited, and the main increase comes from the migration and flow of the population. It can be said that the floating population is the vitality of the sustainable development of megacities. When providing public services, it must Taking fully into account the needs of various groups, although the urban floating population is large in number, there are still some differences and exclusions between the basic public services provided by them and the registered population. The floating population provides higher quality comprehensive services and strengthens their management. What we need is to meet the various needs of the floating population living and developing in the city, including education needs, medical and health needs, housing needs, social security needs, employment and entrepreneurship needs, etc. What we also need to consider is the specific needs of the floating population at different stages and different groups of floating population, so as to provide corresponding services and management in a targeted manner. All in all, with the continuous rapid development of megacities and the rapid population expansion today, for the management of the population of megacities, strengthening

comprehensive population services and management is our top priority. Simple administrative comprehensive population regulation to control population size is not feasible .

In order to strengthen the comprehensive service and management of the population and promote urban development, a complete set of supporting support from the welfare system is very necessary. The first thing to carry out is the reform of the household registration system, so that the floating population has more opportunities to settle down and enjoy the treatment of residents, and then the reform of the residence permit system, so that the benefits and treatment that holders can enjoy are more reasonable and humane It also needs supporting financial system and welfare system as support. These measures will enable the city to more actively respond to the challenges brought about by population expansion and enhance the city's future development potential.

4.2 Countermeasures for sustainable development of social subsystem

The countermeasures of the social subsystem mainly include two aspects: perfecting the construction of public infrastructure and improving the level of urban planning.

4.2.1 Improve public infrastructure construction

The countermeasures to improve the construction of urban infrastructure and improve the level of sustainable development of infrastructure mainly include the following:

First, formulate sustainable development strategies and plans for urban infrastructure. At present, the government does not pay enough attention to the sustainable development of urban infrastructure. In response to this problem, the government should formulate relevant strategic goals and long-term plans according to local conditions and time, and provide a stable platform and a good environment to regulate and restrain its development.

Second, urban infrastructure construction must achieve coordinated and balanced development. First of all, urban infrastructure is a whole. It is composed of various infrastructures, such as roads, pipelines, electricity, communications, etc. They are not simply mechanically assembled as a whole. They influence and restrict each other. After a dynamic coordination among these facilities is realized, the entire urban infrastructure can operate normally, and the production activities in the city can be carried out normally. The principle of sustainability is the primary principle that must be adhered to in the sustainable development of urban infrastructure. Only by adhering to the basic concept of people-oriented and focusing on improving people's livelihood can the level of urban infrastructure be comprehensively improved. We must vigorously strengthen the construction of some environmental protection infrastructure, such as sewage treatment, domestic waste treatment, public toilets, etc. Second, urban infrastructure should develop in harmony with external factors.

Third, improve the level of urban infrastructure management. At present, some problems have appeared in the infrastructure construction of many cities in our country. For example, the construction of infrastructure and its management links are out of touch with each other, and even the importance of construction is only emphasized while the importance of management is underestimated.

Fourth, establish an early warning mechanism for sustainable development. Combined with the information management of urban infrastructure, by relying on Internet information technology, online analysis and processing systems, and geographic information systems, we can establish an electronic dynamic monitoring system, collect relevant data, and use the electronic system to conduct scientific analysis and propose corresponding early warning countermeasures. In the past, urban infrastructure construction was often a kind of passive regulation, but this model turns the regulation into active, prior and dynamic.

4.2.2 Improve the level of urban planning

Improving the level of urban planning is mainly achieved from three aspects: the innovation of urban planning and management system, the innovation of urban

planning and management mechanism, and the comprehensive innovation of urban planning and management.

First, the innovation of the management system. One is the innovation of the legal system, which is to establish a sound urban planning legal system. The second is to innovate the administrative system, reform the administrative system, and transform government functions, so as to break the existing phenomenon of administrative intervention.

Second, management-oriented innovation. It is to be guided by the object of management to establish a city management system.

Finally, innovation in management decision-making. One is the establishment of information analysis systems, such as expert think tanks and information feedback systems, through which the scientific nature of decision-making can be improved. The second is the establishment of a scientific planning decision-making support system, which can provide necessary decision-making support for every stage of the urban planning process.

4.3 Countermeasures for sustainable development of economic subsystem

The key to the sustainable development of the economic subsystem is to speed up the transformation of the economic growth mode in order to promote the coordinated, sustained and high-speed development of the economy. Countermeasures mainly include:

First, establish the concept of scientific development and change the mode of economic growth. In the process of economic development, people's basic needs have been met, but at the same time, the improvement of health and the improvement of material and cultural living standards are also very important. In today's society, material wealth is increasing rapidly, and it is often easy to blindly pursue material things and ignore them. the overall development of human beings.

Second, promote the independent innovation capabilities of state-owned enterprises. In order to transform the mode of economic growth, it is necessary to

promote the independent innovation of state-owned enterprises. Large state-owned enterprises are the backbone of the entire national economy, such as PetroChina, State Grid, and China Telecom.

Third, deepen system reform and enhance the control capability of enterprises. Macro-control is to promote the transformation of economic growth mode and optimize the economic structure, the main way is to update technology and adjust the investment structure. Therefore, transforming government functions and deepening the reform of government institutions is the work that the government must implement in order to create a good environment for economic development and always maintain the balance of economic aggregate.

Fourth, optimize the industrial structure. First of all, it is necessary to change thinking to ensure the area of arable land, optimize the proportion of cash crops to increase farmers' income, and develop efficient agriculture to enhance competitiveness. Second, we must promote industrial transformation, develop modern service industries and advanced manufacturing industries, adjust industrial structures, accelerate the formation of modern emerging industrial systems, and improve the sustainable competitiveness of economic innovation.

4.4 Countermeasures for sustainable development of resource subsystem

The countermeasures for the sustainable development of the resource subsystem mainly include two aspects: vigorously developing the new energy industry and improving the utilization level of land resources.

4.4.1 Vigorously develop new energy industry

In response to the increasingly serious energy crisis, countries all over the world have stepped up efforts to develop new energy industries to seize the commanding heights of new energy industry development. Countermeasures mainly include:

The first is to provide some policy subsidies to increase financial investment in the production and consumption of new energy, such as consumer subsidies,

investment subsidies, and equipment production subsidies. proportion of capital. The second is to formulate relevant policies to support the development of new energy enterprises, and promote new energy enterprises to become bigger and stronger through preferential fiscal policies and tax policies, and to increase industrial scale to enhance market competitiveness. The third is to implement price and ecological compensation for the new energy power generation industry. Through such compensation measures, the industry orientation and value orientation of the new energy industry can be effectively strengthened. The fourth is to vigorously cultivate and develop new energy enterprises, especially for some high-growth entrepreneurial enterprises. These enterprises have high-quality managers and high-tech products, which can moderately lower the threshold for them to start a business. The fifth is to establish a complete green energy evaluation and labeling system, issue green energy labels to enterprises that meet the requirements, and give these enterprises with certain labels certain encouragement and support in terms of scientific research expenditures, interest discounts or low-interest loans to facilitate development. Sixth, establish a set of strict supervision and restraint mechanisms to limit the development of highly polluting energy industries, and resolutely refrain from introducing projects with high pollution, high energy consumption, and high water consumption.

4.4.2 Improve the use of land resources

An important basis for urban construction is to use limited land resources scientifically and rationally. This is also one of the most important tasks for contemporary urban managers. Therefore, various effective measures must be taken to ensure the rational use of land resources.

First, the urban land management department must always adhere to the scientific concept of development and the concept of sustainable development as the guiding ideology, strictly control the scale of urban land use, and must severely crack down on some people who use the price difference between urban and suburban land to conduct illegal transactions. Guarantee the share of land used for ecological construction and improve the ecological benefits of land use.

Second, to further innovate and reform the urban land property rights system. The government needs to clearly define the legal rights of the government and citizens to use land, and severely crack down on those who use their powers to illegally occupy land for economic benefits. Establish a transparent and open property ownership system to maximize the optimal allocation of land resources.

Third, the use of urban land resources needs to be guaranteed by relevant laws to promote the transparency and openness of land resource property rights, clarify the rights and responsibilities of all parties, rationally plan and use urban land resources, and promote the utilization of urban land resources .

4.5 Countermeasures for sustainable development of environmental subsystem

In order to deal with the increasingly serious environmental problems and realize the sustainable development of the city, the main countermeasures are as follows:

First, there are huge differences in the environmental conditions and requirements of cities. The main influencing factors are the requirements of the country's economic development speed in different periods, the distribution characteristics of cities, the imbalance of economic development between regions, and the differences in geographical conditions in different regions. This requires us to formulate different levels of urban development environmental strategies based on the city's positioning and specific environmental requirements, and use differentiated strategies to guide the coordinated and orderly development of economic construction and environment in different cities.

Second, strict urban planning must be formulated to ensure that future planning will not damage the urban environment, and new planning must be strictly analyzed, evaluated, and feasibility demonstrated to ensure that it is conducive to the improvement of the urban environment.

Third, promote the construction of infrastructure related to sewage treatment, promote the optimization of urban domestic waste treatment methods, strengthen the construction of urban road infrastructure, and comprehensively improve road carrying

and operating capacity

Fourth, control the growth of the number of motor vehicles, and encourage residents to use public transportation to travel by means of odd and even number restrictions, and continuously improve the city's public transportation system.

4.6 Countermeasures for sustainable development of science and technology subsystem

The future, destiny and development potential of a city are closely related to the level of the city's technological innovation functions. How to improve the technological innovation function of a city may change and determine the future destiny of a city or even a country. The specific countermeasures are as follows:

First, build a group of high-quality scientific and technological innovation personnel. At present, Shanghai is in a critical period of scientific and technological innovation, mainly relying on talents who master and create high-tech science and technology.

Second, encourage local enterprises to actively carry out scientific and technological innovation activities. The main body of scientific and technological innovation activities is the enterprise. The government needs to cultivate a large number of local technological and innovative high-tech enterprises, which can comprehensively improve the city's scientific and technological innovation functions.

Third, optimize the city's technological innovation environment. Innovation environment refers to the carrier on which innovation is formed. It is a comprehensive system involving policy environment, market environment, legal environment, and talent growth environment. It is an important force to promote technological innovation.

CONCLUSIONS

With the continuous acceleration of the global urbanization process, cities have achieved rapid development both in scale and in number, and their status in the process of social and economic development has become increasingly prominent, but at the same time there have been many problems that cannot be ignored. Sustainable development has become the focus of the world.

In order to study the comprehensive level of urban sustainable development, this thesis takes Shanghai as a case for analysis. According to the research and analysis of this thesis, the following conclusions can be drawn:

1. Analyzed the symbiotic elements, symbiotic model and symbiotic environment of the urban system as well as the structure and function of the urban symbiotic system, proposed that the urban system is composed of population subsystem (POPU), social subsystem (SOCI), economic subsystem (ECON), technology subsystem (SCIE), resource subsystem, resource subsystem(RESO) and environmental subsystem (ENVI).

2. Introduced the symbiosis theory in biology to establish an urban symbiosis system composed of six subsystems including population, society, economy, technology, resources and environment, and selected representatives from 2011 to 2019 for each system Based on nine groups of data indicators, principal component analysis and analytic hierarchy process are used to process the data indicators, and finally the comprehensive development level of each subsystem in the Shanghai urban system and the comprehensive level of sustainable development in Shanghai are obtained.

3. According to the research and analysis of this thesis, it is known that from 2011 to 2019, the sustainable development situation in Shanghai has shown a wave-like change, but the overall situation is on the rise, which is basically consistent with the actual situation of Shanghai's development in the same period.

4. Although the comprehensive level of sustainable development in Shanghai is on the rise, the comprehensive level of sustainable development in the population and science subsystems is declining, while the comprehensive level of sustainable

development in the environmental subsystem remains almost unchanged. Although it is an international metropolis, not every aspect is developing very well.

5. The establishment of symbiotic relationship in the process of urban sustainable development is a complex issue, and the related theory has not yet been formed. For China, it is still in the exploratory stage to establish the concept of symbiosis in the process of achieving sustainable urban development, and to establish the symbiotic relationship between urban subsystems. Some issues still need to be further studied. The establishment of an early warning and forecast system for development, the construction of a regulatory system for the urban symbiosis system from the perspective of institutional economy, etc.

6. Through the collection and comprehensive analysis of various data in Shanghai Pudong New Area, and the evaluation system for the sustainable development of the urban symbiosis system established by the symbiosis theory, this thesis finds the following problems: one is the lack of symbiosis concepts, and the other is the inadequacy of the symbiosis model. To adapt to sustainable development, the third is that the symbiotic unit itself has defects.

7. In view of the existing problems, the author continues to start from the analytical perspective of symbiosis theory, and further proposes improvement strategies from six aspects of population, economy, society, resources, environment and technology.

8. There are some limitations in the writing of this thesis. First of all, this thesis combines the symbiosis theory with the evaluation of urban sustainable development, and tries to use the symbiosis theory to explain the problems and solutions in urban sustainable development. This is a brand-new research perspective, with few reference materials, and the author's cognitive ability and knowledge structure are limited, so the scientificity of the urban sustainable development symbiosis system constructed in this thesis has yet to be tested. Secondly, the research object of this thesis is limited to Shanghai, and the limited space fails to make a horizontal comparison of multiple urban new districts, which reduces the universality of the results obtained.

Based on the above deficiencies, the following prospects are mainly put forward:

first, to further improve the theoretical system and revise the theoretical model; second, to further expand the research objects and make a longitudinal comparison of multiple urban new districts. The third is to explore a new mathematical model suitable for the evaluation of urban sustainable development.

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APPENDIX A

ABSTRACT

Shanghai occupies a pivotal position in China's economic construction. It is one of the most important old industrial bases in China, and it is also China's largest port, economy, trade center, science and technology center, and important financial center, information and cultural center. Since the reform and liberation, Shanghai has made great contributions to the development of China's economy in many aspects. However, due to rapid urbanization, unreasonable urban planning, industrial pollution, resource consumption, social inequality, and insufficient management, a series of urban diseases have emerged, such as severe employment situation, housing difficulties, traffic congestion, and increasing air pollution. How to realize the sustainable development of cities has become an important issue that city managers need to solve urgently. This thesis takes Shanghai as a research case, and uses the symbiosis theory in biology to establish a Shanghai urban symbiosis system composed of population subsystem, economic, social, environmental, resource and technological subsystem, and establishes a city Sustainable development evaluation index system. By selecting nine representative sets of specific data from 2011 to 2019 for specific analysis, the thesis comprehensively evaluates the sustainable development of Shanghai from the comprehensive level of urban sustainable development, and gives corresponding countermeasures and suggestions.

In this thesis, principal component analysis is used to obtain several groups of data that have the greatest impact on each subsystem, and then the comprehensive level of sustainable development of each subsystem is calculated. Then use the analytic hierarchy process to calculate the weight of each subsystem in the Shanghai urban system to obtain the comprehensive level of Shanghai urban sustainable development. Data processing is done with the help of SPSS25. Using the method of this thesis, the comprehensive level of sustainable development in Shanghai from 2011 to 2019 is consistent with the actual development of Shanghai.

Keyword: sustainable development, urban system, symbiosis theory, principal component analysis, analytic hierarchy process.