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Symbiotic System and Benchmarking Research of Prefabricated Construction Chain Based on SymbiosisTheory

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ABSTRACT

In 2018, China’s construction industry accounted for 26% of GDP. The importance of the construction industry to the national economy is self-evident. However, in recent years, China's construction industry is facing problems such as rising labor costs, serious waste of resources, and large emissions of polluting waste, directly or indirectly affecting the sustainable development of the construction industry. Faced with these problems, the prefabricated building has gradually become the core direction of the upgrading of China's construction industry chain, which has many advantages such as low manpower demand, high construction efficiency and environmental protection in the construction process. However, China's prefabricated buildings are still in the primary development stage, and the proportion of prefabricated buildings in new buildings is only 3%, which is far from the level of developed countries. How to accelerate the industrial upgrading of traditional buildings to prefabricated buildings in China has become an urgent problem to be explored and solved.

Therefore, based on the theory of symbiosis, this paper uses literature research, qualitative and quantitative research, expert consultation and other methods to systematically comb the symbiotic system of China's prefabricated construction industry chain, and proposes the benchmarking model of the prefabricated construction industry chain based on symbiosis theory. The research model (BPRS model) selects Japan as the benchmarking country and conducts benchmarking research with China's prefabricated construction industry chain to explore the development status of China's prefabricated construction industry chain and the future sustainable development proposal of China's assembly industry chain.

Firstly, based on the symbiosis theory, the composition of the symbiosis system of the prefabricated construction industry chain is clarified, and the framework of the symbiosis system of the prefabricated construction industry chain in China is combed from the three aspects of symbiotic unit, symbiotic relationship and symbiotic environment, and the system of assembly-building industry chain is systematically carried out. Explain. Secondly, construct a benchmarking model for the prefabricated building industry chain based on the symbiosis theory, and establish the selection principle of the benchmarking country in the benchmarking model. After researching the prefabricated buildings in developed countries, Japan, which has the highest

comprehensive score in the three aspects of the advanced nature of prefabricated buildings, the similarity of building types, and the similarity of structural types, was selected as the benchmarking country. Finally, based on the symbiosis theory, the symbiosis system of the fabricated building industry chain symbiosis system, the symbiosis system of the fabricated building industry chain in China and Japan is studied, and the development status of the fabricated building industry chain in China is obtained. Combined with China's national conditions and Japan's advanced experience, it proposes to enrich and enhance the symbiotic unit category and quality of the prefabricated construction industry chain, standardize the symbiotic relationship of the prefabricated construction industry chain and build a sustainable assemblage of the prefabricated construction industry chain. Three points for future development of the environment.

Key Words: Prefabricated Building, Industrialized Chain, Symbiosis Theory.

Content

CHAPTER 1 INTRODUCTION

1.1 Background and Research Questions

1.1.1 Research Background

(1)Prefabricated buildings are the main direction of traditional building transformation and upgrading

The construction industry is one of the important pillar industries of the country. From a global perspective, by 2025, the global construction industry's annual output value is expected to reach 15 trillion US dollars[1], accounting for 18% of global GDP. In China, the annual data of the National Bureau of Statistics shows that the total output value of the construction industry in 2018 reached 23.5 trillion yuan, accounting for 26% of the national GDP. In addition, the construction industry also shows great importance to worldwide employment. The Sustainable Building Promotion Council of the United Nations Environment Programme points out that the construction industry provides 5%-10% of jobs worldwide[2].

However, there are many problems in the traditional construction industry in China. First of all, China's construction industry is still in a relatively extensive production stage, with low production efficiency and serious waste. According to the Construction Industry Institute of China, the ineffective work rate in construction industry is 57%, while the same rate is 26% in manufacturing industry2. At the same time, the proportion of direct energy consumption in China's buildings to total energy consumption has increased from 10% at the end of the twenty centuries to 30% today. The power consumption per unit of building in China is 2-3 times of developed countries as well.

Secondly, the Labor costs are rising in China. According to the National Bureau of Statistics, between 2012 and 2017, the average wage of employed people in the construction industry in China rose more than 50%. At the same time, fewer and fewer young people are willing to work as construction workers. Compared with the previous generation, the proportion of the new generation who working as construction workers has dropped from 29.5% to 14.5%. The workforce is becoming another major factor constraining the development of the construction industry in China. The prefabricated building with a series of advantages such as low labor demand, high construction quality, high construction efficiency and low construction pollution is becoming the core

direction of the upgrading of China's construction industry chain. According to data from the Vanke Building Research Center, which is one of the biggest real-estate company in china, the prefabricated building can effectively reduce 63%water consumption, 20% energy consumption, 91% waste generation, and save more than 87% of the formwork, which is the mainstream trend of the construction industry.

In recent years, China's continuous implementation of the prefabricated building promotion policy also shows that the prefabricated building is the promotion direction of the green sustainable development of China's construction industry. China has been implementing industrialization of buildings since the 1950s, but the progress in the first 50 years has been slow. In the past decade, relevant policies and advancement have gradually increased. Especially since 2013, the State Council has clearly proposed to vigorously promote prefabricated buildings. Various provinces and cities have responded to the call of the central government and proposed their own assembly rate development goals and supporting policies. The relevant policies for fabricated buildings in China are shown in Figure 1.1.

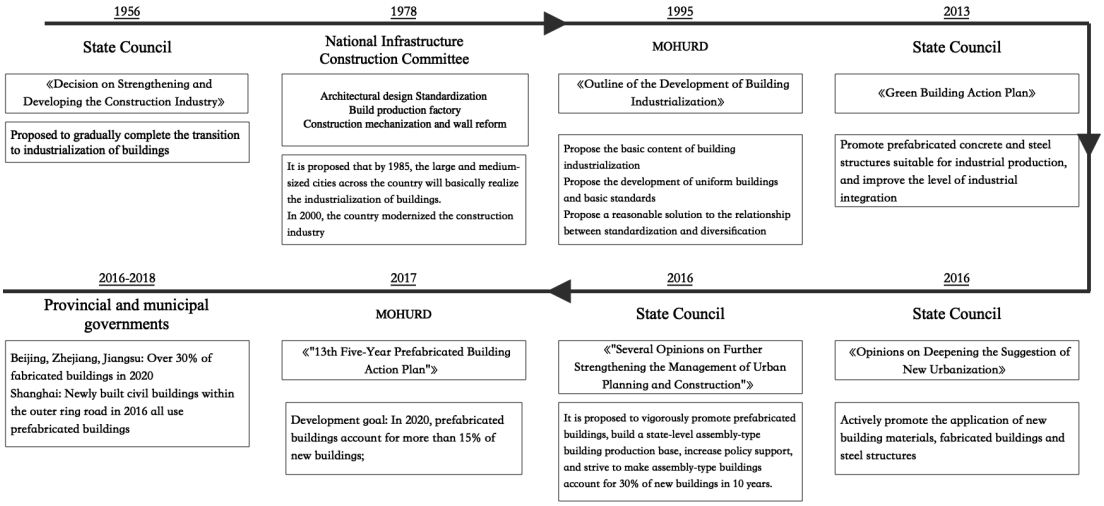

Figure 1.1 China's prefabricated building related policies

In addition, from the end of 2016, the Ministry of Housing and Urban-Rural Development has standardized the technical standards related to prefabricated buildings, promulgated the "Three Technical Standards for Prefabricated Concrete, Steel Structure and Wood Structure", and coordinated the implementation of the "Continuous Health of the Construction Industry" with 18 ministries. Development Opinions, key tasks, division of labor and other policies. In such a large environment, the implementation of China's prefabricated buildings has achieved remarkable results. In 2013-2017, China's

new prefabricated building area is shown in Figure 1.2. In 2017, the newly built prefabricated building area reached 160 million square meters.

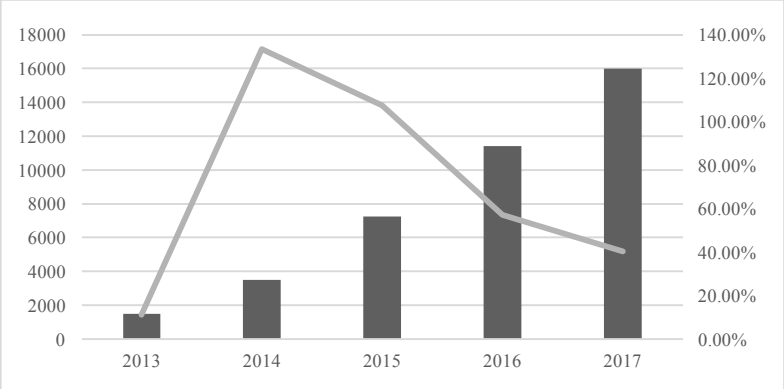

Figure1.2 China's new built-up building area and growth rate (2013-2017)

Therefore, whether it is from the national macro perspective or the development needs of the construction industry, the prefabricated building is the main development direction of the transformation and upgrading of traditional buildings in China.

(2) China's prefabricated construction industry chain is still in the primary development stage

Although the history of prefabricated buildings in China has been more than sixty years, the current development results are not satisfactory. In 2016, China's new prefabricated buildings accounted for only 3.82% of the newly built building area, which is far from the goal of the State Council to reach 30% in 10 years. In recent years, the newly built building area in China's newly built building area is shown in Figure 1.3.

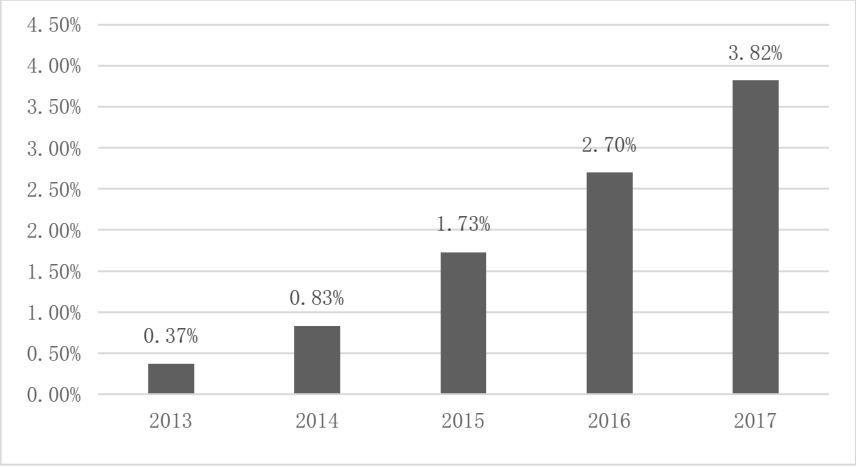

Figure1.3 The proportion of newly-built building area in newly built building area in China

At present, there are still many problems in the development of prefabricated buildings in China. From a policy point of view, China's prefabricated building standards are not systematic; In terms of market development, China's prefabricated construction market is currently less mobile, with high transaction costs and slow marketization; As for itself, the prefabricated construction industry has strong barriers to entry. The initial high investment has kept many participants in the traditional construction industry chain in a wait-and-see state, which indirectly led to imperfections in the industrial chain. Overall, China's prefabricated buildings are still in the initial stage of development.

(3) The development of some countries assembly-type construction industry chain is very mature

At present, many western countries such as the United States, Britain, Germany, Denmark, and Singapore have completed the transformation from traditional architecture to prefabricated architecture. For example, in the 1970s, East Germany achieved industrial construction of 70% of its buildings, mainly using laminated panels, concrete, and shear wall structure systems; the standardization and commercialization of components and parts used in American is extremely high. It has great market versatility, a complete production system and high mechanized production efficiency; the British prefabricated building mainly develops steel structure, and the steel structure in the new project accounts for 70%, and the formed components are designed and produced. The entire process technology and supply chain system to supply.

Japan has promoted prefabricated houses since 1945. All kinds of fabricated building components, parts and equipment have reached a high level in industrialization, marketization and commercial production, accounting for more than 95% of the standard review. Its residential system is extremely advanced. From the 100-year residential construction system (CHS) in 1980 to the “200-year residential concept” in 2007, Japan has enacted a series of residential development policies. The development concept of the house is continuously upgraded and improved (Fig. 1.4). After this series of concepts and laws and regulations, the implementation rate of residential performance in Japan has increased from 16% in 2003 to 50% in 2010. The energy saving response rate of existing homes has increased from 18% in 2003 to 40% in 2015.

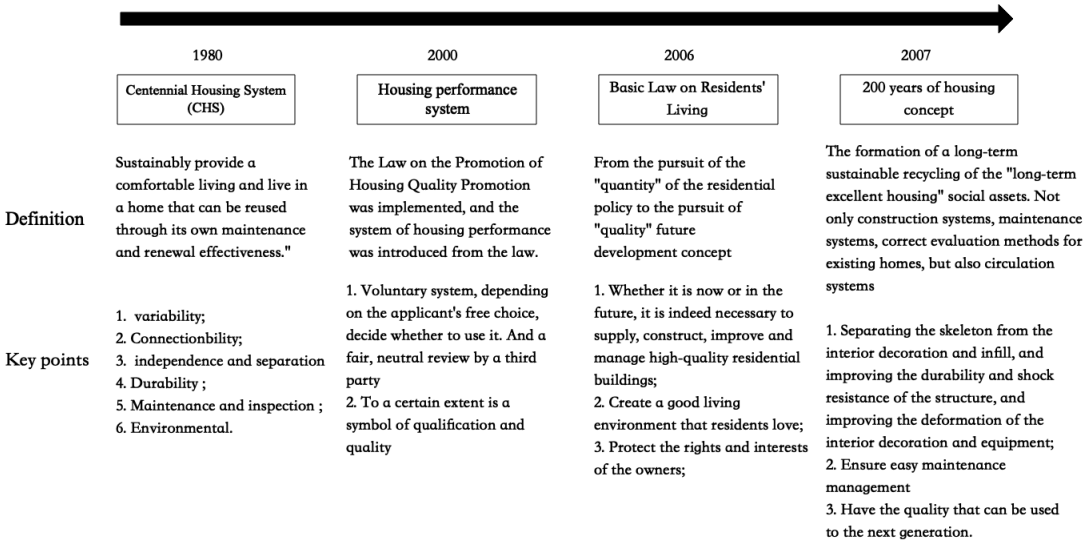

Figure 1.4 Concepts and policies for the sustainable development of Japanese housing in industrialized housing

In the classification of fabricated buildings, the Japanese structural categories are similar to those in China. Among them, wood-framed buildings account for 12-15%, PC assembly structures account for 24%-30%, and light steel structures account for 56%. In addition, in the developed countries where the prefabricated buildings are mature, Japan has the highest consistency with China's population type, housing density, and living habits. Therefore, compared with other countries, the development path of Japanese fabricated buildings is more useful for China.

1.1.2 Research question

In 2016, the State Council of China proposed in the "Regulations on Further Strengthening Urban Planning and Construction" that it strives to make China's prefabricated buildings account for 30% of new buildings in 10 years, but in 2017 this proportion was only 3.8%. How to Within ten years, China's fabricated buildings have developed rapidly, which is the focus of current research.

A prefabricated building is essentially an industrial chain. Each participating unit is the basic node of the industrial chain. Each node is connected into a line to form a chain of enterprise chain, logistics chain, capital chain, etc. Finally, the line is formed into an industrial chain covering the entire life cycle of the assembled building. Therefore, it is necessary to analyze the assembled construction industry chain from the perspectives of point, line and surface.

From the perspective of “point”, we should deeply analyze the various constituent units in the industrial chain and enhance the promotion of the constituent units on the

development of the industrial chain. From the perspective of “line”, we should study the interrelationship of various constituent units in the industrial chain to enhance the tightness and stability of the industrial chain; starting from the "face", we should study the guiding role of the industry chain from economic, policy, science and technology, and social environment. In view of the above situation, this article will try to solve the following problems:

(1) What are the characteristics of the “point, line, and surface” relationship of the prefabricated construction industry chain? What theory can be used to better study and elaborate?

(2) How can the relationship between the compositional framework of the prefabricated construction industry chain and its constituent roles be better elaborated and measured?

(3) Under the vigorous implementation of the policy, what is the current status of the development of China's fabricated construction industry chain? Does the component of the industrial chain have a role in the development of the industrial chain? What should focus on future development?

1.2 Research purpose, method and meaning

1.2.1 Research purpose

Whether it is due to the requirements of China's construction industry upgrading, economic development requirements, or sustainable development, the prefabricated construction industry chain is the main direction of the transformation of the traditional construction industry chain. However, the prefabricated buildings have been developed in China for more than sixty years and are still in the primary development stage. There are many development problems such as imperfect industrial chain, slow industrial chain market process, low standardization of components and asymmetric information of industrial chain,etc.

However, Japan has already completed the industrial upgrading of traditional buildings to prefabricated buildings in the last century, and has begun to pursue green sustainable development goals. Whether it is population type, housing density, or living habits, Japan is the most similar country among China in all developed countries. Therefore, the selection of Japan as a benchmarking country for the development of the assembly-type construction industry chain in China is of reference to understanding the

insufficiency of the development of China's prefabricated construction industry chain and the development path of China's future assembly-type construction industry.

The prefabricated construction industry chain is a network chain industrial chain, which involving many types of enterprises. All nodes on the industrial chain together constitute a symbiotic system. In order to better analyze the composition and internal relationship of the industrial chain, this study selects the symbiosis theory in ecology for analysis. The specific research objectives of this paper have the following four points.

(1) Discusses the practicality and rationality of applying the symbiotic theory to the prefabricated construction industry chain, and combing the framework of the symbiosis system of the prefabricated building industry chain;

(2) Constructing a benchmarking model for the prefabricated building industry chain based on symbiotic theory;

(3) According to the benchmarking model, the benchmark object is determined to be Japan, and the rationality of the choice is demonstrated;

(4) According to the symbiosis theory-based assembly-type construction industry chain benchmarking model, quantitative and qualitative analysis of the Chinese-Japanese fabricated construction industry chain, understanding the development status of China's fabricated construction industry chain, and proposing future development feasibility Suggest.

1.2.2 Research method

Symbiosis theory is a common theory for studying ecosystems with symbiotic relationships, and has been widely used in industrial development, supply chain development, industrial clusters and other fields. In the construction industry, it is also used in urban planning, ancient village protection, tourism scenic area planning and other research, and has a good theoretical expansion. At the same time, the symbiosis theory has three symbiotic elements, symbiotic unit, symbiotic relationship and symbiotic environment, which can systematically study the structure and connotation of “point”, “line” and “face” in the assembly-type construction industry chain. Therefore, through theoretical applicability and innovative analysis, this paper will use the symbiotic theory to study the fabricated construction industry chain. Based on the symbiotic theory, this paper studies the assembly-type construction industry chain in China, and will use the following types of research methods.

(1) Literature research method: summarize the literature research on the prefabricated construction industry chain, symbiosis theory and Chinese-Japanese fabricated architecture, understand the development history and development path of the Japanese fabricated construction industry chain, and define the connotation of the erectile system of the assembly-type building. .

(2) Expert Consultation Law: In order to understand the internal system of China's prefabricated construction industry chain and the development status of China's prefabricated construction industry chain, interviews with experienced practitioners and relevant institutional researchers are supplemented and supplemented by the literature.

(3) Quantitative analysis method: establish relevant mathematical models and solve the analysis, quantitatively study the development status and future development direction of China's prefabricated construction industry chain. In order to understand the research objects more clearly and accurately, more scientifically discover the law of development, grasp the essence, and reflect the influence relationship between related variables in the real problem.

(4) Interdisciplinary research method: This study combines the theory of symbiosis in architectural theory, industrial chain and ecology, and compares the symbiotic system in the natural world with the symbiotic system of the fabricated building industry chain to analyze and solve the assembly type in China. Problems in the construction industry chain.

1.2.3 Research meaning

Firstly, this thesis applies the symbiosis theory to the assembly-type construction industry chain. From the perspective of the symbiotic unit, it looks at the components of the assembly-type construction industry chain such as developers, construction units and design units, and uses the symbiotic relationship in the symbiosis theory to consider the assembly-type construction industry. The chain constitutes the chain relationship between the units, and combines economic, social, technological, policy and other factors to comprehensively study the development environment of the assembly-type construction industry chain, and enhances the systematic nature of the assembly-type industrial chain construction research; secondly, through Introducing the symbiosis theory and proposing quantitative indicators between the symbiosis units of the symbiotic system of the prefabricated building industry chain, which can more clearly and intuitively understand the mutual promotion and containment relationship between

symbiotic units, and also clarify the different symbiotic units in the prefabricated construction industry chain. The difference in contribution has enriched the research of the assembly-type construction industry chain. Thirdly, it proposes the principle of selection of benchmarking objects for the benchmarking of the assembly-type construction industry chain. From the three aspects of the advanced nature of prefabricated buildings, the similarity of building types and the similarity of structural types, Japan is the country that studies the most benchmarking significance of China's fabricated construction industry chain. Through the benchmarking of Japan's fabricated construction industry chain, combined with China's national conditions and the development status of the construction industry, learning the advanced aspects of the target object, and proposing a feasible direction for the development of China's fabricated construction industry chain, has practical significance.

1.3 Research content and Technology Path

1.3.1 Research content

Based on the symbiosis theory, this thesis uses literature research, qualitative and quantitative analysis, expert consultation and other methods to study the assembly-type construction industry chain. Firstly, the theoretical combing and literature review are carried out to analyze the applicability and innovation of the symbiosis theory applied to the assembly-type construction industry chain. On this basis, combing the symbiotic system framework of China's prefabricated construction industry chain, and put forward the research model of the assembly-type construction industry chain based on symbiosis theory, select Japan as the benchmarking country, and benchmark with China's fabricated construction industry chain. Study and understand the development status of China's fabricated construction industry chain, and get the sustainable development proposal of China's assembly industry chain in the future.

Based on the above research content, the structure of this paper is as follows.

Chapter 1, Introduction. Firstly, the core research object of this paper is China's prefabricated construction industry chain. On this basis, the ecological symbiosis theory is introduced to make a more systematic and in-depth analysis of China's prefabricated construction industry chain. At the same time, the research objectives, research methods and research significance of this paper are clarified, and the research content and technical path of this paper are put forward.

Chapter 2, a summary of related theories. Explain the theory of industrial chain, the theory of assembly-type construction industry chain and the theory of symbiosis. Then, based on the theory of industrial chain and symbiosis theory, combined with the characteristics of fabricated construction industry chain, the applicability and innovation of symbiosis theory applied in the research of assembly-type construction industry chain are analyzed to verify the feasibility of the theoretical framework.

Chapter 3, Analysis of the framework of the symbiotic system of the fabricated building industry chain. According to the symbiosis theory, it is clear that the symbiosis system of the prefabricated building industry chain is a symbiotic unit consisting of the basic components of each assembly-type construction industry chain. Under the influence of the symbiotic environment, using the symbiotic interface such as assembly-type building standards and information interaction systems, A diversified social science ecosystem in which symbiotic energy is exchanged and circulated between symbiotic units for material flow, information flow, and capital flow. At the same time, according to the three elements of symbiosis theory, the framework of the symbiosis system of the assembly-type construction industry chain was sorted out.

Chapter 4, the benchmarking research model (BPRS model) of the fabricated building industry chain based on the symbiosis theory. Based on the three elements of symbiosis theory, namely symbiotic unit, symbiotic relationship and symbiotic environment, combined with the characteristics of fabricated buildings, the benchmarking model of the fabricated building industry chain (BPRS model) is constructed, and the benchmarking object is determined based on the advanced nature and comparability. The basic principle of choice. After researching the prefabricated buildings in developed countries, Japan, which has the highest comprehensive score in the three aspects of the advanced nature of prefabricated buildings, the similarity of building types, and the similarity of structural types, was selected as the benchmarking country. In addition, data collection and pre-processing are carried out to prepare for the benchmarking study in Chapter 5.

Chapter 5, Empirical Analysis—Study on the Sino-Japanese fabricated construction industry chain based on BPRS model. In order to find out the development status of China's prefabricated construction industry and the gaps and gaps between China and Japan's prefabricated construction industry chain, using macro data and BPRS model, from the three aspects of symbiotic unit, symbiotic mode and symbiotic environment the fabricated construction industry chain was systematically analyzed.

Finally, based on the analysis results, the future development proposals are proposed from three aspects: symbiotic unit, symbiotic relationship and symbiotic environment.

1.3.2 Technology Path

In this paper, according to the logic of asking questions, analyzing problems and solving problems, aiming at the status quo of the low level of development of China's fabricated construction industry chain, combined with the theory of symbiosis, in-depth analysis of China's fabricated construction industry chain, and introduced Japan as a pair The standard country, with China's fabricated construction industry chain to conduct benchmarking research, proposed the future development of China's fabricated construction industry chain. The specific research technology path is shown in Figure 1.5.

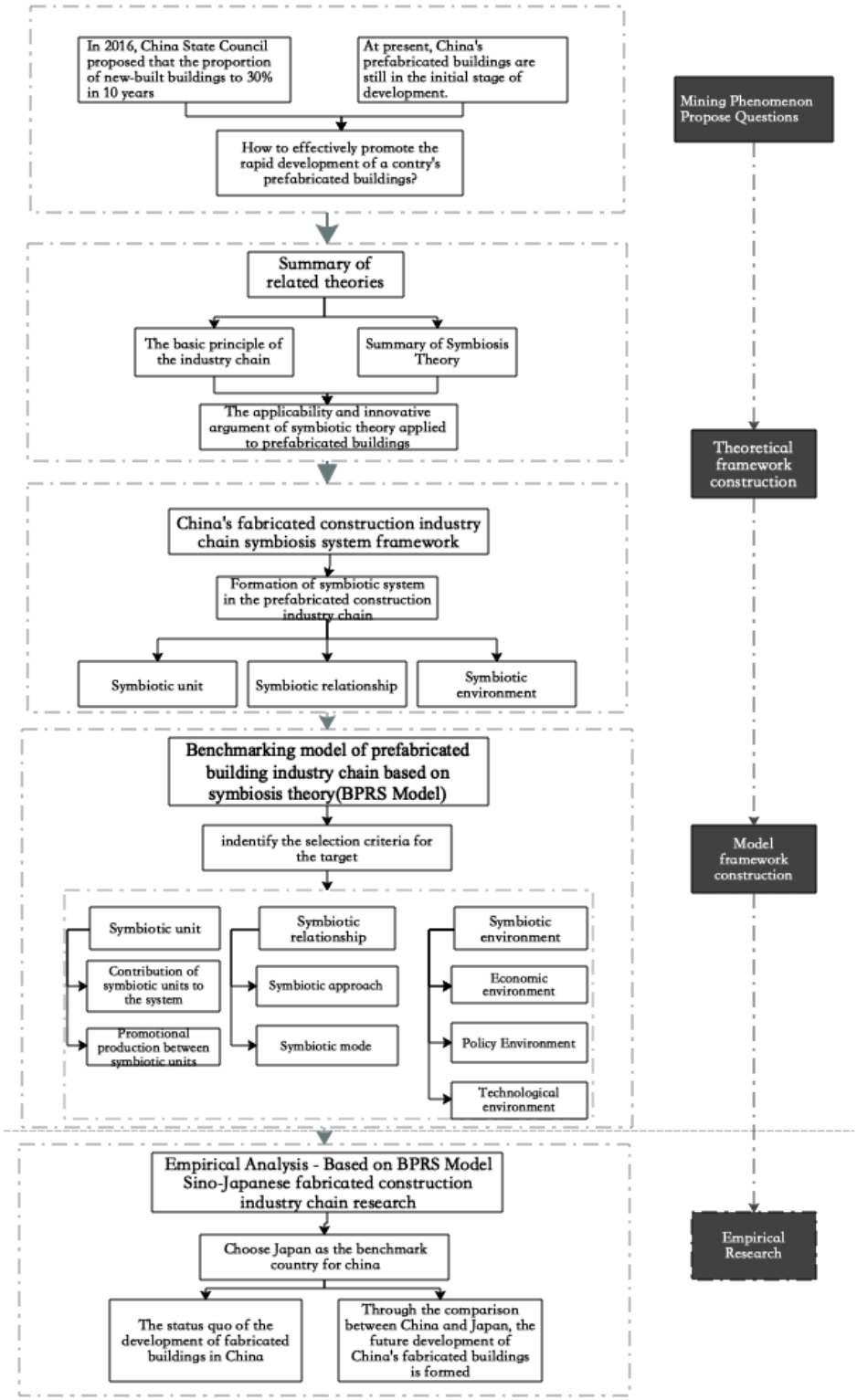

Figure 1.5 Technology Path

CHAPTER 2 Theory Overview

The core idea of this research is to apply the symbiosis theory in ecology to the research of the assembly-type construction industry chain. The theoretical framework is shown in Figure 2.1. In order to clarify the feasibility of this theoretical framework, firstly, according to the theory of fabricated architecture and industrial chain, combing the characteristics of the assembled construction industry chain; secondly, introducing the basic concepts of symbiosis theory and its formation mechanism; finally, combining the characteristics of the assembled construction industry chain And the principle of symbiosis, discussing the applicability and innovation of applying symbiotic theory to the prefabricated construction industry chain

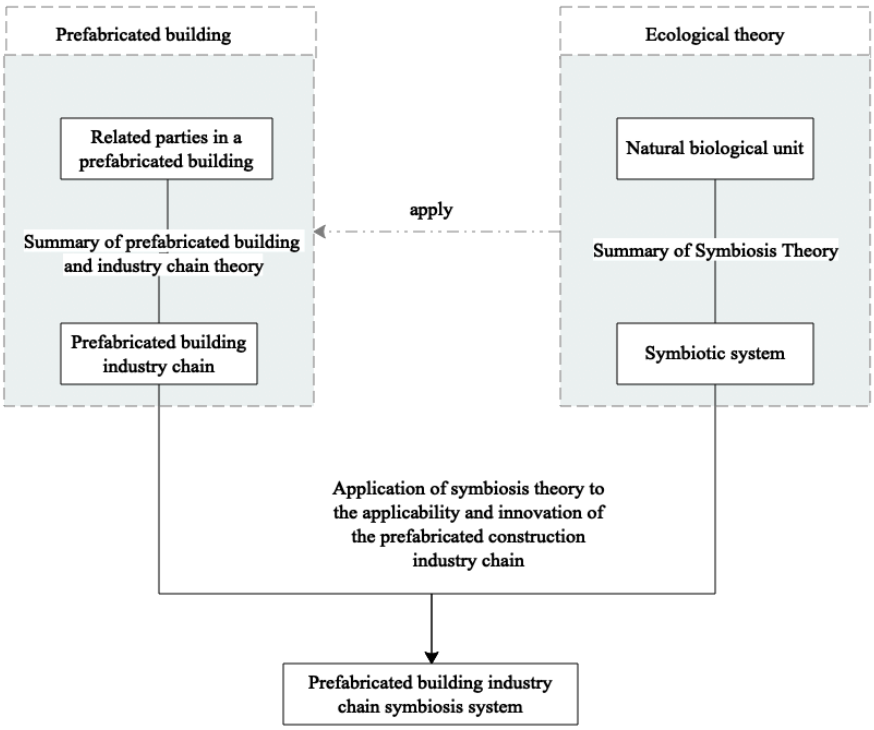

Figure 2.1 Theoretical framework

2.1 Industry Chain Theory

2.1.1 Basic Principles of the Industry Chain

In order to meet the needs of customers, various stakeholders have joined forces to provide products (services) to customers in order to achieve their own profit goals, so

that the dynamic collection of chained networks formed between enterprises is called the industry chain. From the intrinsic meaning of the industrial chain, the industrial chain can be seen as a collection of value chains, supply and demand chains, space chains and enterprise chains.

(1) Value chain. Porter believes that the value chain is a general term for a series of value creation processes from the selection of raw materials to the final delivery of products to consumers[3]. Chains can maximize utility as each participant continues to add value to the product and eventually produce the product[4]. The utility consists of two parts, one is value and the other is the risk that the value can be realized, such as performance risk and cooperation risk.

(2) Supply and demand chain. Each constituent unit is connected by the relationship between supply and demand, which represents the objective existence of the production process and the industrial level. The flow of demand for supply chain demand is the foundation of the industry chain.

(3) Space chain. An industrial chain can be distributed across multiple regions or in different regions. When the industrial chain has a concentrated effect on the geographical, industrial agglomeration emerges. Many scholars believe that regional unity can bring economic effects and promote the development of the industrial chain. Therefore, the industrial chain is one of the driving forces for the formation of industrial agglomeration.

(4) Enterprise chain. Enterprises are the carriers of the industrial chain. Due to the emergence of enterprises, the industrial chain can be connected to the line. Therefore, the relationship between enterprises is especially important for the industrial chain. In the same node of the industry chain, there can be one enterprise or multiple enterprises, and one enterprise can also be in a single node or multiple nodes.

2.1.2 Characteristics of the prefabricated building industry chain

Prefabricated building refers to the production of building components in a factory, transporting complete or semi-finished components to a construction site, and finally assembling the components on site to produce an architectural form of the building[5]. The entire life cycle of a prefabricated building requires the participation of multiple units. In the early stage of development, developers, project management units, design units, construction units, component units, supervision units, research institutes,

equipment suppliers and other units are required to participate; in the sales and operation stage, sales units, property management units and users Play an important role; at the end of life, the recycling mechanism is required to recycle the components. Each participant constitutes a set of interest-driven chain-type network dynamic enterprises, namely the assembly-type construction industry chain.

In addition to the characteristics of the industrial chain's value chain, supply chain, space chain and enterprise chain, the prefabricated construction industry chain also has the characteristics of technology chain, information chain, supply chain and policy chain.

(1) Value chain: The assembled construction industry chain can provide consumers with multi-faceted products and services, and its value chain runs through the entire life cycle of the assembled building. In the process of assembly-type building output, the developers, construction units, design units, supervision units and other units jointly add value to the assembly-type buildings, and finally produce the assembly-type buildings; in the construction operation phase, the component suppliers provide users with the needs. Updated components, property management companies provide property services to users. In the building recycling phase, the component recycling unit provides component recycling services to users. In addition, in the process of realizing value, the internal and external cooperation risks and performance risks of the prefabricated construction industry chain also exist, such as the rise of short-term costs, the inability to install prefabricated components on the construction site, and the more complicated construction site management after the addition of prefabricated components.

(2) Supply and demand chain: the components of the assembly-type construction industry chain are connected because of the relationship between supply and demand. If the developer needs the project management unit to manage the project, the project unit needs the design unit to carry out the design and structure of the project. Design, the project unit needs construction units to carry out on-site construction. In addition, the supply chain of the prefabricated construction industry chain has a more macroscopic significance, which is an upgrade of the traditional construction industry chain. The upgrade comes from the needs of society and the country for environmental protection and resource conservation. The industry's demand for construction efficiency

and the demand for high quality and diversification of the housing are also the supply and demand attempts of enterprises to respond to industrial upgrading.

(3) Space chain: The construction project itself has the characteristics of large volume, unity and difficult mass production. The emergence of the prefabricated construction industry chain has made mass production of components possible. However, compared with the on-site production of traditional buildings, the production of factory components requires the cooperation of logistics to transport the components to the site, and the space chain is more dispersed. However, with the increase of component manufacturers and the development of the logistics industry, space will not become a factor blocking the development of the assembly-type construction industry chain.

(4) Enterprise chain: In addition to the enterprises that include the traditional industrial chain, the most important change is to join the role of component suppliers, and the participation functions of the original enterprises and their participation in the industrial chain are also A change has occurred. For example, in the construction stage of the prefabricated building, the workload of on-site construction decreased, and the workload of on-site installation increased, which led to the development of the installation industry. As the standardization and commercialization of components are further enhanced, more types of enterprises will join the assembly-building industry chain.

(5) Technology chain. In China, the components of prefabricated buildings are still in the process of standardization and standardization. There are many technical problems to be solved in the top design, raw material processing, installation equipment manufacturing, component production, construction simulation and actual construction and installation. These technologies all use the "products produced in the industrial chain" as a carrier to establish a connection relationship.

(6) Information chain. Different from other industrial industries, in the assembly-type construction industry chain, there are often multiple participants in the same production stage, and there are strong correlations in different production stages. Therefore, the interoperability of information in the chain has a great impact on the output of the final product. At present, many projects have established their own ERP system, connecting each node in the project, or using BIM for information sharing.

(7) Supply chain. The prefabricated building industry forms a supply chain network structure by integrating resource flows and information flows, relying on the supply

and demand relationship between upstream and downstream. Since a large number of components of a prefabricated building are derived from factory prefabrication, supply chain management plays a more important role in the project management of prefabricated buildings than the traditional construction industry chain. At the same time, with the advocacy of the sustainable development concept and the improvement of the fabricated component technology, the supply chain of the fabricated construction industry chain will form a closed loop, which can be recycled and recycled when the components are damaged.

(8) Policy chain. Prefabricated buildings are the form of construction that is currently being vigorously promoted in China. In order to achieve the goal of rapid development, the Chinese government has escorted the development of prefabricated buildings from the aspects of finance, planning, taxation, bidding management methods, and pre-sale certificate sales management methods. It is extremely policy-oriented.

Therefore, starting from the concept of the industrial chain and its intrinsic meaning, the prefabricated construction industry chain not only has the basic characteristics of the industrial chain, but also has special chain features including technology chain, information chain, supply chain and policy chain.

2.2 Symbiotic theory

2.2.1 Three elements

The term Symbiosis was first proposed by the German biologist De Berry in 1879 to express the theory that two or more unrelated species exchange material, energy or information to achieve symbiotic needs[6]. Vernon proposes that the relationship between symbionts can be divided into three types: Mutualism, Commenslism, and Parasitism[7]. According to the symbiosis theory, the symbiotic system has three elements, namely the symbiotic unit, the symbiotic mode and the symbiotic environment.

(1) symbiotic unit

The symbiotic unit is a component of the symbiotic system, the basic unit that forms the symbiotic relationship, and the basic unit of energy and exchange []. For example, in the symbiosis system of the Sangji fish pond, rice, pond fish, sugar cane and sericulture are all symbiotic units in the system. In the fabricated construction industry chain studied in this paper, the symbiotic unit is the various stakeholders in the industrial chain, such as developers, project management units, design units,

construction units, and component suppliers. The roles and characteristics of the symbiotic unit are different in different symbiotic systems. In order to express the characteristics of the symbiotic unit, two concepts of qualitative parameters and image parameters are introduced. The qualitative parameter indicates the intrinsic property of the symbiotic unit. The qualitative parameters of each symbiotic unit have different mapping effects on the symbiotic unit in different periods. The qualitative parameter of the dominant mapping effect is called the main parameter []; The parameters reflect the external environment properties of the symbiotic unit.

In order to better understand the relationship between symbiotic units, the concepts of symbiosis, feature symbiosis, single factor symbiosis, system total factor symbiosis, and symbiotic coefficient are introduced.

Symbiosis: The degree of correlation between changes in qualitative parameters between two symbiotic units or symbiotic units and symbiotic systems, reflecting the degree to which two qualitative parameters interact. Assuming that two symbiotic units A and B are common in the symbiotic system S, the symbiosis between A and B is:

$$\delta_{ij} = \frac{dZ_i / Z_i}{dZ_j / Z_j} \qquad (2.1)$$

Characteristic symbiosis: The mass parameter that plays a leading role in the symbiotic unit is the main parameter of the symbiotic unit. If the Z_i and Z_j are the main parameter of the symbiotic unit seperately, then the characteristic symbiosis of A and B is $\delta_{ij} = \delta_{ij}^m$. Characteristic symbiosis is the most representative variable representing the symbiotic characteristics of A and B.

Single symbiosis factor: δ_{Si} represents the symbiosis of a single symbiotic unit relative to a symbiotic system.

$$\delta_{ij} = \frac{dZ_i / Z_i}{dZ_s / Z_s} \qquad (2.2)$$

System symbiosis: indicates the symbiosis of the entire symbiotic system, expressed by δ_s.

$$\delta_s = \frac{1}{\lambda}\sum_i^m \delta_{Si} \quad (2.3)$$

Symbiosis coefficient*:* a parameter used to reflect the contribution of symbiotic units in symbiosis. The symbiotic coefficients θ_i^m and θ_j^m defining the main parameters of A and B are:

$$\theta_i^m = \frac{\left|\delta_{ij}^m\right|}{\left|\delta_{ij}^m\right|+\left|\delta_{ji}^m\right|} \quad (2.4)$$

$$\theta_j^m = \frac{\left|\delta_{ji}^m\right|}{\left|\delta_{ij}^m\right|+\left|\delta_{ji}^m\right|} \quad (2.5)$$

Obviously, $\theta_i^m + \theta_j^m = 1$, The greater the symbiosis coefficient, the greater the contribution of the symbiotic unit to the symbiotic system.

（2）Symbiotic relationship

Symbiosis refers to the form of interaction between symbiotic units, including material exchange, information exchange, and energy exchange. In general, symbiotic relationships include symbiotic symbiosis (symmetry and asymmetry), neutral symbiosis, partial symbiosis, parasitic symbiosis, and competitive symbiosis [13, 14]. In terms of time dimension and interaction density, it includes symbiotic modes such as point symbiosis, intermittent symbiosis, continuous symbiosis and integrated symbiosis [14]. The state of different symbiotic systems and the possibility of their emergence are summarized in the market competition environment, as shown in Table 2.1.

Table 2.1 The state of different symbiotic systems of enterprises and the possibility of emergence under the market competition environment

Status of the symbiotic system (* indicates the possibility of a state appearing)	**Point symbiosis mode M_1** An interaction occurs at a specific moment between the symbiotic unit	**Intermittent symbiosis mode M_2** Multiple interactions between symbiotic units during time interval T	**Continuous symbiosis mode M_3** The symbiotic unit has a continuous interaction for a period of time	**Integrated symbiosis model M_4** The symbiotic unit forms a symbiotic body with independent properties and functions in a closed time interval.
parasitic R_1 The symbiotic unit A relies on the symbiotic unit B to obtain resources, cash flow, materials, etc., generally only one-way value flow	R_1M_1 **	R_1M_2 **	R_1M_3 *	R_1M_4 *
Partial symbiosis R_2 The resources and benefits acquired by the symbiotic system are only biased towards one side and have bilateral liquidity.	R_2M_1 **	R_2M_2 **	R_2M_3 **	R_2M_3 *
Asymmetric reciprocal symbiosis R_3 The symbiotic unit is based on the division of labor and the new value of cooperative output is asymmetrically distributed among the symbiotic units, with multilateral liquidity.	R_3M_1 ***	R_3M_2 ***	R_3M_3 ***	R_3M_4 ***
Symmetric reciprocal symbiosis R_4	R_4M_1	R_4M_2	R_4M_3	R_4M_4

The symbiotic unit is based on the division of labor and the new value of cooperative output is symmetrically distributed among the symbiotic units, with multilateral liquidity.	**	**	***	***

（3）Symbiotic environment

The sum of all factors outside the symbiotic unit constitutes a symbiotic environment [14]. In the prefabricated construction industry chain, the symbiotic environment mainly refers to the building economic environment, policy environment and technological environment.

2.2.2 Principle of quality parameter compatibility

The intrinsic connection between symbiotic units that can express each other is the premise of the existence of symbiotic relationship, which is called qualitative parameter compatibility.

In the existing symbiotic units A and B, there are many qualitative parameters in the two symbiotic units, wherein the mass parameter of the symbiotic unit A is represented by Z_i, and the mass parameter of the symbiotic unit B is represented by Z_j. If $Z_i = f(Z_j)$exists, that is, the relationship between A and B can be expressed mutually, it means that the two satisfy the principle of quality parameter compatibility. The symbiotic relationship between the two can be distinguished by the type of the qualitative parameter relationship function of the two, as shown in Table 2.2.

Table 2.2 The relationship between symbiotic mode and qualitative parameter function

$f(Z_j)$ Function type	Random function	Discontinuous function	General corresponding interval continuous function	Interval-free continuous function
Possible symbiotic mode of A and B	Point symbiosis mode	Intermittent symbiosis	Continuous symbiosis mode	Integrated symbiosis model

（2）Symbiotic energy generation principle

Symbiotic energy means that in a symbiotic system, symbiotic units generate new energy through interaction. The new energy is the ecological symbiosis of the symbiotic system, and it can also react to the ecosystem and promote the development of the

ecosystem. In order to better understand and analyze the symbiotic energy, two concepts of symbiotic density and symbiotic dimension are introduced.

Symbiotic density: the density of a symbiotic unit in a symbiotic system, expressed as P_s,

$$P_s = \frac{N}{V} \quad (2.6)$$

Where N represents the number of such symbiotic units in the symbiotic systemS, and V represents the symbiotic space.

Symbiotic dimension: the category of the reaction symbiotic unit in the symbiotic system, represented by H_s

$$H_s = \frac{W}{V} \quad (2.7)$$

Where W represents the number of heterogeneous symbiotic units in the symbiotic system S.

Symbiotic energy: symbiotic energy means that in a symbiotic system, symbiotic units generate new energy through interaction, represented by E_s. The symbiotic energy and the symbiotic density, symbiotic dimension and symbiosis of the symbiotic system are closely related, ie

$$E_s = f(\delta_s, P_s, H_s) \quad (2.8)$$

(1) Principle of symbiotic interface selection

The symbiotic interface is an important part of the formation of the symbiotic system, and it is the basic bridge between the symbiotic units, which has a direct constraint on the formation and promotion of symbiotic energy. The symbiotic interface has two commonly used important parameters, namely the symbiotic interface damping characteristic index and the symbiotic interface selection coefficient.

Symbiotic interface damping characteristic index: one of the important parameters for expressing the symbiotic interface, expressed by λ, $\lambda \in [0,+\infty]$. It reflects the AC resistance of symbiotic energy and can be divided into risk loss cost damping and transaction cost damping. And efficiency cost damping, etc. The smaller the λ, the smaller the resistance of the symbiotic interface information and energy conduction, and the higher the efficiency of the symbiotic interface[8].

Co-occurrence interface energy use selection index: indicates the proportion of symbiotic energy applied to different functions, represented by C, and to some extent is the mapping of the direction of development of the symbiotic system.

$$C = \frac{r}{k},\ C \in [0, +\infty] \quad (2.9)$$

Where r refers to the proportion of symbiotic energy used for the increase of the number of symbiotic units, and k refers to the specific gravity used for the improvement of the function of the symbiotic unit, $r + k = 1$.

2.3 Theoretical framework applicability and innovation analysis

2.3.1 The applicability of Theoretical framework

(1) The commonality of the prefabricated construction industry chain and the natural symbiosis system

Coupling the characteristics of the prefabricated building industry chain and the symbiotic system, we can discover the symbiosis of the prefabricated building industry chain and nature from the aspects of symbiotic unit, symbiotic relationship, symbiotic environment, symbiotic energy, symbiotic interface, structure level and food chain characteristics. The commonality of the system is shown in Table 2.3.

From the perspective of organizational structure, the prefabricated construction industry chain is consistent with the basic elements of the natural symbiosis system, and has three roles of producers, consumers, and decomposers, and has energy interactions before and after. For example, plants produce oxygen for feeding to mammals, and mammals feed back to excrement to promote plant growth. In prefabricated buildings, developers provide pre-assembled building products to users, and user feedback is streamed. From the perspective of organizational relationship, the compositional relationship between the prefabricated construction industry chain is similar to the natural symbiosis system, mainly for mutual symbiosis and competition symbiosis, and there are also a small number of parasitic and partial symbiotic relations, such as Vanke's early construction of prefabricated components. During the research process, the Prefabricated Component Research Center in Vanke was a parasitic relationship.

Whether it is for the natural symbiosis system or the fabricated construction industry chain, the common agglomeration of the constituent units can often achieve the effect of “1+1>2”. Therefore, producers, consumers and decomposers gather together for mutual benefit and collectively produce symbiotic energy. The developers, design units, construction units, supervision units, component suppliers, users, component recycling units and other enterprises gather together to produce the final product. That is, a

prefabricated building that is put into use, operated, and recycled. Therefore, from the perspective of symbiotic properties, the prefabricated construction industry chain can be seen as a symbiotic system.

Table 2.3 Analogy between the fabricated construction industry chain and the natural symbiosis system

Symbiotic element	Natural symbiosis system	Prefabricated construction industry chain
Symbiotic unit	Producer, consumer, decomposer	Construction production chain, user, component recycling unit
Intrinsic association	The output of the former is the source of the latter energy	The output of the former is the input of the latter
Symbiotic relationship	Mutual symbiosis,partial symbiosis,parasitism, competitive symbiosis	Mainly mutual symbiosis and competitive symbiosis,a small number of biased symbiosis and parasitic relationships.
Symbiotic environment	Soil environment, air environment, water resources environment, competitive environment	Economic environment, policy environment, technological environment, etc.
Symbiotic energy	Accumulation of food and resources	Increase in profits, resource conservation, environmental protection, etc.
Symbiotic interface	Inter-biological information exchange medium, substance conduction medium, energy transmission carrier	Assembly building standards, information interaction systems, project management information systems, trading systems, etc.
Structural hierarchy	Individual, population, community	Enterprises, the same category of enterprises, industry chain
Food chain characteristics	Food chain network	Food chain characteristics Industry chain
Individual life cycle	Born, part of a symbiotic system, growing up, dying	Start-up, development, becoming part of the assembled construction industry chain, rapid development, stable development, aging or re-innovation
System life cycle	Bare ground formation, settlement and reproduction, species competition, community stability and balance	The fabricated construction industry chain in developed countries experienced the burgeoning period of the 1930s and 50s, the rapid development period of the 1950s and 1980s, and the quality improvement period of the 1990s and the 21st century.

(2) Principles of formation of symbiotic system in the prefabricated building industry chain

According to the principle of symbiotic system formation as described in 2.2.2, the formation of a symbiotic system needs to meet three conditions:

The first is the principle of qualitative parameter compatibility. In the prefabricated construction industry chain, there is an interest exchange relationship between each symbiotic unit. For example, component suppliers provide developers with the components needed for construction projects, reduce inventory and obtain cash flow. In the entire prefabricated construction industry chain, the symbiotic units continuously exchange and exchange cash flow, logistics, information flow and even talents, and such relationships can be expressed to each other to meet the conditions of qualitative parameter compatibility.

Secondly, the principle of energy symbiosis, the common goal of the symbiosis unit in the assembly-type construction industry chain is to conduct more lean management while ensuring economic benefits, reduce the abandonment rate and improve the utilization rate of waste. This is a virtuous cycle. As the recognition of prefabricated buildings increases, the proportion of the prefabricated construction industry chain to the entire construction market will gradually increase, and the total amount of symbiotic energy will also increase. The accumulation of economic benefits within the industrial chain can further promote the development of the assembly-type construction industry chain, thereby improving the efficiency and competitiveness of the industrial chain. In addition, in addition to the traditionally understood symbiotic energy, the prefabricated construction industry chain also has other symbiotic energy, including the reduction of production abandonment rate, the improvement of waste utilization rate, and the reduction of building energy consumption. This is a deeper level and higher order. The symbiotic energy is the green goal that all human beings need to work together to achieve.

Finally, the principle of symbiotic interface selection, in the assembly industry chain symbiosis system, the symbiotic interface is an important carrier, which is of great significance to the accumulation of energy in the industrial chain. The symbiotic interface refers to the economic legal system related to the business model of the assembly-type construction industry chain and the interactive platform. In this system, the most common symbiotic interface is the building information model system, and each participant can conduct information exchange, design change and construction simulation through the information interaction platform.

According to the above analysis, the fabricated construction industry chain satisfies the formation principle of the symbiotic system and can be treated as a special symbiotic system.

(3) Successful application of symbiosis theory in other scientific fields

The theory of symbiosis is now widely used in various fields. In foreign countries, Renner(1947) proposed the term "Industrial Symobiosis" in 1947, and it was fully realized in an ecological industrial park in Kalundborg, Denmark. In this industrial park, refineries, power stations, gypsum board factories, pharmaceutical factories, cities and residents constitute a complete symbiotic system, which realizes the symbiosis of interests[9]. In recent years, the application of symbiosis theory has become more widespread. Sokka(2011)[10], Velenturf(2016)[11], and Chohaney(2016)[12] studied the environmental benefits of industrial symbiosis, the industrial symbiosis of waste utilization, and the symbiotic model of the savings and development of automobile supply chains.

In China, the theory of symbiosis was first introduced by Yuan Chunqing(2002) into the social sciences in 1997. He believed that symbiosis refers to the relationship between symbiotic units formed according to a certain symbiosis pattern in a certain symbiotic environment. Later, Cheng Datao(2003) linked the symbiosis theory with the enterprise cluster for organizational research . Cao Yugui(26) established a symbiosis model of enterprise clusters and proposed stability development for development center enterprises . In response to the previous theoretical basis, Tao Yonghong(2007), Yang Chunhe(28), Liu Chang, Gao Jie(2009), and Tang Jing(30) respectively competed on the ship industry cluster and development , the formation of logistics industry clusters], the agricultural industrialization organization , and the electronic waste-related enterprises. The relationship was studied. However, in the construction industry, the application of symbiosis theory is not extensive. At present, it is mainly used in urban planning, such as the design planning of characteristic towns , the protection of marginal ancient villages [], the study of tourism scenic spots .

The research on symbiosis theory and industrial chain first appeared in 2008. Ren Yingwei (2008) studied the stability mechanism of the industrial chain through symbiosis theory. He believed that the expansion of the symbiotic relationship between organizations at all levels of the industrial chain can effectively solve the industrial chain. System instability and inefficiency issues. Wang Guohong (2010) studied the stability of the ecological industrial chain in the eco-industrial park and believed that

cooperation and symbiosis is the basic model among ecological enterprises. In terms of architecture, Xiao Wei (2012)applied the symbiosis theory to the development mechanism of the green building supply chain. Zhou Wei (2012)analyzed through symbiotic theory that at present, the venture capital VC and private equity investment in the Shanghai venture capital industry chain. The relationship between PE is between indirect symbiosis and continuous symbiosis. Teng Yue (2016) conducted a symbiotic relationship study on stakeholders in the industrial chain of construction industry, Tao Yingying (2016)using the symbiotic theory to construct the green building industry chain.

According to the above literature review, we can see that the application of symbiosis theory in social sciences and natural sciences has been very extensive. Compared to mechanical systems, ecosystems are more able to demonstrate the dynamic nature of evolution and are therefore more suitable for economic system research in humans. At the same time, the symbiosis theory has the methodological advantages to describe information transmission, material exchange, energy transmission, cooperative symbiosis mode and environment among complex populations. The symbiosis theory has been widely applied and extended in the fields of enterprise cluster, shipbuilding industry, agricultural industry, logistics industry, pre-construction planning, green building industry chain, etc., which further improved the symbiotic theory framework, and also explained that symbiosis theory can help more deeply to the industry. Analysis of clusters and industry chains. In summary, the symbiosis theory has compatibility and applicability to the research of the assembly-type construction industry chain.

2.3.2 Innovation of the theoretical framework

Foreign supply chain management (Supply Chain Management) is similar to the concept of China's construction industry chain. The concept of the supply chain first appeared in Toyota's production system, so that Toyota's automated factory can get the required raw materials at the right time and in the right place[13](Shingo, 1998) Due to the high degree of uncertainty in the construction industry, the building's production process is not as efficient as other manufacturing industries in terms of quality, delivery cycle, productivity and cost[14]. Burgess [15] (1998) believes that the construction supply chain is a large multi-organizational network that includes capital, information, logistics, and labor exchange. Therefore, strengthening cooperation and transparency among participants is very important to the construction industry.

In the study of the construction supply chain, scholars mainly focus on project management and information management. In project management, Vrijhoef[16] (2000) proposed that supply chain management in buildings includes four types of work, including the impact of supply chain on the construction site, supply chain management, construction transfer from the site to supply chain management, integration management and supply chain sites. Improvements in production, etc. Per[17] (2000) and other scholars believe that the introduction of lean management concepts can help improve the level of collaboration and performance development in the construction supply chain. Cheng[18] (2010) proposed that the supply chain can be modeled using the Supply Chain Operation Reference developed by the Supply Chain Commitment to perform performance tests on mechanical, electrical and pipeline construction projects. Behera [19] (2015) conducted a qualitative analysis of the construction supply chain management of coal-based thermal power plants, and considered that the construction supply chain can be regarded as an ecosystem including the concept phase, the procurement phase, the production phase and the cleanup phase. In terms of information management, Xue Xiaolong[20](2005) starts from the internal organization of the supply chain, integrates the construction organization and multi-attribute negotiation model in the construction supply chain into the multi-agent system, and solves the supply chain in the construction through the multi-attribute negotiation mechanism on the network. Coordination issue. Min[21](2008) proposes a building supply chain simulation system based on computer agent technology modeling, providing real-time information at any time, improving information transparency and making it easier for project managers to identify potential risks. Tae[22](2011) established a seamlessly integrated information management framework based on RFID to provide logistics information to stakeholders in the construction project supply chain.

For the prefabricated construction industry chain, there are currently few related studies, mainly focusing on industrial promotion, cost management, and information management. In terms of industry promotion, Gao Xin (2011)proposed a fully-renovated residential industrial production model with the protection of housing as a breakthrough. Qi Baoku (2015) analyzed the core competitiveness of related enterprises in the prefabricated construction industry chain to encourage relevant enterprises to foster strengths and avoid weaknesses and promote the development of the industrial chain. In terms of cost management, scholars such as Kim[23](2016) focus on the cost model of the fabricated building supply chain and reduce the total cost of the project

from the perspective of a time-driven supply chain. Liu (2017) studied the cost control of fabricated buildings located in the industrial chain, and proposed that the high cost of fabricated buildings comes from the contradiction between the non-industrial production organization model and the industrial production mode. Lan Zhaohong (2017) proposed a PEP five-in-one + BIM parallel project management mode for prefabricated buildings. . In information management, Tian Dong (2017) proposed a method of deepening design of fabricated buildings based on BIM technology to solve the problem of information coordination of fabricated buildings. Javier[24] (2013) integrated BIM and GIS to form a new GIS-BIM model that tracks the state of the building supply chain and provides warning signals to ensure material delivery.

In summary, domestic and foreign scholars have studied various fields such as construction supply chain, fabricated building supply chain, and industrial chain from different research perspectives. Among them, the research on the construction supply chain is more comprehensive, but there are few researches on the assembly-type construction industry chain, and most of the researches focus on the advantages of the assembly-type construction industry chain, cost control, assembly-type construction and BIM cooperation. There is still a certain research gap.

First of all, the structure of the prefabricated construction industry chain lacks systematic review. As an industrial chain covering the entire life cycle of fabricated buildings, the prefabricated construction industry chain is linked. Therefore, in the analysis of the prefabricated construction industry chain, it is necessary to start from the point, connect the line into a line, form a line, and comprehensively explain the composition, structure and environment of the assembly-type construction industry chain.At present, although there is research on the assembly-type construction and assembly-type construction industry, there is a lack of systematic review of the structure of the assembly-type construction industry chain.

Secondly, the research on the constituent units of the fabricated construction industry chain and its constituent units is insufficient. The constituent units are the basic components of the industrial chain and play a decisive role in the development of the industrial chain. In the existing research, the measurement method that constitutes the unit relationship is lacking, and it is difficult to accurately quantify and deeply study it. Furthermore, in the process of developing an industrial chain, it is necessary not only to develop itself, but also to create a development path that suits oneself. It is also

possible to learn from the development of advanced industrial chains at an appropriate time, to take its essence and to ruin it. At present, there is a big gap between the development goals and development status of China's fabricated buildings. A reasonable study of foreign advanced experience is conducive to accelerating the development of China's fabricated construction industry chain. However, experience cannot be copied, and it should go deep into the assembly-type construction industry chain to carry out more refined benchmarking analysis.

The introduction of the symbiosis theory has made it possible to make up for the above gaps. This paper proposes a research on the assembly-type construction industry chain based on the symbiosis theory. Compared with the previous research, it has the following innovations:

(1) Viewing the components of the prefabricated construction industry chain, such as developers, construction units, design units, from the perspective of the symbiotic unit, using the symbiotic model in the symbiosis theory to consider the symbiotic relationship between the components of the assembly-type construction industry chain, and combining the economy Various factors such as society, science and technology, and policy have comprehensively considered the development environment of the assembly-type construction industry chain, and more systematically expounded the assembly-type construction industry chain, enriching the perspective of the assembly-type construction industry chain.

(2) By introducing the symbiosis theory and establishing the quantitative indicators between the symbiosis units of the symbiotic system of the prefabricated building industry chain, the mutual promotion and containment relationship between the symbiotic units can be more clearly and intuitively understood, and the different symbiotic units can be more clearly assembled. Differences in contributions in the architectural industry chain.

(3) Introduce the benchmarking management of the assembly-type construction industry chain. Through benchmarking, combining with China's national conditions and the development status of the construction industry, learning the advanced aspects of the benchmarking object, and proposing a feasible direction for the development of China's fabricated construction industry chain.

2.4 Chapter Summary

This chapter sorts out the theoretical framework of the research. In the industrial chain, the four concepts of the industry chain theory: supply chain, company chain, space chain and value chain and the formation mechanism of the industry chain are briefly described. In terms of symbiosis theory, this chapter mainly introduces the basic principles of symbiosis theory and three important elements, namely symbiotic unit, symbiotic relationship and symbiotic environment. Then, based on the theory of industrial chain and symbiosis theory, the paper analyzes the applicability and innovation of the formation of the assembly-type construction industry chain and the symbiosis theory applied to the assembly-type construction industry chain, and verifies the feasibility of the theoretical framework. Analysis of the framework of symbiotic system in the prefabricated construction industry chain.

CHAPTER 3 Analysis of the framework of symbiotic system in the prefabricated construction industry chain

3.1 Overview of the symbiotic system of the prefabricated construction industry chain

The symbiosis system of the prefabricated construction industry chain is a symbiotic unit with the basic components of the prefabricated construction industry chain, such as developers, design units, construction units, component suppliers, users, financial institutions, etc., in the economic environment, policy environment, scientific and technological environment, etc. Under the influence of the symbiotic environment, the symbiotic interface such as the assembly building standard, the information interaction system, the project management information system, and the trading system is used to exchange and circulate the material flow, the information flow, and the capital flow between the symbiotic units, thereby generating direct A diversified social science ecosystem with symbiotic energy such as economic benefits, assembly-type construction industry chain production market value, and assembly-type construction industry chain market share. These symbiotic units form a complete assembly-type construction industry chain, interacting and co-output, obtaining symbiotic energy, and then using symbiotic energy and symbiotic external environmental variables to further develop in density and dimension.

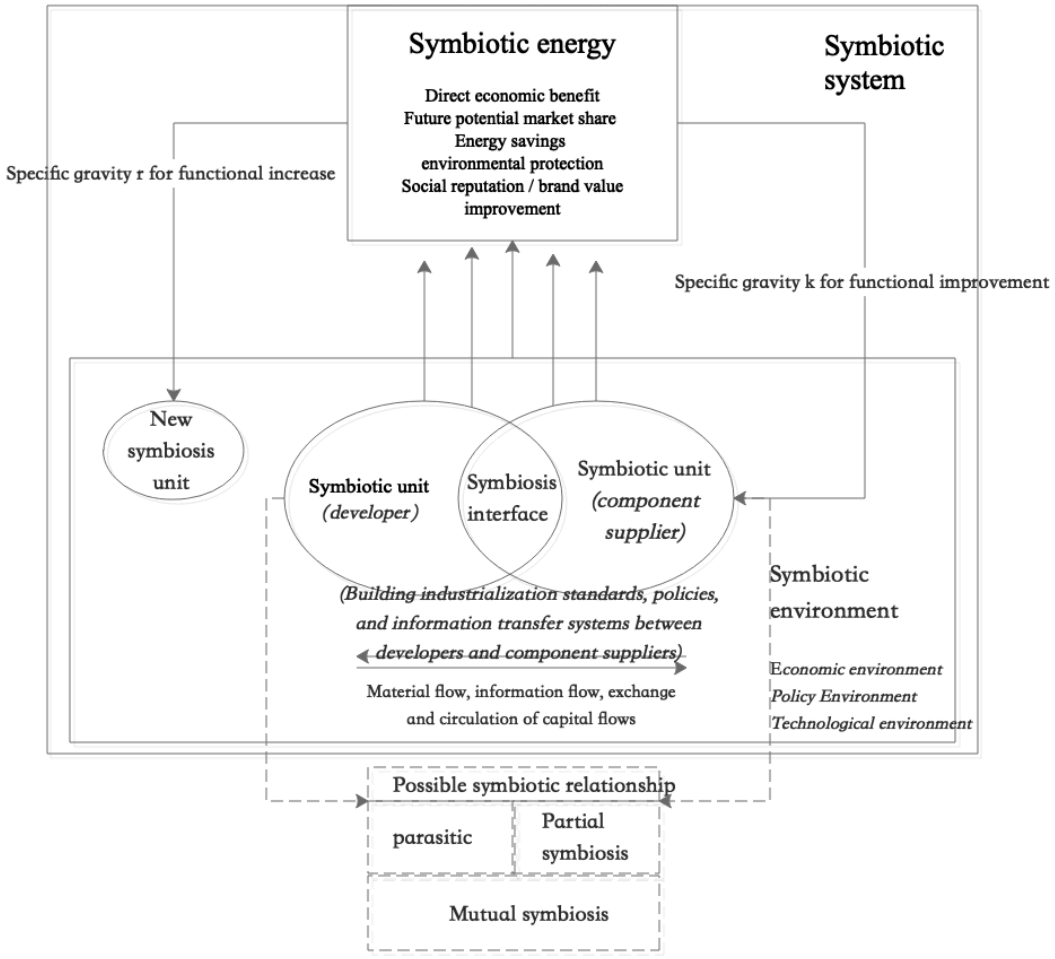

Figure 3.1 prefabricated construction industry chain symbiosis system with developers and component suppliers as examples

In Figure 3.1, the developer and component suppliers are taken as an example to explain the composition of the symbiotic system of the prefabricated building industry chain. In a symbiotic environment, symbiotic unit developers and symbiotic unit component suppliers carry out material flow and information flow through a symbiotic interface constructed by building industrialization standards, policies, and information transfer systems between developers and component suppliers. The circulation and exchange of capital flows, thus forming symbiotic energy. Symbiotic energy may include direct economic gains, increased market share, energy savings, and environmental protection. Among the symbiotic energy generated, the specific gravity is used to increase the number of symbiotic units in the symbiotic system, and the specific gravity k is used to improve the function of the symbiotic unit or the symbiotic system, and to continuously promote the benign development of the symbiotic system. In the process of

development, from the perspective of benefit distribution, there may be multiple symbiosis methods such as parasitism, partial symbiosis and mutual symbiosis. From the perspective of organizational evolution, the symbiotic system will have four symbiotic modes: point symbiosis, intermittent symbiosis, continuous symbiosis, and integrated symbiosis.

This chapter starts from the three elements of symbiosis theory, namely, symbiotic unit, symbiotic relationship and symbiotic environment, and combs the framework of the symbiosis system of assembly-building industry chain.

3.2 Prefabricated building industry chain symbiosis unit

The symbiotic system consists of symbiotic units, and the relationship between symbiotic units plays an important role in promoting the symbiotic system. In order to conduct an in-depth analysis of the symbiotic system of the prefabricated building industry chain, it is first necessary to understand the structure of the symbiotic system, that is, the structure of the prefabricated construction industry chain. Secondly, according to the structure of the industrial chain, the functions of the symbiotic unit role are defined, so as to understand the relationship between the symbiotic units in the symbiotic system of the prefabricated building industry chain, and lay a theoretical foundation for the subsequent quantitative research.

3.2.1 Symbiotic unit logical architecture

Each country's fabricated construction industry chain is different, but the overall framework is basically similar. This chapter takes China's fabricated construction industry chain as an example. In China, fabricated buildings are used in residential, industrial buildings, infrastructure, and so on. Among them, the most important application is still concentrated in the residential, and the residential development process is highly representative in China, so this paper mainly studies the residential development process. From this, we will sort out the roles and functions of the symbiotic units in the symbiotic system of the prefabricated building industry chain at different stages to obtain a clearer industrial chain structure.

Different scholars have different understandings of the division of residential development in the traditional construction industry. In a broad sense, the more recognized process is “investment decision-making stage, planning and design stage,

construction stage, sales stage, and use stage". For the prefabricated construction industry chain, the on-site production process is replaced by prefabricated construction parts in the factory, so the procurement needs to be separated from the construction process, and is an integral part of the assembly construction industry chain. In addition, the marketing and closing stages have less impact on the main construction process and construction results of the building, and do not have a direct symbiotic relationship with most symbiotic units, so the marketing and closing stages are not listed separately here. In summary, the process of the assembled residential industrial chain can be summarized by "investment decision-making stage, planning and design stage, procurement stage, construction stage, and use stage".

For the project contracting method, China mainly has general contracting, independent contracting and joint contracting. In 2016, the State Council put forward the policy of "deepening the reform of the organization and implementation of construction projects and promoting the general contracting system". The general contracting method of the project was paid attention to and was vigorously promoted nationwide. The general contracting of engineering is divided into EPC (Engineering, Procurement, Construction), which is the design, procurement and construction general contracting mode; DB (Design and Built), namely the design and construction general contracting mode; EPCM (Engineering, Procurement, Construction Management), ie Design procurement and construction management model; PMC (Project Management Consulting), that is, integrated project management mode. In this paper, in order to more clearly explain the role and participation relationship of each symbiotic unit in the prefabricated construction industry chain, the traditional project contracting mode is adopted, that is, the project owner entrusts the project to the project management unit (may be the project owner's own The subordinate unit carries out project management, and the owner distributes the subdivision functions such as design, construction and supervision to the corresponding units, and the project management unit manages them in a unified manner.

The investment decision stage can also be called the concept stage. At this stage, developers such as real estate development companies/governments are the dominant players. The developer needs to determine the land to be taken according to the company's long-term plan, and fully investigate the current status and geological conditions of the land with the assistance of the survey unit. Second, with the help of

the engineering consulting company, the developer writes a feasibility study report. Clarify the investment value of the parcel and confirm the estimated input cost, development cycle, cash flow demand, feasibility and prefabrication rate of the prefabricated building construction method and bidding; at the same time, the developer will finance with the help of the financial unit or Investing capital to prepare for land acquisition. In the investment decision-making stage, the main players include developers, consulting firms, financial institutions, and exploration units employed by all parties in the parcel.

The preliminary planning stage. At this stage, the developer has already taken the land parcel and can carry out further plot research based on the feasibility study stage to clarify the project positioning. At the same time, the project owner needs to invite the project management unit, design unit, construction unit, etc., and at the same time carry out contract management for the contracted package behavior. In the prefabricated construction industry chain, component suppliers participate in the design phase, work with the design unit, construction unit and project management unit to determine the component plan and deepen the design of the special components []. In order to ensure the fit of the components on site, the construction should also be simulated in the building information system at this stage. In the early planning stage, the main participants are the project owner, design unit, government department, construction unit, consulting unit, and component supplier.

Component procurement production phase. As a unique stage in the prefabricated construction industry chain, the component procurement production stage can best reflect the characteristics of the prefabricated building, that is, factory prefabrication instead of on-site processing. As China's current standards for the use of prefabricated buildings are still not perfect, it is very likely that problems will arise on the site when implementing prefabricated buildings. In order to prevent this problem, the accuracy should be strictly controlled in the preliminary planning stage and the procurement production stage to maximize the efficiency of on-site assembly. At this stage, developers and project management units need to select the appropriate component products according to their needs. Under the basic premise of meeting the needs, consider the logistics, precision and other factors to improve the common interests of component manufacturers and developers. In the component procurement production stage, the participants include project management units, construction units, component suppliers, and material equipment suppliers.

Construction phase. In the traditional construction project, the construction phase can be divided into three stages: construction preparation, main body and supporting construction, and completion acceptance. However, in the prefabricated construction industry chain, installation will occupy a larger proportion. At present, the prefabrication degree of prefabricated buildings in China is not high and the standardization degree is not enough Many on-site construction personnel have reported that the assembly components often have dimensional errors when installed on site, resulting in the inability to closely install the various components, and the rework phenomenon is endless. Therefore, this stage requires the design side, project management unit and component suppliers to work closely together to reduce on-site rework and design changes. In addition, for residential development projects, the developer can apply for a pre-sale certificate according to the progress (generally after the completion of the main project) and sell it in advance. This standard can often be relaxed for prefabricated buildings. In the construction phase, the participants include developers, project management units, component suppliers, materials and equipment suppliers, construction units, and supervision units.

Use phase. In the use phase, the real estate company's subordinates or commissioned property management companies generally operate and maintain users and real estate. In the prefabricated construction industry chain, component suppliers need to maintain and repair components during the use phase. After the component life cycle is over, the component recycling unit will recycle and return to the site for reuse. However, the symbiotic density of the symbiotic unit of China's component recycling unit is very small. Participants at this stage are mainly households, property management companies, component suppliers, component recycling units and developers.

3.2.2 Symbiotic unit role function

According to the above analysis of the logical architecture of China's fabricated construction industry chain, we can understand the roles and functions of each symbiotic unit in different construction stages, as shown in Table 3.1.

Table 3.1 The symbiotic unit and its role functions involved in the various stages of the prefabricated construction industry chain in China

Step	Symbiotic unit	Role function
Investment decision stage	Developer	• Identify the Feasibility Study Report • Make investment decisions • Application for "State-owned Land Use Certificate" and "Building Land Planning Permit"
	Survey unit	• Conduct preliminary land surveys prior to bidding for construction land
	government (landowner)	• Organizational survey • Organize land bidding and transfer of land use rights
	Engineering consulting unit	• Assist developers in conducting preliminary research, bidding, etc.
	Financial institution	• Assist developers in identifying financing options
	Household	• housing needs
Preliminary planning stage	Developer	• Under the general construction method, the developer conducts bidding, determines the project management unit, and determines the design unit and construction unit. • Participate in the conceptual design of the project and communicate with the project management unit in a timely manner to clarify the project requirements and project schedule • Application for "Construction Engineering Planning Permit"
	Project management unit	• Project management, confirming the project schedule, determining the economic budget based on the design and construction plan, and identifying the component plan • Management and coordination of design units and construction units • Prepare for pre-construction, such as preparing management manuals, personnel training, material preparation, etc. • After the design plan is determined, carry out building information simulation of the production process, optimize the construction and installation plan, prevent risks and avoid risks.
	Design unit	• Obtain the developer's needs, carry out conceptual design according to the surrounding conditions of the land, and then carry out the scheme design, preliminary design, construction drawing design • Hydropower HVAC structural design
	Component supplier	• Coordinate with the design unit, construction unit, and project management unit to confirm the component plan and deepen the design of the special components.
Component procurement production stage	Project management unit	• Management and supervision of each unit to achieve prefabricated components - construction site integration
	Component supplier	• Deliver prefabricated components on time and on demand, and commission as needed
	Construction unit	• Check prefabricated components for assistance in commissioning
	Design unit	• Check prefabricated components for assistance in commissioning
	Material equipment supplier	• Prepare before construction to determine raw material preparation, building materials preparation, equipment preparation, etc.

（Continued Table 3.1）

step	Symbiotic unit	Role function
construction stage	Developer	• Completion acceptance
	Project management unit	• Construction schedule management, including sub-items, construction management of important nodes, etc. • Project cost management • Project quality management • Delivered to the developer after completion, compiling the final accounts
	Construction unit	• Project site construction, construction schedule management • On-site component stacking and finished product protection management • Implement design changes
	Design unit	• Make design changes / modify design changes
	Component supplier	• Provide prefabricated components • Assist in installation and construction
	Material equipment supplier	• Supply of raw materials, equipment and building materials to meet construction and installation needs
	Supervisory unit	• In fact, the supervisory unit has joined the construction project from the previous planning stage. Before the construction, the relevant construction plan and drawings will be reviewed and the supervision rules will be confirmed. • Supervised quality inspection of prefabricated component fabrication, transportation and installation work • Completion acceptance
Business stage	Developer	• Confirm and hire a property management company to sustain the project • Sell the project to the household with the participation of the marketing management department/company
	Property management company	• Daily property management of the project • Contact the component supplier to resolve the problem with the component in the construction project
	Component supplier	• Repair and maintenance of prefabricated components
	Component recycling unit	• When the life of a prefabricated component expires or there is a loss, the component that is also used by the value of the product is recycled and reused.
	Household	• Buy a house and enjoythe right to live

3.2.3 Selection of the main parameters of the raw unit

The qualitative parameter indicates the intrinsic property of the symbiotic unit. The qualitative parameters of each symbiotic unit have different mapping effects on the symbiotic unit in different periods. The qualitative parameter of the dominant mapping effect is called the main parameter. The principal parameter is the basis for determining the symbiosis between the symbiotic unit and the system, and understanding the

symbiotic relationship between the symbiotic units and the symbiotic unit and the system. Therefore, the selection of the main parameters will be mainly analyzed in this section.

(1) Main quality parameter selection method

Through the analysis in Section 3.1, we can see that from the perspective of the entire assembly-type construction industry chain, developers, project management units, design units, construction units, component suppliers, material equipment suppliers and users in the entire industrial chain process There are more participations and symbiotic relationships with different symbiotic units; while property management units and marketing units have fewer participation processes and have less impact on the construction projects. Therefore, when further analysing the symbiotic relationship between symbiotic units, the two symbiotic units are not considered, and the analysis focuses on the core symbiotic unit.

There is currently no uniform method for determining the main parameters of symbiotic units. Hu Xiaopeng divided the symbiotic relationship into three categories according to the reasons of industrial symbiosis: the industrial symbiosis relationship formed by the business connection, the industrial symbiosis relationship formed by the technical nature, and the industrial symbiosis relationship formed by the supply and demand relationship, respectively Value added rate, output growth rate and total factor productivity are the main parameters. However, these three types of indicators currently do not have accurate statistics and are difficult to quantify.

Since the prefabricated construction industry chain itself is a business chain, different types of enterprises are fundamentally symbiotic units in the symbiotic system. Studying the main parameters of the symbiotic unit is essentially studying different categories in the prefabricated construction industry chain. The main parameters of the enterprise. Therefore, this paper starts from the development goal of the enterprise. Su Dongshui [] proposes that the development goal of the enterprise has four dimensions: First, the contribution goal of the enterprise to the society is generally expressed by indicators such as variety, output, profits and taxes, and contribution to sustainable development of green; Second, the market objectives of the company. Generally speaking, the market share of enterprise products is increased, and the market share is increased. Third, the development goals of enterprises. It is usually expressed as R&D investment, improving corporate efficiency, increasing production and product category contribution. Fourth, the company's interest objectives are generally expressed in terms

of sales revenue, profits, benefits or dividends. In this paper, combined with the different characteristics of each symbiotic unit in the assembly-type industrial chain symbiosis system, the main parameters are determined for the symbiotic unit according to the above classification.

(2) Selection of main parameters

For the assembly-type construction industry chain in different countries and different periods, the main parameters of the symbiotic unit are not the same. This section takes the Chinese fabricated construction industry chain as an example for reference. In actual use, it needs to be handled according to the characteristics of the country's development and the characteristics of the times.

At present, the development of the prefabricated construction industry chain in China is still not perfect, and the boundary with traditional buildings is not clear. And the development goal of China's fabricated construction industry chain lies in the improvement and establishment stage of the system. Therefore, the main parameters of most symbiotic units are still the main interests. Among them, component suppliers have relatively low input and output in the early stage of industrial chain development, and are supported by the government and large-scale developers. Therefore, the main parameters of the prefabricated products are used to construct the steel structure industry. The output value represents the calculation.

For prefabricated buildings, China's primary development goal is to increase the area of new fabricated buildings, with the further goal of promoting green buildings. Therefore, for the erected system of the prefabricated construction industry chain, the market target (the proportion of the prefabricated building area in the newly started construction area) and the social target (the carbon emission per unit of building energy consumption) are jointly measured. The selection of the main parameters of the symbiotic unit in the prefabricated construction industry chain in China is shown in Table 3.2.

Figure 3.2 Selection and calculation method of main parameters of symbiotic unit in China's fabricated industrial chain

Symbiotic unit	Reference dimension	Main parameter	Calculation formula
DeveloperC_1	Interest goal	Sales revenue of Prefabricated construction	Annual real estate development enterprise operating profit * newly built assembly area / national new construction area
Project management unitC_2	Interest goal	Prefabricated construction project project management unit construction industry enterprise total output value	Total contracted construction industry construction industry total output value * new assembly building area / national new building area
Component supplierC_3	Contribution goal	Steel structure industry output value (represented by steel components)	Construction steel structure industry output value (100 million yuan) * new assembly floor area / national new construction area
Design unit C_4	Interest goal	Engineering design income	Survey and design unit engineering survey revenue new construction type building area / national new building area
Construction unit C_5	Interest goal	Project contract revenue	Survey and design unit engineering design revenue new construction type building area / national new construction area
Exploration unit C_6	Interest goal	Engineering survey income	Survey and design unit project contracting revenue Newly built building area / national new building area
Material equipment supplier C_7	Interest goal	Material equipment sales	Sales of building materials wholesale goods (100 million yuan) * Newly built building area / new construction area in China
Supervisory unit C_8	Interest goal	Construction project supervision's operating income on prefabricated construction projects	Construction project supervision business income (ten thousand yuan) * Newly built assembly area / national new construction area
Prefabricated construction industry chain C_s	Market target Social goal	Area ratio (prefabrication rate) and building energy consumption of industrial buildings in newly started construction area	Newly built construction area / new construction area nationwide Unit building energy consumption carbon emissions

3.3 Prefabricated construction industry chain symbiotic relationship

The symbiotic relationship refers to the mutual relationship between the symbiotic units, including bidding, bidding, management, coordination, trading, etc. in the prefabricated construction industry chain. In the market competition, the symbiotic relationship is mainly driven by interests. Under the support of some policies, it is also influenced by status-driven and relationship-driven.

The symbiotic relationship is divided into two dimensions. From the perspective of benefit distribution, it includes symbiosis such as parasitism, reciprocal symbiosis, and partial symbiosis. According to the current status of China's prefabricated construction industry chain, the state policy support is great, and the new fabricated building area has grown steadily in recent years. The possibility of mutual symbiosis is even greater, but it remains to be confirmed. From the perspective of organizational evolution, there are four evolution modes including point symbiosis, intermittent symbiosis, continuous symbiosis and integrated symbiosis, which are determined by the viscosity and cooperation frequency between symbiotic units. Next, the four symbiotic models will be compared and analyzed. .

3.3.1 point symbiosis mode

The point symbiosis model is very common in the initial development stage of the prefabricated construction industry chain. Due to the slow development of China's fabricated construction industry chain in the twentieth century, until the beginning of the 21st century, the point symbiosis model in the fabricated construction industry chain is very common. There are two possibilities for this phenomenon:

(1) The symbiotic unit has just entered the prefabricated construction industry chain and found that this model is not suitable for the development of its own business, then choose to evacuate, return to the original comfort zone or try new areas. If a small developer wants to try a small-scale construction of a prefabricated building, it finds that the assembled component supply market is still not circulated, and it is impossible for small developers to form economies of scale. Therefore, they will leave temporarily and wait for the opportunity to see if they enter.

(2) The symbiotic unit has decided to develop in the prefabricated construction industry chain for a long time, but the market is in the stage of vigorous development. There are new symbiotic units pouring into the system, and the level of level is not uniform, resulting in poor cooperation between symbiotic units. The secondary cooperation rate is low, and there is a point of symbiosis.

3.3.2 Intermittent symbiosis mode

The formation of intermittent symbiosis is largely due to the re-cooperation after point symbiosis. The indirect symbiosis pattern commonly found in China's fabricated construction industry chain is after the 21st century. At this stage, the symbiotic units

have a certain degree of understanding with each other, and they are confident that the next cooperation can achieve the desired effect of both parties, but the relationship is still not close enough. In the prefabricated construction industry chain, there are also two situations:

(1) The total amount of business of a symbiotic unit in a certain industry chain is small, and the discontinuity of orders and services leads to discontinuity of symbiosis. In the construction industry, this phenomenon is very common. For example, in an architectural design company, only 10% of design orders in a year are about the design of prefabricated buildings. In this case, the architectural design enterprises are in the prefabricated construction industry chain. The symbiosis often has discontinuities.

(2) The development between symbiotic units is different. Different symbiotic units have different strategic development goals and development steps. When the two do not match each other, it will cause discontinuity of cooperation.

3.3.3 continuous symbiosis mode

In the continuous symbiosis phase, the relationship between symbiotic units tends to be stable, and the symbiotic relationship between units is continuous and uninterrupted. In China, continuous symbiosis has also emerged, mainly in large enterprises with independent research and development and long-term development strength. .

In the continuous symbiosis phase, there is a long-term business cooperation between the symbiotic units. There are two prerequisites. The first is that the symbiotic units have already communicated with each other to ensure that the other party meets their own cooperation requirements. The second is that during the symbiotic and intermittent symbiosis, the symbiotic units have found a meeting between the symbiotic units. The symbiotic balance, such as reciprocal symbiosis.

3.3.4 Integrated symbiosis mode

Integrated symbiosis means that the symbiotic units have common interests and future development goals, and are the optimal development model in the symbiotic mode. At this stage, not only the strategic cooperation between the symbiotic units is formed, but also the phenomenon of mutual acquisition and merger is more likely to occur, so that different symbiotic roles exist in one enterprise. In theory, the emergence of such a super-large company makes the symbiotic interface more effective, and is more

conducive to the target development of the symbiotic system and the cohesion of symbiotic energy.

At present, there are also enterprises with such strengths in China, such as Yuanda Labor, Vanke, etc. Among them, Yuanda's workers mainly focus on prefabricated buildings and are in the leading position in China's fabricated construction industry chain.

3.4 Prefabricated construction industry chain symbiotic environment

The sum of all factors outside the symbiotic unit constitutes a symbiotic environment. In the prefabricated construction industry chain, the symbiotic environment mainly refers to the economic environment, policy environment and technological environment of the prefabricated building.

(1) Economic environment. The economic environment is the external social and economic conditions for the activities of the symbiotic unit, which are related to the income level of consumers, the mode of consumer expenditure, the structure of consumption, and the level of economic development. Prefabricated buildings are widely used in residential construction. Consumers are more concerned with factors such as geographical location, sales price, and surrounding environment when purchasing a house. They are less related to the quality of the prefabricated building itself, so it is difficult to meet consumer demand. Based on the micro level of preferences and preferences, analyze the economic environment of the prefabricated construction industry chain. Through the research on the development history of fabricated buildings in developed countries, it is found that the rapid development period of fabricated buildings is often related to the state's large historical events and economic development stages. For example, the vigorous development of prefabricated buildings in Japan, Europe, and the United States stems from the social phenomenon of a large shortage of post-war housing. The efficiency of traditional building construction cannot meet the urgent needs of housing growth. At the same time, the rapid development stage of its prefabricated buildings is in line with the rapid economic development stage. Therefore, research should be conducted mainly from the macro level to the economic environment.

(2) Policy environment. The policy environment is the external policy conditions and responsibilities of the symbiotic unit for activities, including the principles of action to

be followed, the clear tasks to be completed, the methods of work implemented, the general steps taken and specific measures, etc. For prefabricated buildings, the state In the areas of standard norms, economic subsidy policies, research and development policies, market policies, etc., various types of policies such as tax optimization, financial finance, land support, demonstration projects, scientific and technological research and development, education and training, and information services are proposed. The research policy environment should be combined with other symbiotic elements. The results of the study will fill in the gaps in existing policies and provide a sound policy environment for the prefabricated construction industry chain.

(3) Science and technology environment. The technological environment refers to the technical factors that affect the development of the prefabricated construction industry chain. The assembly-type construction industry chain is complex in structure and has many technical nodes, such as the standard technical system of components corresponding to the type of building structure, the effectiveness, accuracy and real-time of the symbiotic interface, the fabricated building construction technology system during construction, intelligent construction, etc. . An effective technological environment is a prerequisite for the rapid development of the assembled construction industry chain. Therefore, when analyzing the assembly-type construction industry chain, we should pay attention to key technology nodes, discover technical loopholes in time, and protect the development of the assembly-type construction industry chain with a good technology environment.

3.5 Chapter summary

According to the symbiosis theory, this chapter clarifies that the symbiosis system of the prefabricated construction industry chain is a symbiotic unit with the basic components of the assembly-type construction industry chain, such as developers, design units, construction units, component suppliers, users, etc. Under the influence of the symbiotic environment, The use of prefabricated interfaces such as fabricated building standards, information interaction systems, project management information systems, and trading systems to exchange and circulate material flows, information flows, and capital flows between symbiotic units, thereby generating a symbiotic energy diversified social science ecosystem system. At the same time, according to the three elements of symbiosis theory, the framework of the symbiosis system of the

installed building industry chain is sorted out, which lays the framework foundation for the later research.

CHAPTER 4 Benchmarking model of prefabricated building industry chain based on symbiosis theory (BPRS Model)

4.1 Research on benchmarking of assembly-type construction industry chain based on symbiosis theory

The prefabricated construction industry chain is a symbiotic system with wide dimensions, many components and complex symbiotic relationship. It provides a more systematic understanding and understanding of the symbiotic system of the prefabricated construction industry chain. From the three elements of symbiosis theory, namely symbiosis unit and symbiosis Starting from the relationship and symbiosis environment, combined with the characteristics of prefabricated buildings, the fabricated industrial chain was studied. In addition, in order to understand the symbiotic status of the researched industrial chain, explore the feasibility direction of the future development of the research industry chain, introduce advanced and comparable benchmarking objects for benchmarking research, and build a prefabricated construction industry chain. The Benchmarking model of prefabricated building industry chain based on symbiosis theory, referred to as the BPRS model, is shown in Figure 4.1. There are four basic steps in benchmarking management: determining benchmarking factors, selecting benchmarking objects, researching and comparing benchmarking factors, and analyzing benchmarking factors. In this section, the benchmarking factor, the benchmarking model, is first determined. Next, the symbiotic unit, the symbiotic relationship and the symbiotic environment are elaborated separately.

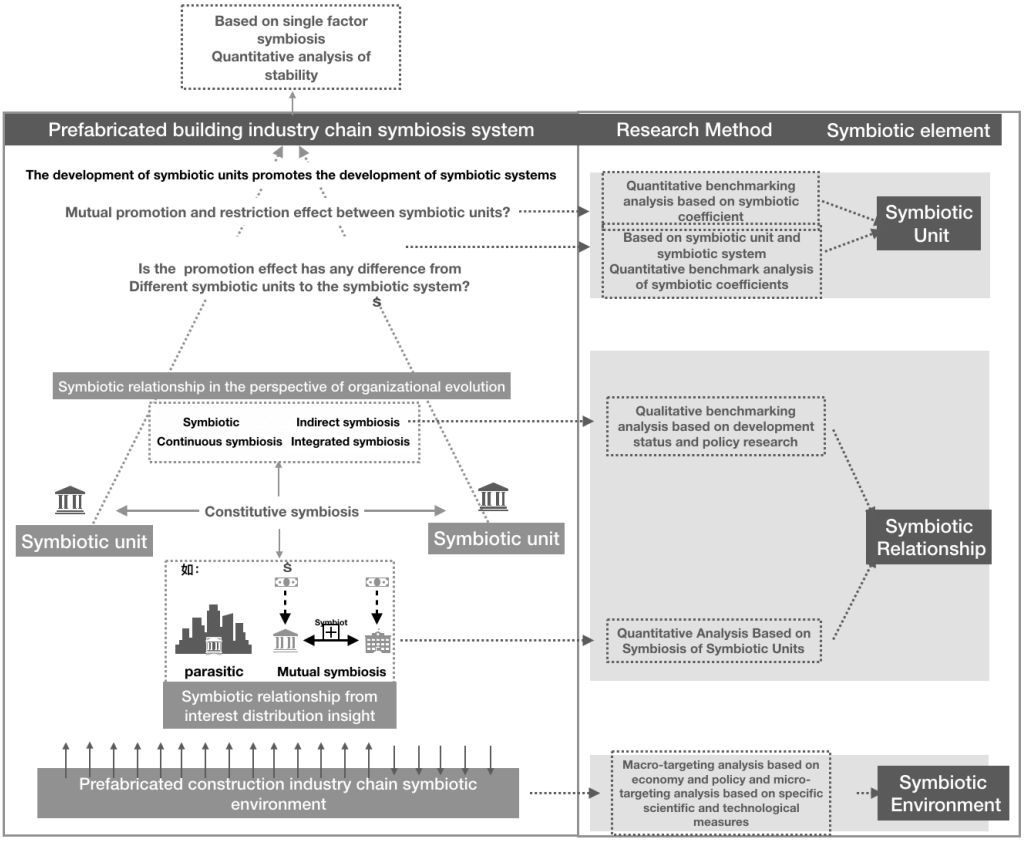

Figure 4.1 Benchmarking model of prefabricated building industry chain based on symbiosis theory (BPRS Model)

4.1.1 Symbiotic unit

The symbiotic unit is the basic component of the symbiotic system. Exploring the role of the symbiotic unit in the symbiotic system is very helpful for understanding the promotion effect of different symbiotic units of the prefabricated building on the development of the industrial chain and the position of the symbiotic unit in the industrial chain.

Taking China's prefabricated construction industry chain as an example, according to the current development status and existing problems, two problems are raised for the industrial chain symbiosis unit. First, since the state vigorously promoted assembly-type construction, which symbiotic units have the greatest driving effect on the development of China's fabricated construction industry chain symbiosis system?

Secondly, at present, there are some problems in the assembly-type construction industry chain in China, where the design units participate in the node night, and are

subject to large problems caused by the construction unit and the contractor. Does this affect the contribution of the design unit to the symbiotic system?

In order to solve the above problems, the symbiotic unit is studied from two aspects.

(1) Contribution of different symbiotic units to promote the development of symbiotic systems

The propagating effect of symbiotic units on the development of symbiotic systems can be measured by single factor symbiosis, which indicates the symbiosis of a single symbiotic unit relative to the symbiotic system,expressed by δ_{Si}.

$$\delta_{si}^{m} = \frac{dz_i^m / z_i^m}{dz_s^m / z_s^m} \tag{4.1}$$

The higher the single element symbiosis, the greater the propulsion of the symbiotic unit to the development of the symbiotic system, and the higher the contribution to the generation of symbiotic energy. For the application of symbiotic unit contribution, it can be studied from two dimensions.

First, analyze the contribution of different symbiotic units to promote the development of symbiotic systems. Starting from the time dimension, it compares the change of the contribution of the symbiotic unit in the process of industrial chain development, judges whether the trend of the contribution of the symbiotic unit is reasonable, and analyzes which symbiotic unit development can promote the development of the symbiosis system of the assembly-type construction industry chain.

Secondly, in combination with the reference industry chain, the author compares the contribution of the symbiotic unit of the industrial chain and the reference symbiosis unit of the reference industry chain horizontally, and analyzes the national conditions of the two countries, and seeks the future development direction from the differences.

(2) Promotional production between different symbiotic units

The symbiotic coefficient can reflect the contribution of different symbiotic units in the symbiosis. By comparison, it can reflect the mutual promotion or production between different symbiotic units. The symbiotic coefficient θ_{ij}^{m}、$\theta_{ji}^{m}$of the the main parameter C_i and C_{j} are:

$$\theta_{ij}^{m} = \frac{\left|\delta_{ij}^{m}\right|}{\left|\delta_{ij}^{m}\right| + \left|\delta_{ji}^{m}\right|} \tag{4.2}$$

$$\theta_{ji}^{m} = \frac{\left|\delta_{ji}^{m}\right|}{\left|\delta_{ij}^{m}\right| + \left|\delta_{ji}^{m}\right|} \tag{4.3}$$

The greater the symbiosis coefficient of which party, the greater the contribution of this party to the symbiosis, indicating that this symbiotic relationship has a higher

contribution to the symbiotic energy generation of the symbiotic system. At the same time, it often means that this party has a higher voice in this relationship.

In the prefabricated construction industry chain, different symbiotic units play different roles in the industrial chain, and there are different symbiotic coefficient distributions among the symbiotic units, in order to understand the development status and improvement direction of the symbiotic unit of the fabricated building industry chain in China. The benchmarking industry chain is benchmarked, and the symbiotic coefficient of the symbiotic unit of the industrial chain and the reference industrial chain symbiosis unit are compared horizontally. At the same time, qualitative analysis is carried out in combination with the development of national conditions in different countries, and the future development direction is sought from the differences.

4.1.2 Symbiotic relationship

Symbiosis refers to the interrelationship between symbiotic units. In the assembly industry chain, it includes bidding, bidding, management, coordination, trading, and other relationships. In the market competition, it is mainly driven by interests. Under the support of some policies, it is not excluded to be driven by status and relationship. The symbiotic relationship is divided into two dimensions. A symbiosis method from the perspective of benefit distribution, that is, parasitism, reciprocal symbiosis, deviation from symbiosis, etc., can be determined by determining the prefabricated construction industry through symbiosis. Another symbiosis model based on organizational evolution is determined by the viscosity and cooperation frequency between symbiotic units, and qualitative analysis based on development status and policy research.

(1) Symbiotic mode

According to the symbiosis theory, the relationship between symbiotic units can be expressed by symbiosis. The symbiosis refers to the degree of correlation between the two symbiotic units or the changes in the mass parameters between the unit and the symbion, reflecting the degree to which the two qualitative parameters interact. By comparing the symbiosis, you can get the type of symbiotic relationship. Assume that there are 8 types of symbiotic units in the assemblage system of the prefabricated construction industry chain, namely developers C_1, project management units C_2, component suppliers C_3, design units C_4, construction units C_5, exploration units C_6, material equipment suppliers C_7 and supervision units C_8, and symbiotic systems are

expressed by C_S. Among them, the mass parameter of different symbiotic unit C_i and C_j are expressed by Z_i, Z_j $(i, j = 1,2 \ldots n)$, and the symbiosis formula 3.1 is shown follows:

$$\delta_{ij} = \frac{dZ_i / Z_i}{dZ_j / Z_j} \quad (4.4)$$

If Z_i and Z_j are the main parameter of the symbiotic unit seperatly, then the calculated symbiosis is called the characteristic symbiosis, which is the most representative variable representing the symbiotic feature. The characteristic symbiosis calculation is expressed as Equation 4.5.

$$\delta_{ij}^m = \frac{dZ_i^m / Z_i^m}{dZ_j^m / Z_j^m} \quad (4.5)$$

The symbiotic relationship between symbiotic units can be illustrated in Table 4.1

Table 4.1 The definition of symbiosis and symbiosis

Symbiosis	$\delta_{ji} > 0$	$\delta_{ji} = 0$	$\delta_{ji} < 0$
$\delta_{ij} > 0$	Mutual symbiosis	Partial symbiosis	parasitic
$\delta_{ji} = 0$	Partial symbiosis	neutral	Partial symbiosis
$\delta_{ij} < 0$	parasitic	Partial symbiosis	Competitive symbiosis

Among all kinds of symbiosis, the reciprocal symbiosis is the optimal symbiosis of the symbiotic system, which is most conducive to the long-term development of the symbiotic system.

(2) Symbiotic mode

The symbiotic model includes point symbiosis, intermittent symbiosis, continuous symbiosis and integrated symbiosis. The evolution mechanism is shown in Figure 4.2. In the point of symbiosis, the first cooperation between the symbiotic units in the prefabricated construction industry chain, but based on the effect of the first cooperation, decided not to carry out the next cooperation; in the indirect symbiosis stage, the number of symbiotic unit cooperation increased, However, due to factors such as partner trust, project continuity, and partner capabilities, cooperation is intermittent. In the continuous symbiosis phase, the frequency of repetitive cooperation increases, the trust degree and dependence between symbiotic units increase, and the stability of the symbiotic system increases. In the final integrated symbiosis stage, symbiotic units with different functional divisions may exist in the same enterprise or enterprise cluster, which can maximize the advantages of the industrial chain and reduce the energy consumption between the symbiotic units, thereby accumulating and producing More symbiotic energy.

For the analysis of the symbiotic model, a qualitative analysis method based on development status and policy research is adopted. According to the development history of the assembly-type construction industry chain, policy promulgation, standard implementation, assembly rate and other factors, the main symbiosis modes at different stages of development are analyzed. In the analysis of the symbiotic model, it is also necessary to include benchmarking comparisons in the benchmark industrial chain. It is possible to fit the evolutionary process of the benchmark industrial chain with the researched industrial chain, understand the development status of the researched industrial chain, and predict the future development trend. In each symbiotic mode, continuous symbiosis and integrated symbiosis are symbiotic modes that are more favorable to the steady development of the prefabricated construction industry chain. Understanding the symbiotic mode of the prefabricated construction industry chain is significant for understanding the entire life cycle of the prefabricated construction industry chain. Significance

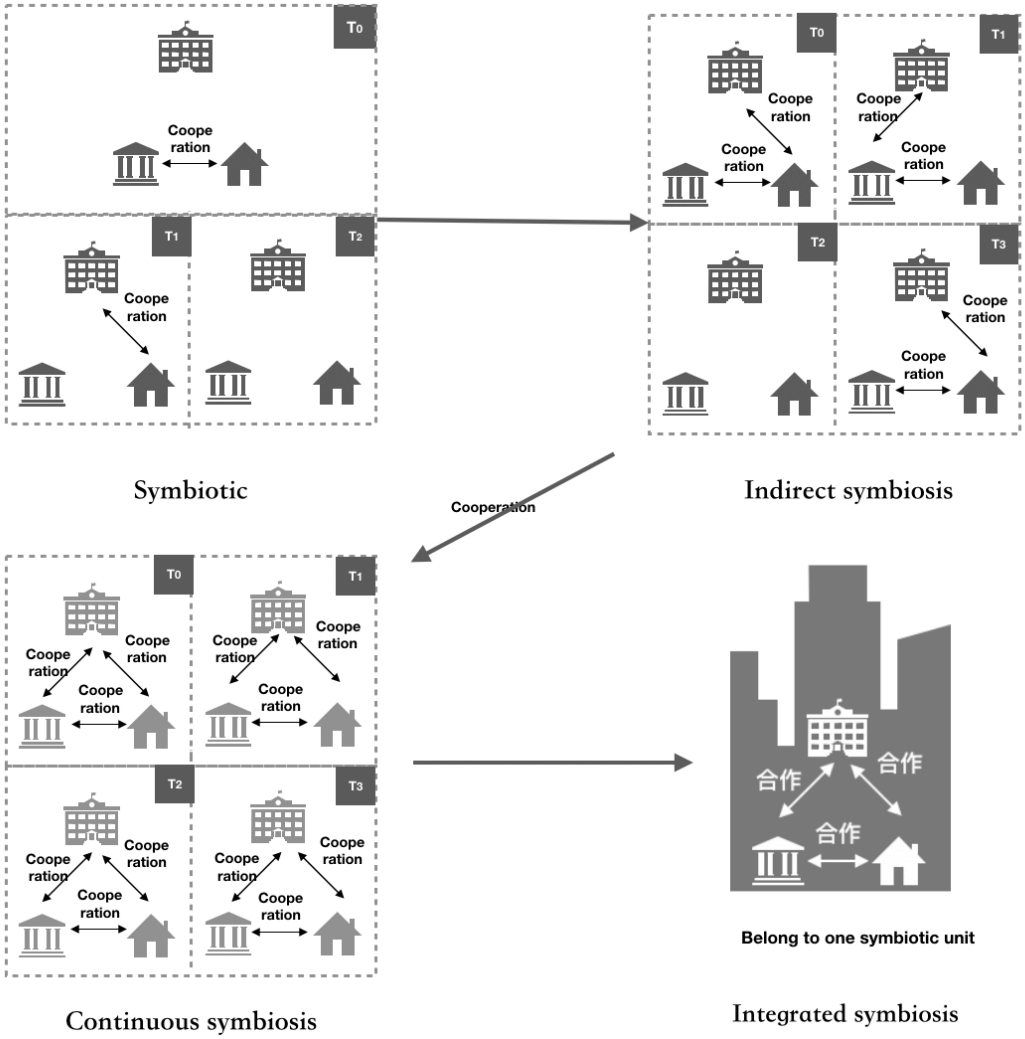

Figure 4.2 The evolution process of symbiotic mode in the prefabricated building industry chain

4.1.3 Symbiotic environment

The symbiotic environment of the prefabricated construction industry chain includes economic, policy and technological environments. The study of the symbiotic environment consists of two parts.

Firstly, we will study the status quo of China's symbiotic environment, understand the current economic, policy and technological environment of China's prefabricated construction industry chain, and secondly, benchmark the China's prefabricated construction industry chain and the benchmark national assembly-type construction industry chain. Analyze the differences between economy and policy, study the scientific and technological measures of the prefabricated construction industry chain from the micro level, compare the advanced measures of the benchmarking countries,

and make suggestions for the development of the symbiotic environment of China's prefabricated construction industry chain.

4.2 Selection of the target object

4.2.1 Selection principle

When selecting the target object, we should pay attention to two points. First, it is advanced. When the target object is more advanced and superior than all aspects of the research object, the target is valuable. Secondly, it is comparable, only the object. When the development goals, development structure, current framework, and existing components are similar, they have the meaning of benchmarking. Based on the two criteria of advancedness and comparability, the principle of selecting the target of selection for the symbiosis system of China's fabricated building industry chain is proposed:

(1) Advancement of the benchmark industrial chain

For the symbiosis system of the prefabricated construction industry chain, the advanced nature should be reflected in two aspects.

The first is “How is the promotion?”, that is, the scope of implementation of the prefabricated construction industry chain, which can be the proportion of the prefabricated construction industry chain in new buildings.

The second is “how is the effect after promotion?”, that is, the implementation effect of the prefabricated construction industry chain can be measured by the reduction of building energy consumption.

(2) Building type similarity

The main types of buildings in different countries vary widely. The type of building is related to factors such as national culture, ethnic type, population density, and population habits. In countries that are sparsely populated, the main types of housing are houses and villas, while in densely populated countries, high-rise apartments tend to take up a larger share. The proportion of different types of buildings will affect the development of prefabricated buildings and the structure of the prefabricated industrial chain. In China, prefabricated buildings are mainly used in houses. Therefore, when selecting the benchmarking country, we should focus on the countries with similar building types on the dwellings and similar countries in China. In actual comparisons,

many countries do not have specific statistics on the type of building, where the type of building is described by population type, population size, and per capita residential area.

(3) Structure type consistency

The main types of building structures developed in the industrial chain include steel structures, wood structures, precast concrete structures, and shear wall structures. Different types of building structures reflect the needs of buildings in different countries based on topography, population density, and housing density. Differences in the type of building structure will affect the role of design, construction, component suppliers, installation and other symbiotic units in the design, construction and installation of the building, and will also affect the standardization of various standard systems of the assembled building. Therefore, the industrial chains with similar development directions of building structures are more comparable.

4.2.2 Selection of target objects

At present, in the international arena, the countries with mature development of prefabricated buildings include the United States, the United Kingdom, Germany, Denmark and Sweden, Japan, Singapore, etc., and these countries are selected as candidates for bidding, based on the above principles, further screening, As shown in Table 4.2.

Table 4.2 National prefabricated-type construction industry chain

Selection principle	Corresponding indicator	China	japan	US	German	UK	Danmark	Singapor
The advanced nature of the industrial chain	Prefabricated rate	3%	55%	Around 40%	The proportion of prefabricated components in residential buildings reached 94.5%	70% of steel structures in new projects	80% of common parts in new homes 到 80%	70%
	building energy consumption/ capita ranking	/	1	6	2	4	3	5
Building type similarity	Type of race	Asian	Asian	70% for Caucasians	>90% for Caucasians	>87% for Caucasians	>90% for Caucasians	>90% for yellow people
	The population density	144	335	33	232	271	22	134
	housing area m2/person ㎡ /people	40.8	37.4	59	47	44	52	30
Structural type consistency	Prefabricated building development type	Wood structure, steel structure, precast concrete structure	Wood structure, steel structure, precast concrete structure	Low-rise steel structure, wood structure	Laminated version, concrete, shear wall structure	Steel structure	Concrete structure	Precast concrete, shear wall, laminated board

In order to select the most suitable benchmarking objects from various countries, a scoring system for scoring objects is established. According to the rankings of the six countries on different indicators, the scores are given in descending order. The countries with the highest scores should be selected as the assembly in China. The benchmarking object of the construction industry chain. Give the same weight to the three selection principles, namely, the industrial chain advanced, the architectural type similarity, and the structural type consistency. The same weight is also given to each indicator that

constitutes the principle of selection. For the principle of advancedness, ranking according to the advanced nature, the most advanced countries get 6 points, the least advanced countries get 1 point, and so on; for the principle of comparability, according to the similarity with China, the most similar countries have to 6 points, the most dissimilar country scored 1 point, and so on. This gives the benchmark scores for each country relative to China, as shown in Table 4.3.

According to the calculation results, Japan has the highest score among the six countries, and it has obvious advantages in both advancement and comparability. Therefore, in this paper, the Japanese fabricated construction industry chain is regarded as the benchmark industrial chain of China's fabricated construction industry chain.

Table 4.3 Worldwide prefabricated -type construction industry chain

Corresponding indicator	China	japan	US	German	UK	Danmark
Prefabricated rate	3	1	6	2	5	4
building energy consumption/ capita ranking	6	1	5	3	4	2
total	9	2	11	5	9	6
Industry chain advanced score	5	1	6	2	5	3
Type of race	6	4	2	3	2	5
The population density	3	2	5	4	1	6
housing area m2/person	6	1	4	5	2	3
total	15	7	11	12	5	14
Building type similarity score	6	2	3	4	1	5
Structure type consistency score	6	5	2	4	3	2
Industry chain advanced score	17	8	11	10	9	10

4.2.3 Japan's prefabricated construction industry chain symbiosis unit logic and role functions

There are two concepts of "residential industrialization" and "residential industrialization" in the prefabricated buildings of Japanese houses. Residential industrialization refers to the method of decomposing a house into components and parts, industrial production, and then assembling on site, similar to the concept of prefabricated residential buildings in China, is a kind of production mode of the construction industry. Improvement. To achieve industrial production, it is necessary to decompose the house into “materials” (also referred to as “structural components” in China) and “parts” (generally referred to as “non-structural components” in China). In

this paper, “components” and “components” are used. To represent these two types of components, and to explain the difference between the two (as shown in Table 4.4).

Table 4.4 The similarities and differences between "components" and "parts" of two types of products in industrial production in Japan

classification	Component (structural member)	Parts (non-structural components)
Commonality	Factory-made products	
difference	• Part of the structure, the separation is difficult • Form a one-to-one relationship with the building, low commercial circulation	• Non-structural, separable • Can be independent of specific buildings through standardization and serialization, with commodity liquidity • Added value for industrial production and commodity circulation

The "household industrialization" began with the production and circulation of parts. The concept of house industrialization was first proposed by the Ministry of International Trade and Industry in Japan in 1968. The concept is to use industrialized production methods to produce houses and improve housing. Production productivity while reducing construction costs . The residential industry runs through the life cycle of the residential area, mainly consisting of the construction industry, the decoration engineering industry, the residential building materials industry, the transportation industry and the distribution industry of building materials and the DIY industry. This concept is very similar to the concept of China's fabricated buildings. Housing industrialization is not only reflected in the improvement of building production efficiency and the improvement of building production methods, but also in the richness of the entire industry chain and the improvement of housing quality. The core part of the Japanese fabricated construction industry chain, that is, the standardization system for parts, has been perfected after five eras.

In the project management mode, Japan is similar to China, mainly including DB (Design-Build), that is, design-build mode; DBO (Design-Build-Operate), design-build-operate mode; PFI (Private Finance Initiative) , that is, the private financing leading model. But now, the construction management (CM) system is more widely used. The owner/developer will first contract the project to a qualified project management company (Construction Manager), which is responsible for design, duration, quality, cost management and control.

In the Japanese residential industrialization industrial chain, the construction management (CM) system is selected for decomposition and research, and the association of various symbiotic units in the industrial chain is gradually revealed. Its fabricated construction industry chain is shown in Figure 4.4.

Investment decision stage. Japan's land system is different from that of China. China's land is state-owned, and the right to use is purchased. Japan's land system is private, so the source of land transfer is not just the government. Secondly, Japanese real estate development companies have a high degree of standardization. In daily investigations and research, real estate development companies will investigate customer needs and implement requirements as product planning and design standards. Therefore, large real estate companies have often developed a set of product allocation and practice grading standards based on the needs of different customer groups, forming a “style book” for use in subsequent projects. In the case of a single project survey, such large real estate development companies generally do not hire external consulting and use their own internal research centers. In Japan, the pre-planning phase and the procurement phase have a high degree of integration, so the two phases are combined and named as the pre-planning and procurement phase. After the project is established, the developer generally entrusts the project to the project management unit by means of general contracting. In the contract, it is necessary to clarify the quality assurance clauses for the owner, the general contractor and the subcontract. After that, the project management unit selects the professional engineering company, recommends the design company to the developer, and confirms each subcontracting unit. Generally speaking, in order to save bidding time, large-scale real estate development companies will provide their own standardization rules to long-term partners, such as products such as “Model Book” and “Standard Chart” for different user groups. When bidding, you can quickly give design drawings and quotations, greatly improving efficiency. At the same time, contract management at this stage of the construction project is also very important. Taking Tokyo Construction Company as an example, the company will formulate a “Design Checklist” according to standard tools such as “Model Book” and “Standard Chart”. Before signing a formal contract with the project management unit, both parties need to reach a consensus based on the “Design Checklist”. If the design is found to be inconsistent with the standards of Tokyo construction during the subsequent project, the project management unit will assume full responsibility. Therefore, the

quality assurance clause is directly linked to the general package and the economic interests of each subcontractor. If the quality of the project is neglected, in addition to bearing the economic losses, the contractor and subcontractors will also credibility, and it will be difficult to obtain bidding opportunities in the future. In the early planning and procurement process, the design unit needs to determine the suppliers and models of parts and components; confirm the relationship between parts and parts, parts and buildings to ensure continuity during construction. The parts manufacturer will provide design technical descriptions to the designer, and the content is often not limited to the scope of the parts, and even includes the relationship with the surrounding and the technical standards of the installation connection. It is important to be clear that in Japan, the manufacturer of the parts is an independent industry that is not affiliated with the developer or builder, and the part manufacturer is the developer of the parts.

In the construction stage, because of the high degree of prefabrication in Japan, the construction on site is relatively small, and the installation accounts for a relatively large proportion. For single-family homes, you can even install and stay in one day. Due to its high prefabrication rate, part manufacturers that provide components and parts still have a high level of participation at this stage. The parts manufacturer not only needs to provide construction technical instructions to the construction unit, but in many cases, the installation and connection of the parts is also carried out by the parts manufacturer.

As for the supervision unit, in the Japanese supervision mechanism, the government project is uniformly supervised by the government bureau, and the private owner is also supervised by the design unit.

In the use phase, there is little difference between the property management and the domestic. However, the use stage of the Japanese fabricated construction industry chain is more focused on the protection and maintenance of houses. In response to the Japanese government's 200-year residential goal, the owner of the house should try to maintain the value of the house. Therefore, homeowners should carry out regular maintenance, daily repairs, planned repairs and long-term repairs to their homes. In addition, since the implementation of the SI Residence (Skeleton Infill), the structure (Skeleton) is separated from the interior decoration and facilities (Infill), and the owner can change the structure of the house by replacing only the infill or parts. Service life. The symbiotic units and role functions of each stage of the Japanese fabricated construction industry chain are shown in Table 4.5.

Table 4.5 The symbiotic unit and its role in all stages of the Japanese fabricated construction industry chain

Step	Symbiotic unit	Role function
Investment decision stage	Developer	• Make investment decisions • Purchase of land • Conduct research on target users, surrounding projects, urban planning, etc., and determine project product planning
	Survey unit	• Plot preliminary survey and in-depth survey
	Financial institution	• Assist developers in identifying financing options
	Household	• Ask for housing needs and accept research
Pre-planning and procurement phase	Developer	• Bidding to determine the project management unit • Determine contract terms and specify quality assurance terms for owners, general contractors, and subcontractors
	Project management unit	• Project management, confirming the project schedule, determining the economic budget based on the design and construction plan, and identifying the component plan • Management and coordination of design units and component manufacturers • Prepare for pre-construction, such as preparing management manuals, personnel training, material preparation, etc. • Purchasing based on the procurement needs provided by the design
	Design unit	• Obtain the developer's needs, carry out conceptual design according to the surrounding conditions of the land, and then carry out the scheme design, preliminary design, construction drawing design • Select the appropriate parts and parts manufacturers to adjust the relationship between the parts and parts, parts and buildings to ensure that the parts used meet the performance needs of the building. • Identify the standard style book for decoration, communicate with the user, determine the interior decoration plan, and feed back the procurement requirements to the project management unit.
	Construction unit	• Determine the construction plan • Identify construction and installation plans with component manufacturers to achieve the performance of components and buildings
	Component manufacturer	• Identify component inventory and shipping cycles to meet project needs • Some manufacturers may be responsible for the design related to the part • Projects involving component design, design and production scheduling
construction stage	Project management unit	• Management and supervision of each unit, management of the project, and integration of prefabricated construction sites • Delivered after completion
	Component manufacturer	• Deliver prefabricated components on time and on demand, and commission as needed • Provide construction technical instructions to the construction unit
	Construction unit	• Project site construction, construction schedule management • On-site component stacking and finished product protection management • Implement design changes

(Continued table 3.1)

Step	Symbiotic unit	Role function
construction stage	Supervisory unit	• Review construction plan, construction plan, drawings, and confirm supervision rules • Submit a formula supervision report
	Design unit	• May be concurrently supervised • Make changes to the design changes that occur and maintain a full exchange of information with the component manufacturer • Drawing "Residential Sales Drawings as a Benchmark" as an important reference material for users during the sales phase
	Material equipment supplier	• Supply of raw materials, equipment and building materials to meet construction and installation needs
Business stage	Developer	• Confirm and hire a property management company to sustain the project • Sell the project to the household with the participation of the marketing management department/company
	Property management company	• aily property management of the project
	Component supplier	• Repair and maintenance of prefabricated components • Provide users with new parts
	Household	• Buying a home and enjoying the right to live • Hire management company for house maintenance, responsible for the maintenance and management of the private part of the house, and record the maintenance and management of the house to achieve the goal of 200 years of residence.
	Professional management company	• Carry out daily repairs, planned repairs, and long-term repairs

In the symbiosis system of the prefabricated construction industry chain, the symbiotic unit includes developers, project management units, design units, subcontractors, engineering consulting units, and financial institutions. These symbiotic units form a complete assembly-type construction industry chain, interacting and co-output, obtaining symbiotic energy, and then using symbiotic energy and symbiotic external environmental variables to further develop in density and dimension. The symbiotic units in the assembly-building industry chain in China and Japan have many similarities. First, the basic composition of the symbiotic units is similar. The main participants are developers, project management units, design units, construction units, component suppliers, materials and equipment. Suppliers, property management companies, users, etc. Second, the basic needs of symbiotic units are similar. The differences between the symbiotic units of the China-Japan prefabricated construction industry chain can be expressed in Table 4.6.

Table 4.6 Similarities and differences between symbiotic units in China-Japan prefabricated building industry chain

Symbiotic unit	Japan	China
Land owner	Japan is a privately owned country. The source of land is not necessarily the government, but it may also be privately owned.	If it is a newly developed building, it is generally a government organization land auction.
Component supplier	In Japan, this role is generally referred to as "component manufacturer", and component manufacturers play an important role in the Japanese residential industrialization symbiosis system, and provide a large number of standardized components for design selection and procurement, with high degree of specialization.	China's component suppliers bear more of the role of "suppliers" and have lower voice rights.
Design unit	The design unit is responsible for the selection of the parts manufacturer and determines the procurement plan for the parts. In many cases, it also serves as the supervisor.	The determination of the component supplier is generally determined by the project management unit, and the design unit serves as an aid
Supervisory unit	Construction supervision and design as two basic parts together constitute the basic business functions of Japanese architects, in fact the technical consultants and supervisors of the owners . In the supervision and design, it is necessary to obtain the "Architect", in which the first-class architects can engage in the design and supervision of various buildings, while the second-level architects currently function in the design and supervision of wooden structures.	Generally, it is an independent supervisor and needs to obtain the "supervisor engineer qualification certificate".
Construction unit	Mainly undertake the construction of basic engineering and on-site infrastructure, such as scaffolding, tower cranes, etc.	At present, most of the construction projects are not prefabricated, and the construction unit needs to undertake more work.

Household	There are obligations to regularly maintain and repair the house. And after the delivery of the house, DIY can be done on the interior decoration of the house according to the demand.	What is sold in China is the ownership of the house, and there is no obligation to carry out regular maintenance on the house. After the delivery of the house, the cost of internal renovation and renovation is high and it is difficult to change the structure.
Installation unit	In many cases, it is installed directly by the parts manufacturer. The installation unit is an important participant in the construction of the site.	Under normal circumstances, the construction unit and component suppliers share
Housing management company	Users hire professional management companies to carry out maintenance and repairs in the later stages of the house	There is no clear role for the time being.

4.2.4 Selection of main parameters of symbiotic unit in Japan's prefabricated construction industry chain

In order to study the benchmarking factors of the symbiotic system of the prefabricated construction industry chain in China and Japan, it is necessary to determine the main parameters of the symbiotic unit of the Japanese fabricated construction industry chain. Japan has entered the stage of quality integration and development, and green development and durability are the core development goals of the prefabricated construction industry chain. Green and sustainability are reflected in the production process and are reflected in the use process. Therefore, for the core symbiotic unit parts suppliers of the prefabricated construction industry chain, the carbon dioxide emissions from the production stage and recycling of the building materials and the geometric mean of the carbon dioxide emissions in the residential phase of the new detached houses are used as part suppliers. The main parameters. The design unit is an important part of the Japanese prefabricated construction industry chain, and even plays the role of supervision in many moments. Therefore, the design quantity of the building design performance certification is obtained as the main parameter of the design unit every year.

At the same time, Japan's prefabricated construction industry chain is currently concerned with the durability of housing and the suitability of residence. Long-term excellent housing is an important cornerstone of Japan's 200-year residential

development plan. Therefore, the use of new prefabricated residential buildings accounts for the proportion and long-term proportion of new residential buildings. Two new indicators for good residential certification are the main parameters of the entire ecosystem. The main parameters of the compositive unit of the Japanese fabricated construction industry chain are shown in Table 4.7.

Table 4.7 Main parameters of the symbiotic unit of the Japanese fabricated construction industry chain

Symbiotic unit	Reference dimension	Main parameter	Calculation formula
DeveloperC_1	Interest goal	Sales revenue of Prefabricated construction	Top 50 builders receive contract for housing construction * number of prefabricated houses / total number of new homes
Project management unitC_2	Interest goal	Total contracted construction industry total output value of prefabricated construction projects	Project management unit Total number of residential buildings * Number of prefabricated houses / total number of new homes
Component supplierC_3	Social goal	Reactive production and use of green development sustainability indicators	The amount of carbon dioxide reduced during the production phase and recycling, and the carbon dioxide emissions during the residential phase of the new detached house
Design unit C_4	Social goal	Design quantity for performance certification	Performance evaluation of building design by delivery number (household)
Construction unit C_5	Interest goal	Project contract revenue	The subdivision data of the construction unit is difficult to obtain, and the influence of the construction unit is incorporated into the general contractor.
Exploration unit C_6	Interest goal	Engineering survey income	Geological Survey Operating Income* Prefabricated Residential Buildings / Total New Residential Buildings
Material equipment supplier C_7	Interest goal	Material equipment sales	Material Equipment Supplier Operating Revenue* Prefabricated Residential Buildings / Total New Residential Buildings
Supervisory unit C_8	Interest goal	Construction project supervision's operating income on prefabricated construction projects	Construction Consultant Operating Income* Prefabricated Residential Buildings / Total New Residential Buildings
Prefabricated construction industry chain C_s	Market target Social goal	Proportion of prefabricated homes in new homes New number of long-term excellent residential certifications	New total number of fabricated houses / total number of new homes Newly delivered homes after long-term excellent residential certification

4.3 Data acquisition

4.3.1 Data source

Domestic data comes from public statistics, including the National Bureau of Statistics' China Statistical Yearbook 2008-2016, the Ministry of Housing and Urban-Rural Development Statistics Bulletin, and the Steel Structure Industry Report 2008-2016. At present, China has no complete information about it. The public statistics of newly-built prefabricated building area was obtained through telephone survey of the Science and Technology and Industrialization Development Center of the Ministry of Housing and Urban-Rural Development of China.

The Japanese data comes from the E-stat Japanese government statistics general window, which is equivalent to the National Bureau of Statistics. Part of the data comes from the report of the Construction-related Industry Activity Survey of Japan's Ministry of Land, Infrastructure, Transport and Tourism, the Japan Prefabricated Building Association's "Eco-Action 2020" 2011-2016 fiscal year survey report, and the Japan Residential Performance Evaluation Association - Long-term Excellent Residential Building Plan Technical review results, etc.

4.3.2 Basic processing of symbiotic unit data in China

The macro data collected in China is processed as follows.

(1) Processing for missing data

First of all, because the 2017 data is not complete enough, in order to ensure the integrity of the model, the data from 2008 to 2016 will be analyzed.

Secondly, the data of survey and design unit engineering survey income, design income and contracted income are missing in 2012. The data loss here is Missing At Random (MAR), and it has economic development, industry development and international situation. relationship. In order to eliminate the influence of single data missing on the overall result, the stratified mean interpolation method is used to interpolate, that is, the indicators of the two years before and after the missing year are taken as the mean reference, and the horizontal average is calculated for interpolation.

For China's newly-built assembled building area data, China began to carry out statistics from 2013. The data in 2012 and before are relatively vague. It is only known that the total installed building area in China in 2012 and before is about 30 million square meters. In order to understand the overall trend in the past 10 years, it is assumed that

China's newly built prefabricated building area will be 3 million square meters in 2008, with the same growth rate (35.2%) per year, and the total area of new prefabricated buildings in China during the five years from 2008 to 2012. It is 30 million square meters to get the annual data of new built-up buildings in China from 2008 to 2012.

(2) Removing macroeconomic development factors

Since the basic data contains income-related indicators and area indicators, and the income indicators will be affected by monetary economic inflation, the macroeconomic development factors are eliminated based on the 2008 consumer consumption index. The raw data is shown in Table 4.8, and the data is presented in Appendix A after the above assumptions.

Table 4.8Raw data of the basic situation of China's construction industry

Index	2016	2015	2014	2013	2012	2011	2010	2009	2008
Household Consumption Level Index (1978=100) [I]	1723	1870	206	2249	2443	2617	2835	3015	3217
Real estate development enterprise operating profit (100 million yuan) [I]	3432	4728	6111	5798	6001	9562	6143	6165	8673
Total contracted construction industry construction industry total output value [I]	54227	67965	85155	103764	122474	142434	176713	100396	105589 II
Construction steel structure industry output value (100 million yuan) [I]	2000	2500	2750	3190	3500	4100	4300	4650	4747
Survey and design unit engineering survey income (100 million yuan)[III]	337	409	530	653	2720	800	735	743	833
Engineering design revenue of survey and design units (100 millio n yuan) [I]	1399	1655	2151	2667	14757	4540	5398	3365	3610
Survey and design unit project contracting income (100 million yuan) [I]	3218	3883	5634	7886	38377	15476	9381	9498	10784
Building materials wholesale goods sales (100 million yuan) [I]	4430	4389	5965	8763	9980	11689	12755	11950	12713
Construction project supervision business income (100 million yuan) [I]	657	854	1196	1492	1717	2046	2221	247	2695

New prefabricated building area (10,000 m²) [I]	22.36	24.54	27.75	31.64	35.87	40.15	42.34	42.08	42.24
Proportion of new prefabricated buildings in construction houses [IV]	300	405.	548	742.	1003	1500	3500	7260	11400
Carbon emissions per unit of building energy consumption (Kg CO2/Kgce) [V]	2.28	2.34	2.34	2.34	2.41	2.36	2.25	2.2	2.18

Data resource:

I、 National Bureau of Statistics Annual Data of china

II、 《"Statistical Analysis of Construction Industry Development", Department of Planning, Finance and Foreign Affairs, Ministry of Housing and Urban-Rural Development

III、 "2008-2016 Steel Structure Industry Report", Shanghai Steel Structure Industry Association

IV、 Interview data of Science and Technology and Industrialization Development Center of the Ministry of Housing and Urban-Rural Development

V、 China Building Energy Research Report 2018, China Building Energy Conservation Association Energy Consumption Statistics Committee

Defined $Z_i, (i = 1,2 \dots 8)$ as the main parameters of the symbiotic unit of China's fabricated construction industry chain, according to the formula described in the previous chapter, using the data in Table 4.8 for calculation, the main parameters of the symbiotic unit of the fabricated building industry chain in China are shown in Table 4.9. Show.

Table 4.9 Main parameters of the symbiotic unit in China's prefabricated construction industry chain

Symbiotic unit	2008	2009	2010	2011	2012	2013	2014	2015	2016
Developer Z_1	4.61	7.2	10.09	10.42	11.84	23.52	30.87	60.79	125.38
Project management unit Z_2	72.76	103.52	140.6	186.41	241.64	350.29	887.98	989.9	1526.4
Component supplier Z_3	2.68	3.81	4.54	5.73	6.91	10.08	21.61	45.85	68.62
Design unit Z_4	0.45	0.62	0.88	1.17	1.34	1.97	3.69	7.33	12.05
Construction unit Z_5	1.88	2.52	3.55	4.79	7.28	11.17	27.13	33.18	52.19
Exploration unit Z_6	4.32	5.91	9.3	14.17	18.93	38.06	47.14	93.66	155.9
Material equipment supplier Z_7	5.94	6.69	9.85	15.74	19.69	28.75	64.1	117.83	183.79
Supervisory unit Z_8	0.88	1.3	1.97	2.68	3.39	5.03	11.16	24.4	38.97
Prefabricated construction industry chain Z_{s1}	0.13%	0.17%	0.20%	0.23%	0.28%	0.37%	0.83%	1.73%	2.70%

Prefabricated construction industry chain Z_{s2}	2.28	2.34	2.34	2.34	2.41	2.36	2.25	2.2	2.18

Remarks: Z_{s1} is the proportion of newly built buildings in the construction industry,while Z_{s2} is carbon emissions per unit of building energy consumption

4.3.3 Basic processing of symbiotic unit data in Japan

The macro data collected in Japan is processed as follows.

(1) Data year

Due to the rapid development of the Japanese fabricated construction industry chain in the 1950s and 1990s, it is difficult to obtain data for comparison. Therefore, only the recent data is selected to analyze the stability of the symbiotic system of Japan's current fabricated construction industry chain. . It has a forward-looking significance for the development of China's fabricated construction industry chain.

Japan's fabricated construction industry chain has developed more steadily in recent years, in order to best reflect the Japanese fabricated building symbiosis system in recent years, and to select the year that can get the most accurate data, that is, 2010-2016 to reflect the Japanese fabricated construction industry. The status quo of the chain symbiosis system.

(2) Removing macroeconomic development factors

Since the underlying data contains income-related indicators and area indicators, the income indicators will be affected by monetary economic inflation. The raw data is shown in Table 4.10, and the data is presented in Appendix A after the above assumptions.

Table 4.10 Basic data on the basic situation of the Japanese construction industry

Index	2010	2011	2012	2013	2014	2015	2016
The top 50 builders received the contract for the construction of the house (million yen)	99	103	102	99	99	99	99
Total residential building (100 million yuan)	7119461	9650994	9183044	8847002	7579098	7361676	7119461
CO2 emissions from the residential phase of a new detached house (Kg/per household per year)[II]	141603	156319	157896	162487	146209	143705	141603

Waste reduction and recycling during the production phase (Kg/M^3)[II]	2962	2832	2844	2862	2857	2846	2962
Architectural design business approximate expansion area [III]	19	18	18	19	19	20	19
Geological survey industry operating income (million yen)	58136	38867	32196	37609	33309	32662	58136
Material equipment supplier operating income (million yen)[IV]	59034	67049	71064	77806	69520	62073	59034
Consultant Operating Income (million yen)	576838	793285	848864	756285	658348	609160	576838
Total number of new prefabricated houses [V]	371435	477166	489644	522190	457961	422018	371435
Total number of new homes [V]	126671	143549	140501	146402	132244	126770	126671
Newly delivered homes after long-term excellent residential certification [VI]	813126	909299	892261	980025	882797	834117	813126
Performance evaluation of building design by delivery number (household)[VI]	100850	102587	98137	114682	102972	102032	100850

Data resource:

I、 E-stat Japan Statistics Bureau public data

II、 "Eco-Action 2020" 2011-2016 Fiscal Year Survey Report, Japan Prefabricated Building Association

III、 Construction-related industry dynamic survey, e-stat Japan Statistics Bureau public data

IV、 Japanese construction-related industry activity survey (112 construction companies including construction machinery and equipment leasing industry)
Japan Prefabricated Building Association public data

V、 Japan Housing Performance Evaluation Represents Association - Technical Review of Long-Term Good Residential Building Program

It is defined $U_m, (m = 1,2 \ldots 7)$ as the main parameter of the symbiotic unit m of the Japanese fabricated construction industry chain. According to the formula described in the previous chapter, using the data in Table 4.10 for calculation, the main parameter values of the symbiotic unit of the Japanese fabricated construction industry chain are shown in Table 4.11.

Table 4.11 Main parameters of the symbiotic unit in China's prefabricated construction industry chain

Main parameter	2010	2011	2012	2013	2014	2015	2016
Developer U_1	1121745	1132777	1151898	1329801	1412694	1485491	1486161
Project management unit	22311	22113	22221	24424	24290	24061	24706

U_2							
Component supplier (carbon dioxide emissions during the residential phase of a new detached house) U_{31}	2962	2846	2857	2862	2844	2832	2784
Component supplier (quantity of carbon dioxide reduced during production and recycling)U_{32}	19	20	19	19	18	18	15
Design unit (design performance evaluation by number of delivered households) U_4	193581	197748	202960	231636	196021	200236	226997
Exploration unitU_5	9301	9551	10566	11695	10932	10320	10811
Material equipment supplierU_6	90887	93734	100058	113678	130587	122103	116885
Supervisory unitU_7	58523	64938	69603	78491	75325	73446	77017
Prefabricated construction industry chainU_{S1}	100850	102032	102972	114682	98137	102587	107202
Prefabricated construction industry chainU_{S2}	0.39%	0.38%	0.22%	0.04%	0.81%	0.04%	0.43%

Remarks: U_{s1} represents the number of newly-built houses that have been certified for long-term excellent housing, while U_{s2} represents the proportion of prefabricated new homes

4.4 Chapter summary

In order to have a better understanding and understanding of the symbiotic system of the prefabricated construction industry chain, this chapter starts from the three elements of symbiosis theory, namely symbiotic unit, symbiotic relationship, symbiotic environment, combined with the characteristics of prefabricated buildings, and constructs the benchmarking of the prefabricated construction industry chain. Model (BPRS model), and determine the criteria for selection of benchmarking objects based on the two principles of advancement and comparability. Japan, which has the highest comprehensive score in the three aspects of the advanced nature of prefabricated buildings, the similarity of building types, and the similarity of structural types, is selected as the benchmarking country. In addition, data collection and pre-processing were carried out to prepare for the benchmarking study in Chapter 5.

CHAPTER 5 Empirical Analysis: Research on China-Japanese Prefabricated Construction Industry Chain Based on BPRS Model

5.1 symbiotic unit

5.1.1 Status of China's prefabricated building industry chain system symbiosis

According to formula 4.5, the characteristic symbiosis between the symbiotic units of China's fabricated building industry chain during 2013-2016 is calculated as shown in Table 5.1.

Table 5.1 China's prefabricated construction industry chain symbiosis system symbiosis coefficient (2013-2016)

Symbiotic Characteristic θ_{ij}^{m}	Developer Z_1	Project management unit Z_2	Component supplier Z_3	Design unit Z_4	Construction unit Z_5	Exploration unit Z_6	Material equipment supplier Z_7	Supervisory unit Z_8	Symbiotic coefficient θ_{ij}^{m}
Developer Z_1	-	1.26	1.03	1.12	1.21	1.15	1.08	0.96	2.02
Project management unit Z_2	0.79	-	0.82	0.89	0.96	-	0.86	0.76	1.60
Component supplier Z_3	0.97	1.22	-	1.08	1.17	-	-	-	1.95
Design unit Z_4	0.89	1.13	0.92	-	1.08	-	-	0.85	1.80
Construction unit Z_5	0.83	1.04	0.86	0.93	-	-	0.89	0.79	1.67
Exploration unit Z_6	0.87	-	-	-	-	-	-	-	1.76
Material equipment supplier Z_7	0.93	1.17	-	-	1.12	-	-	-	1.87
Supervisory unit Z_8	1.05	1.32	-	1.17	1.26	-	-	-	1.65

It can be seen from the calculation results that the characteristic symbiosis between all symbiotic units is greater than zero, which indicates that each pair of symbiotic units is mutually reciprocal symbiotic relationship, which also confirms the assembly type of China's prefabricated construction industry chain. The rationality of the construction industry chain.

At this stage, the developer ($\delta_{s1}^{m} = 2.02$)), component supplier design unit ($\delta_{s3}^{m} = 1.95$), material equipment supplier ($\delta_{s7}^{m} = 1.87$), design unit (($\delta_{s4}^{m} = 1.80$) has a greater degree of symbiosis to the system, indicating that these symbiotic units are developing vigorously during the (2013-2016) years. The development of the prefabricated construction industry chain has achieved remarkable results.

5.1.2 Analysis of the Co-occurrence Coefficient of China's Prefabricated Construction Industry Chain

The symbiotic coefficient can reflect the contribution of different symbiotic units within the symbiosis. Through calculation, the symbiotic coefficient of the symbiosis system of China's prefabricated building industry chain is shown in Table 5.2.

Table 5.2 China's prefabricated construction industry chain symbiosis system symbiosis coefficient (2013-2016)

Symbiotic coefficient θ_{ij}^{m}	**Developer Z_1**	**Project management unit Z_2**	**Component supplier Z_3**	**Design unit Z_4**	**Construction unit Z_5**	**Exploration unit Z_6**	**Material equipment supplier Z_7**	**Supervisory unit Z_8**
Developer Z_1	-	0.61	0.52	0.56	0.59	0.57	0.54	0.48
Project management unit Z_2	0.39	-	0.40	0.44	0.48	-	0.42	0.36
Component supplier Z_3	0.48	0.60	-	0.54	0.58	-	-	-
Design unit Z_4	0.44	0.56	0.36	-	0.54	-	-	0.42
Construction unit Z_5	0.41	0.52	0.36	0.36	-	-	0.44	0.39
Exploration unit Z_6	0.43	-	-	-	-	-	-	-

Material equipment supplier Z_7	0.46	0.86	-	-	0.56	-	-	-
Supervisory unit Z_8	0.52	0.86	-	0.58	0.61	-	-	-

According to the symbiotic coefficient of China's prefabricated construction industry chain from 2013 to 2016, the following conclusions can be obtained.

(1) From the perspective of symbiosis coefficient, the contribution of developers to the symbiotic system of the prefabricated building industry chain is basically greater than that of other symbiotic units, especially the project management unit and construction unit ($\theta_{12}^{m} = 0.61,\ \theta_{15}^{m} = 0.59$). This is because at this stage, the developer decides whether to adopt the prefabricated building construction method and the most joint nodes of the prefabrication rate, which directly affects the area of the new building in the prefabricated building. In addition, the developer's financial strength and R&D strength are generally higher than other symbiotic units in general, and as an important pioneer in the industry, it has a leading role.

(2) In addition to the developers, the contribution of component suppliers to the symbiosis system is also significant ($\theta_{32}^{m} = 0.60,\ \theta_{34}^{m} = 0.54,\ \theta_{35}^{m} = 0.58$), which is also consistent with the development status of China's fabricated buildings. Since the country vigorously promotes assembly-type construction, component suppliers are important entities jointly developed and implemented by governments and developers at all levels. As an important part of the field of construction production, the development of the assembly-type construction industry chain must be Has a significant effect. The symbiotic relationship data shows that the implementation of the construction of suppliers in China has achieved results in recent years;

(3) The degree of contribution of the design unit to the symbiosis system is also large ($\theta_{42}^{m} = 0.56,\ \theta_{45}^{m} = 0.54$). The design unit is also an important unit to promote the development of the assembly-type construction industry chain. The pre-design of the design unit greatly affects the efficiency and effect of the assembly-type construction industry chain. However, at present, China's design units are greatly influenced by developers, and their independent opinions are low, and they are still in a state of unequal symbiotic relationship ($\theta_{41}^{m} = 0.44$). At the same time, when designing the component procurement plan, the design unit is affected by many factors such as the

number of components, the standard degree, and the production cycle. Therefore, the component supplier is highly towed, so that the design unit is relative to the component supplier, the ecosystem. Low contribution ($\theta_{43}^{m} = 0.36$);

(4) The contribution of the construction unit to the symbiotic system is relatively low. This is because at this stage, there are still a lot of practical problems in the field assembly of fabricated buildings. The biggest problem is the cost problem. In the case of non-scale formation, the cost of using the prefabricated building in construction units is much higher than that of traditional buildings. Taking concrete as an example, compared with cast-in-place concrete, the use of precast concrete is increasing per square meter. The cost of 200-400 yuan, which is the direct cause of the lower contribution of construction units to the assembly-type construction industry chain. Other reasons include the lack of pre-construction simulation, which caused the on-site components to be unable to match the installation; the layout of the site layout was unreasonable, resulting in a large number of secondary handling phenomena; problems with component size, resulting in delays in construction. In addition, at present, China's contract system for the assembly-type construction industry chain is still not perfect. It is often not defined in the contract that the above-mentioned situation is distributed in the actual situation. The construction unit, as a direct participant, is easily directly harmed by the interests. At the same time, most of the construction units in China still stay in the stage of traditional building construction, and do not have the theoretical system and practical basis for the construction of prefabricated buildings, which affects their contribution to the symbiotic system.

5.1.3 Benchmarking Analysis of symbiotic coefficient of China-Japan prefabricated building industry chain system

Compared with Japan's fabricated construction industry chain symbiosis system, there are still gaps in China. It is necessary to make a horizontal and vertical comparison of each symbiotic coefficient. This paper selects the three most important assembly-type construction industry chain symbiosis units of developers, development units and component suppliers. A comparative analysis was conducted to draw the following conclusions.

(1) Developer

Table 5.3 Co-relationship coefficient between developers and other units in the China-Japan prefabricated construction industry chain

Developerθ_{ij}^{m}	Project management unit	Component supplier	Design unit	Construction unit	Exploration unit	Material equipment supplier	Supervisory unit
2008-2012	0.40	0.53	0.45	0.33	0.28	0.38	0.33
2013-2016	0.61	0.52	0.56	0.59	0.57	0.54	0.48
Japan	0.86	0.80	0.74	-	0.81	0.89	0.71

The comparison of the contribution of developers in the symbiotic energy of the symbiotic system of the assembled-type construction industry chain in China and Japan and the dynamics of China are shown in Table 5.3. It can be seen that in China, in addition to the symbiotic relationship coefficient with respect to component suppliers, in general, the contribution of developers in the assembly-type construction industry chain has increased significantly in recent years. This reflects the effectiveness of the policy and the shift in the attitude of the market environment in China. However, at present, there is still a big gap between the degree of contribution of Chinese developers to the symbiotic system (0.6) and Japan (0.86). This is because there are a large number of symbiotic and integrated symbiosis in the compositive system of the fabricated building industry chain in Japan. The large construction group and the housing group have a complete industrial chain production strength and have a strong influence on the market. In addition, in Japan, government housing institutions account for a large proportion of the market, such as the Communist Youth League, the commune, the public camp, etc. are the first government organizations to start research and development and build assembly buildings, they can quickly respond to government policies, and occupy a larger Market share. The degree of contribution from developers has, to a certain extent, reflected the position of developers in the prefabricated construction industry chain. Developers with greater voices can have a greater driving effect on the development of the industry, and can also promote market reform and development more efficiently.

(2) Component supplier

Table 5.4 Co-relationship coefficient between component suppliers and other units in China-Japan prefabricated construction industry chain

Component supplier θ_{ij}^{m}	Developer	Project management unit	Design unit	Construction unit
China 2008-2012	0.47	0.37	0.42	0.31

China 2013-2016	0.48	0.60	0.54	0.58
Japan	0.20	0.60	0.41	-

As shown in Table 5.4, since 2013, the contribution of component suppliers to the symbiotic energy of the symbiotic system of the fabricated building industry chain in China has increased significantly, especially for project management units, design units and construction units. Since 2013, China's component factories have greatly improved both in quantity and quality, and the symbiotic relationship coefficient has assisted the effectiveness and necessity of this measure. Compared with Japan, the coefficient of symbiosis of the component suppliers in China is relatively large, indicating that the component suppliers have a containment effect on the design units. It is also necessary to promote and standardize the standardization system of the fabricated building components in China as soon as possible.

(3) Design unit

Table 5.5 Symbiotic relationship coefficient between design units and other units in the China-Japan prefabricated construction industry chain

Design unit θ_{ij}^{m}	Developer	Project management unit	Component supplier	Construction unit	Supervisory unit	Material equipment supplier
China 2008-2012	0.55	0.45	0.36	0.38	0.38	-
China 2013-2016	0.44	0.56	0.36	0.54	0.42	-
Japan	0.26	0.68	0.59		0.46	0.73

As shown in Table 5.5, the contribution of China's design units to the symbiotic system of the prefabricated building industry chain has increased, especially for project management units, construction units and supervision units. It means that China's prefabricated buildings have gradually completed the design-to-construction penetration. The design has two-way voice right to the project management unit and construction unit in the preliminary planning and construction stage, which has a positive effect on the efficiency of the assembled building. The coefficient of symbiotic relationship between Japanese design units and project management units is 0.68, which is higher than the current level in China. In addition, the influence of China's design units on component suppliers is far less than that of Japan. The interaction between component suppliers and design units should be formed. It is not just the supply

relationship between component suppliers and standard component product catalogs. At the same time, the design unit should also propose reasonable component requirements to the component suppliers according to the actual situation, and mass production after inspection. Therefore, the stickiness between China's design units and component suppliers is still insufficient. At the same time, we should also pay attention to the role of material equipment suppliers in the assembly-type construction industry chain, and standardize the standardization system of component installation and equipment transportation while formulating the component standardization system.

5.2 Symbiotic mode

The symbiotic relationship refers to the mutual relationship between the symbiotic units, including bidding, bidding, management, coordination, trading, and other relationships. In the market competition, it is mainly driven by interests. With the support of some policies, the influence of status-driven and relationship-driven is not excluded. The symbiotic relationship is divided into two dimensions, one is the symbiotic way, that is, parasitic, reciprocal symbiosis, deviation from symbiosis, etc., which has been demonstrated in the fourth chapter. The symbiosis system of the prefabricated building industry chain in China is a reciprocal symbiotic relationship with the rationality and development prospects of existence. The other is the symbiotic model, which is determined by the viscosity and cooperation frequency between the symbiotic units. The four symbiotic models will then be compared and analyzed.

5.2.1 Point symbiosis mode

Table 5.6 Comparison of point symbiotic modes between China and Japan's prefabricated building industry

Country	Japan	China
Time of appearance	1950s-1960s	1950s - 1970s
Point Symbiotic mode	apan began to implement prefabricated buildings in the 1950s. In the early stage of development, the government and the public group carried out research and development of parts, and proposed the KL part system of "standard parts for public housing" to standardize and modularize parts. However, due to the early development, and the material and size are limited, the flexibility is not high, so the repurchase rate is low. And the entire residential industrialization industrial chain is also in the initial stage of development, the information is not completely symmetrical, the cooperation can not be continuous, in a typical point of symbiosis	In 1956, the State Council of China first proposed the "Decision on Strengthening and Developing the Construction Industry" . In 1978, the National Infrastructure Construction Committee proposed the industrialization of buildings with the focus on "three transformations and one reform", namely, building design standardization and component production plants. Chemicalization, construction mechanization and wall reform. Later, it gradually proposed the "Building Industrialization Development Outline" (1995), "Green Building Action Plan" (2003) and other documents to promote the development of industrialization of buildings, but in 2016 the State Council issued "on the development of prefabricated buildings. Before the Guiding Opinion China only proposed the goal of building industrialization in terms of policy, but it was not enough to guide and implement. The process of China's fabricated construction industry chain was slow. In the past 60 years, the mode of symbiosis between the symbiotic units in the fabricated building industry chain in China is very common.

The comparison of point symbiosis patterns in the symbiotic system of the China-Japan prefabricated building industry chain is described in Table 5.6. It can be seen that Japan experienced a stage of symbiotic mode in the 1950s and 1960s. However, in China, a mid-point symbiosis model of the prefabricated construction industry chain was very common ten years ago, which also confirmed China's assembly. The construction industry chain has developed slowly in the twentieth century.

5.2.2 Intermittent symbiosis

Table 5.7 Comparison of Intermittent symbiotic modes between China and Japan's prefabricated building industry

Country	Japan	China
Time of appearance	1970s-1990s	Since the 21st century
Intermittent symbiosis	After the 1970s, Japan's parts development entered an era of integration. The "good part identification mechanism", BL (Better Living), was launched. The parts of private enterprises can be certified for performance, and the market's recognition of assembly houses is enhanced. The energy of the symbiotic system is rapidly accumulating, and the symbiotic interface has also expanded from the government level to the civilian level, and intermittent symbiosis has begun to increase.	Since the 21st century, the development of China's building industrialization has accelerated, and the density and dimensions of the fabricated building industry chain have gradually increased. Enterprises have improved their understanding of the practice of prefabricated buildings, and the symbiosis has gradually shifted to indirect symbiosis. However, there are also developmental differences. For example, Yuanda's workers focus on the development of prefabricated buildings, and the development of certain comprehensive types of enterprises that are faster than the main business. This may lead to technical or conceptual disagreements, resulting in discontinuous symbiotic relationships.

The comparison of intermittent symbiosis patterns in the symbiotic system of the China-Japan prefabricated building industry chain is described in Table 5.7. The indirect symbiosis model of the prefabricated construction industry chain in China is generally after the 21st century, but Japan appeared in the 70s and 90s of the last century. With the implementation of the excellent parts identification mechanism, Japan began to slowly move toward high-quality goals on the basis of the guaranteed amount. At present, China is still working hard in this direction.

5.2.3 Continuous symbiosis

Table 5.8 Comparison of Continuous symbiotic modes between China and Japan's prefabricated building industry

Country	Japan	China
Time of appearance	1970s-1990s	Since the 21st century
Continuous symbiosis	After the 1990s, both the Japanese component market and the development of the residential industrial chain began to enter a stable development period. The participants in the market competition also possessed their own product features and reputation, which increased the proportion of	Continuous symbiosis has also emerged in China, such as the construction unit Shanghai 20 Yeye and Yuanda Residence based on long-term cooperation in Changsha large industrial park and airport projects.

continuous symbiosis.

The comparison of continuous symbiosis patterns in the symbiotic system of the China-Japan prefabricated building industry chain is illustrated in Table 5.8. Continuous symbiosis is currently very common in Japan's fabricated construction industry chain, and due to its long development years, many companies have established a good reputation and reputation, and it is easier to achieve a close relationship of continuous symbiosis. In China, continuous symbiosis has also emerged, mainly in large enterprises with R&D and long-term development strength.

5.2.4

Table 5.9 #Comparison of Intermittent symbiotic modes between China and Japan's prefabricated building industry

Country	Japan	China
Time of appearance	1970s-1990s	Since the 21st century
Integrated symbiosis model	At present, the Japanese construction industry has already focused on the construction and renovation of energy-efficient assembly buildings. Large-scale housing suppliers, such as Yamato House, Sekisui, Mizusawa, large-scale builders such as Dacheng Construction, Maeda Construction, etc. They all have their own independent research and development system, component production plant, design department and design department, which can cover most of the roles in the assembly building industry chain. Take Mizutake as an example. In 1962, the group was established. In 1965, a prefabricated parts factory was opened. In 1967, Sanze House was established. In 2001, the total number of prefabricated houses was 1.22 million. Sanze's current research focuses on the transformation of housing durability and aging housing.	At present, there are also enterprises with such strengths in China, such as Yuanda Labor, Vanke, etc. Among them, Yuanda's migrant workers focus on prefabricated buildings and are in the leading position in China's fabricated construction industry chain. But in general, the integrated symbiosis of China's fabricated construction industry chain is not as common as Japanese residential industrialization.

Integrated symbiosis is the best model in the symbiotic model, which means that the symbiotic units have common interests and future development goals. Not only the strategic cooperation between the symbiotic units, but also the phenomenon of mutual acquisition and merger between the symbiotic units, so that different symbiotic units exist in one enterprise, which is more conducive to the overall management. In theory, the emergence of such a super-large company makes the symbiotic interface more effective, and is conducive to the target development of the symbiotic system and the cohesion of symbiotic energy.

The integrated symbiosis model in the symbiotic system of the China-Japan prefabricated building industry chain is shown in Table 5.9. In the prefabricated building industry chain, the symbiotic units that can achieve the integrated symbiosis model are often large-scale housing suppliers and developers. Construction units, etc., are the same in China and Japan. At present, the emergence of China's integrated symbiosis model is still less than that of Japan. However, from the scale and quantity of large-scale developers and construction units in China, the model of integrated symbiosis will become more and more common in the future.

5.3 Symbiotic environment

A symbiotic environment refers to the environment in which a symbiotic system is located. The prefabricated construction industry chain is essentially a construction industry, but the construction industry is closely related to the real estate industry and indirectly linked to the national economic situation. The external environment of the prefabricated construction industry chain includes the economic environment, policy environment, and technological environment.

5.3.1 Economic environment

China's rapid economic development period has a huge gap with Japan. From Figure 5.1, we can see that the Japanese economy has been in a state of rapid development from the 1950s to the end of the 20th century. This is also the rapid development of the Japanese fabricated construction industry chain. In its period, its symbiotic system experienced an advance in point symbiosis-indirect symbiosis-continuous symbiosis (explained in detail in Section 5.2)

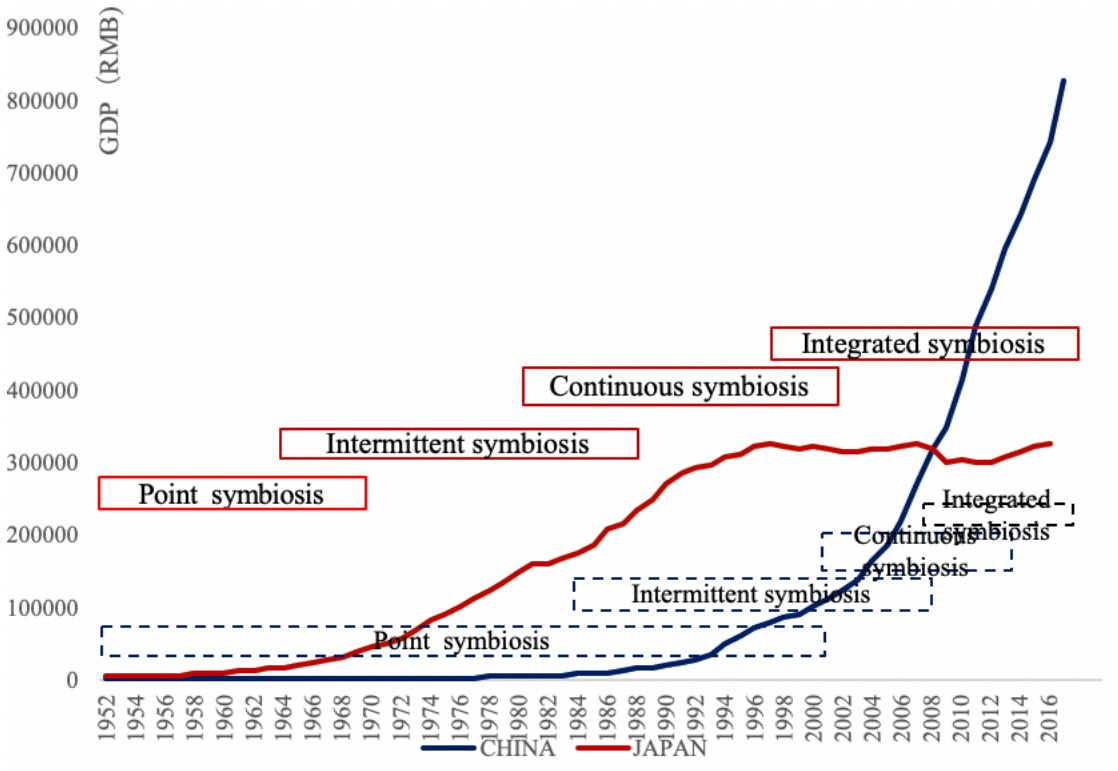

Figure 5.1 China and Japan's 1950-2016 GDP development trend and the corresponding assemblage model of the prefabricated construction industry chain

China's rapid economic growth since the 1990s is still in a period of rapid economic development. Judging from Japan's experience, China's current sound economic development environment and economic accumulation are conducive to the rapid development of China's fabricated construction industry chain.

5.3.2 Policy and social environment

From the research background of the first chapter, we can see that although China proposed to promote the industrialization of buildings in the 1950s, it has not been until the last decade that there has been a real substantive policy progress. There are two reasons for this. First of all, China's current demand for reform of construction methods is not urgent enough. The reason for the development of prefabricated buildings in Japan is that the prefabricated buildings have the characteristics of high production efficiency, low labor demand, and low cost under the premise of scale effect. They are very suitable for solving the problem of housing shortage in Japan after World War II. And after World War II, Japan has the economic strength to develop prefabricated buildings. Under the dual effects of demand and capacity, prefabricated buildings have

flourished in Japan. However, in the early days of the founding of New China, the demand for more other events and articles was higher than that of houses. At that time, the whole country faced many problems such as poverty, shortage of resources, and scarce personnel, which was not conducive to the development of prefabricated buildings. Until 2013, China has introduced a large number of policies to support fabricated buildings, and assembled buildings have once again entered the public eye.

Secondly, China's national cultural development level is not as good as that of Japan. Most businessmen or people are more interested in short-term interests. The sense of social recognition of prefabricated buildings is difficult to improve and cannot stimulate market demand. Therefore, in addition to the vigorous promotion of policies, the Chinese government and related enterprises should also popularize the concept and characteristics of prefabricated buildings to the public, and educate the people to achieve the purpose of expanding market demand. By policy as a “pushing hand”, market demand as a “handle” promotes the development of fabricated buildings in China.

5.3.3 Technology Environment

The building has various structures, including wood structure, brick structure, brick-concrete structure, steel structure, reinforced concrete structure, etc. Therefore, it is necessary to construct a standardized component system with complete structure and various types to meet various architectural requirements. At the same time, there is a need for a highly versatile standard system in the industry. Japan has already had a high degree of ministry, and the rate of miniaturization of general buildings has reached 60%. At the same time, the symbiotic interface of the prefabricated construction industry chain also has high technical requirements, which requires the entire chain to be highly informative, able to fully communicate information, and simulate the construction and installation process in advance during the design phase. Preventing problems that may arise at the scene is one of the important reasons why the use of fabricated buildings is currently blocked in practice in China. Japan achieved the full informationization of public construction projects by 2010, and achieved automatic management of prefabricated buildings, greatly optimized the industrial chain and reduced work errors. In the mid-term construction phase, the prefabricated building has high requirements for on-site construction equipment, and it also poses new challenges to the level of project management. For the hoisting and installation of on-site components and parts,

the degree of mechanization in Japan is extremely high, and engineering robots have appeared in the first-level construction site of parts manufacturing. The all-weather fully automated building construction system ABCS (Automated Building Construction System) has been widely used in the project, greatly reducing the safety and turnover rate during construction and improving construction efficiency. For the project management unit of the prefabricated construction industry chain, it is first necessary to solve the transportation problem of large components, strictly manage the arrival time of the components, ensure the order of the on-site stacking, and reduce the secondary transportation. Second, it is necessary to flexibly coordinate the problems that may arise when components are installed on site. For on-site construction personnel, it is necessary to fully understand the installation method of the components and improve the installation efficiency of the components. In Japan, the 4M solution for safe construction, Management, Man, Medium, and Machine, is implemented, and four core points are captured to ensure efficient project management and safe construction.
In the past ten years, China has been vigorously promoting the independent research and development of fabricated building related products and systems, and has already possessed certain scientific research and development strength. At present, companies have independently developed systematic assembly components. For example, Yuanda’s workers have already realized the marketization of the whole bathroom and have achieved good economic benefits. However, compared with Japan, there are still problems such as high degree of informatization, low degree of mechanization of construction and manufacturing, and inadequate management and improvement of management methods.

5.4 Enlightenment to the development of symbiotic system in China's prefabricated construction industry chain

Based on the BPRS model, a systematic analysis of the fabricated construction industry chain between China and Japan was carried out from three aspects: symbiotic unit, symbiotic mode and symbiotic environment. It has the following enlightenment on the development direction of China's future assembly-type construction industry chain.

5.4.1 Enhance the category and quality of symbiotic units in the prefabricated construction industry chain in China

Based on the analysis of the symbiotic coefficient of the symbiotic unit and the symbiotic coefficient between the symbiotic units, the following suggestions are proposed.

(1) Enrich the symbiotic unit category of the prefabricated construction industry chain. From the perspective of industrial chain structure, China's fabricated construction industry chain covers less symbiotic units than Japan, and fewer or less symbiotic units have component recycling units, professional distribution logistics systems, and professional repair management companies. The addition of more symbiotic units is conducive to the improvement of the industrial chain structure, and also positively promotes the accumulation of symbiotic energy, and further promotes the accumulation of sound volume in the assembled building society.

(2) China's prefabricated construction industry chain should establish a supporting professional logistics distribution system to ensure the timeliness and safety of transportation, weaken the negative impact of regional factors on the development of prefabricated buildings, and reduce the barriers to entry for prefabricated buildings.

(3) Deepen the position of developers in the industry chain. Encourage large-scale developers to independently develop the assembly-type construction industry chain, improve the volume of developers in the assembly-type construction industry chain, and lead the rich and the rich, and drive the development of other small and medium-sized enterprises in the prefabricated building. Improve the proportion of the integrated symbiosis model in China's prefabricated construction industry chain, and promote the structural optimization of the prefabricated construction industry chain;

(4) Enhance the participation of design units in the construction industry chain. Pay attention to the role and power of the design unit in the construction industry chain, cut the participation point of the design unit before the design of the project, beware of the phenomenon of “assembly type” and “assembly type”, reduce rework, improve one-time efficiency, and improve the design unit. The utility of the prefabricated construction industry chain.

5.4.2 Standardizing the symbiotic relationship of the prefabricated construction industry chain

At present, most enterprises in China are in the stage of coexistence of traditional construction and prefabricated construction. The relationship between the assembly-type construction industry chain and the traditional construction industry chain participants is quite different, and it must be satisfied in different situations. Different work requirements, the following points should be noted for the management of the prefabricated construction industry chain.

(1) Defining the role of the component supplier, the component supplier is not only the "supplier" role, but also the installation unit, the design participation unit, and the leader of the entire system technology frontier.

(2) Improve the stickiness between the design unit and the component supplier, and incorporate the design unit into the design and production system of the standard component to improve the integrity of the industrial chain;

(3) Improve the autonomy of the design unit, reduce the stickiness between the developer and the design unit, and weaken the developer's restrictions on the design unit.

(4) Coordinating the relationship between the installation unit and the construction unit, clarifying the division of responsibilities, reducing the problem of responsibilities and frictions that may occur during the project management process, and fulfilling the responsibilities.

5.4.3 Building a sustainable assemblage environment for the prefabricated construction industry chain

(1) Economic environment

At present, China's macroeconomic development is conducive to the development of prefabricated buildings, and the government and various provinces and cities have many economic subsidy policies for prefabricated buildings, which strongly encourages China's fabricated construction market. But in addition, investment in pre-development should be increased. For the prefabricated building, the most important thing is to build a perfect standardized modular system. The government should encourage developers and research institutes with research and development capabilities to develop a modular component solution suitable for China's national conditions. This can also promote the

degree of marketization of fabricated building components and reduce the development burden of the government in the later period.

(2) Policy environment

Although China has issued standards for some fabricated buildings and fabricated components since 2016, it is still far from enough. The standard planning system of the entire prefabricated building should cover the standard system covering the entire chain system, such as product standards, management standards, risk allocation standards, rights and contract standards, and supporting facilities standards. Therefore, China needs to formulate strategic long-term goals and short-term development goals with clear focus and direction; formulate, issue and implement a complete standardization system for China's components as soon as possible; and standardize the construction industry chain as soon as possible about assembly-type buildings in various professions (such as installation, civil engineering) , HVAC, etc. and the industry standards of various symbiotic units (design units, construction units, supervision units, etc.) in the construction industry; standardize the system of distribution of powers and responsibilities in the assembly-type construction industry chain as soon as possible, and establish a contract standard system suitable for national conditions and market conditions. As soon as possible, construct and standardize the standardization system for component transportation and installation equipment supporting the component system; construct a green energy-saving residential performance certification system, rate existing buildings and new buildings, and guide the social and market public opinion trends for green buildings and fabricated buildings.

(3) Technology environment

First, improve the degree of building information. Although building informatization has been implemented in China for many years, the utilization rate in actual operation is not high. Realizing the informationization of the entire chain, we can minimize the problems that may exist in the on-site construction, and make the assembled buildings fully promoted.

Secondly, research and development of automated building construction systems, linking artificial intelligence to buildings, reducing the artificial needs of future fabricated buildings, reducing manual errors and improving construction efficiency. This will be a major direction for long-term development.

Finally, build a full-chain assembly building knowledge system. From the perspective of supply and demand, the popularity of prefabricated buildings is closely related to

consumers' acceptance and demand for fabricated buildings. According to the research in this paper, the market acceptance of prefabricated buildings has been improved, but there is still much room for improvement. Secondly, the popularity of prefabricated buildings involves many industries. The construction of a full-chain assembly-type industrialization knowledge system is conducive to the rapid implementation of prefabricated buildings. At the same time, due to the industrial chain effect, it can generate economies of scale and save knowledge. The cost of implementation. For example, the theoretical system of the prefabricated building construction method in the construction phase is constructed, thereby improving the knowledge reserve and practice reserve of the construction unit on the prefabricated building, and accelerating the transformation from the traditional building to the prefabricated building.

5.5 Chapter summary

This chapter is to find out the development status of China's fabricated construction industry, and the reasons for the gaps and gaps between China's and Japan's fabricated construction industry chain. Using macro data and BPRS model, from the three aspects of symbiotic unit, symbiotic mode and symbiotic environment A systematic analysis of the prefabricated construction industry chain in China and Japan. Finally, based on the analysis results, the future development implications are proposed from three aspects: symbiotic unit, symbiotic relationship and symbiotic environment.

CHAPTER 6 Conclusions and Prospects

6.1 Conclusions

In conclusion, based on the symbiosis theory, this paper uses literature research, qualitative and quantitative analysis, and benchmarking management methods to conduct an in-depth analysis of the symbiotic system of China's fabricated construction industry chain. Looking back at the full text, the main conclusions of this paper are as follows.

(1) The symbiotic properties of the prefabricated construction industry chain are compatible with the natural symbiosis system, satisfying the four principles of symbiotic system formation, and can be studied and elaborated using symbiotic theory, with the applicability and innovation of the theoretical framework.

(2) From the perspective of the advanced nature of prefabricated buildings, the similarity of building types, and the similarity of structural types, Japan is the most suitable country in China for the benchmarking of the fabricated building industry chain in China.

(3) Utilizing the macroscopic data of China-Japan prefabricated buildings, based on the symbiosis theory, the symbiosis system of the prefabricated building industry chain is qualitatively and quantitatively compared, and the development status of China's prefabricated building industry chain is obtained.

From the perspective of symbiotic units, developers, component suppliers, and design units have a greater role in the development of the prefabricated construction industry chain from 2013 to 2016 compared to other symbiotic units in the industry chain. Compared with 2009-2012, the symbiotic coefficients of these three types of symbiotic units have improved, which indicates that the implementation of assembly in China has achieved initial success in recent years.

From the point of view of symbiosis, the symbiosis of the symbiosis system of the prefabricated construction industry chain in China is greater than 0, indicating that the symbiotic units between the industrial chains have formed a mutually beneficial symbiotic relationship, which indicates that the assemblage of the prefabricated construction industry chain in China In the system, each symbiotic unit can coexist harmoniously with other participants, which is also the basis for the formation and development of the industrial chain. From the perspective of symbiosis mode, China's

prefabricated construction industry chain symbiosis system model is more intermittent symbiosis and continuous symbiosis, and after six decades of development, Japan has entered a stage of continuous symbiosis and integration symbiosis. Judging from the experience of Japan, there is still a long way to go in the future of fabricated buildings in China.

In terms of the symbiotic environment, China's current economic development situation is beneficial to the development of the assembly-type construction industry chain, and the policy environment is also conducive to the development of the assembly-type industrial chain, but the public has a low level of understanding of the prefabricated building, and the social environment accepts the assembly-type building. Not high, it is difficult to pull the development of fabricated buildings from the perspective of market demand. Secondly, compared with Japan, the technological environment of China's prefabricated buildings is far from systematic. In addition to focusing on the development of architecture, it should also be more closely integrated with other industries, such as artificial intelligence, information technology, etc., to develop more modular buildings with scientific and technological value.

(4) Based on the above research results, three inspirations for the development of China's fabricated construction industry chain are proposed.

First, upgrade the categorization unit quality and quality of the prefabricated building industry chain. At present, China's fabricated construction industry chain is still not perfect, and there are symbiotic units such as component recycling units and professional repair management companies that are missing or less involved. In terms of long-term development, these symbiotic units are indispensable in the industrial chain. Part of it should be filled as soon as possible. From the perspective of the quality of the symbiotic unit, a professional logistics distribution system for the assembled building components should be established to deepen the position of the developer in the industrial chain and enhance the participation of the design unit in the construction industry chain.

Secondly, the relationship between the symbiotic units of the prefabricated construction industry chain should be standardized as soon as possible. Clear component supplier role, component supplier is not only the "supplier" role, but also the installation unit, is the design participation unit, is the leader of the entire system technology front; improve the adhesion between design units and component suppliers Incorporate the design unit

into the design and production system of standard components; improve the autonomy of the design unit, reduce the adhesion between the developer and the design unit; coordinate the relationship between the installation unit and the construction unit, and clarify the division of responsibilities; Reduce problems that may arise during project management.

Finally, build a sustainable symbiotic environment for the prefabricated building industry chain. In terms of economy, we will increase investment in research and development of prefabricated building-related products, encourage developers and research institutes with research and development capabilities to develop fabricated components and solutions suitable for China's national conditions, and promote the degree of marketization of fabricated building components and reduce The government's development burden in the later period; policy, as soon as possible to develop a standard system covering product chain, management standards, risk allocation standards, rights and responsibilities contract standards, supporting facilities standards covering the entire chain; scientific and technological environment, improve the degree of building information, research and development automation Building construction system, building a complete chain of prefabricated building knowledge system, accelerate the transformation from traditional construction methods to assembly construction.

6.2 Insufficient research and prospects

This study has the following shortcomings. First of all, there is no mature method for selecting the main parameters in the current symbiosis theory. The selection of the main parameters of the symbiotic unit still has some subjectivity. Secondly, although the statistics of the two countries are relatively complete, there is still a small amount of empirical data missing. The situation can only be filled by the lack of means. At the same time, the assembled building data of many symbiotic units are not separately separated and statistically counted. They can only be estimated by a certain ratio, and there is a certain error. Thirdly, in the analysis of symbiotic relationship, the main selection of developers, design units, Component suppliers and other symbiotic units that are more important to the prefabricated construction industry chain are compared and analyzed, and the focus on other symbiotic units in the industrial chain is insufficient.

This paper proposes the development path of China's future development of the prefabricated construction industry chain by comparing the assembled construction industry chain between China and Japan. The most important one is the establishment of the standard norms of the entire industry chain. Due to the limited length of the article, there is no further clarification on the specific content of the establishment of various standards in the industry chain. If you want to conduct further research, you can proceed further from this entry point. Exploring how to distribute can make the symbiotic relationship of the entire industrial chain symbiosis system healthier and have greater development potential.

Secondly, Japan's fabricated construction industry chain has entered a new stage, and housing durability and green sustainability are more important factors to consider. China's fabricated buildings are growing faster than Japan, and may enter this stage in the next decade. It is possible to conduct economic and policy analysis in this direction in advance.

REFERENCE

1. Perspectives G, Economics O. Global Construction 2025.(2013).A global forecast for the construction industry to 2025[J]. Global Construction Perspectives and Oxford Economics.

2.Sbci U.(2009). Buildings and climate change: Summary for decision-makers[J]. United Nations Environmental Programme, Sustainable Buildings and Climate Initiative, Paris: 1-62.

3.Porter, & Michael E. (1985). Technology and competitive advantage. Journal of Business Strategy, 5(3), 60-78.

4.Kleindl B. (2004).Value Chain Analysis[M]// The Internet Encyclopedia.

5.Tam, V. W. Y., C.M. Tam, S.X. Zeng, & William C.Y. Ng. (2007). Towards adoption of prefabrication in construction. Building & Environment,42(10), 3642-3654.

6.Miller G T. (2000). Living in the environment: principles, connections, and solutions[M].

7.Bermudes, D. (1987). Symbiosis. an introduction to biological associations: vernon ahmadjian and surindar paracer university press of new england, hanover, n.h. 1986, 212 p. (us$32.50). Biosystems, 20(3), 305-305.

8.None. (1994). A.e. douglas symbiotic interactions. vii, 148p. oxford university press, 1994. price £ 12.50. Journal of the Marine Biological Association of the United Kingdom, 74(03), 743.

9.R Renner, G. T. (1931). Economic adjustments in liberia. Economic Geography, 7(2), 189-201.

10.Barnes H. (1992). Fertile project exploits recycled wastes. Financial Times Oct. 8

11.Velenturf, & Anne, P. M. . (2016). Promoting industrial symbiosis: empirical observations of low-carbon innovations in the humber region, uk. Journal of Cleaner Production, 128(Complete), 116-130.

12.Chohaney, M. L., Yeager, C. D., Gatrell, J. D., & Nemeth, D. J. (2016). Poverty, Sustainability, & Metal Recycling: Geovisualizing the Case of Scrapping as a Sustainable Urban Industry in Detroit. Urban Sustainability: Policy and Praxis.

13.Shingo, S. 1988. Non-Stock Production. Productivity Press, Cambridge.

14. Kundu K, Staudacher A.(2015). Lean Thinking and E-Commerce as New Opportunities to Improve Partnership in Supply Chain of Construction Industries[J]. World Academy of Science, Engineering and Technology, International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering, 9(11): 3703-3713.

15. Burgess, & Rachel. (1998). Avoiding supply chain management failure: lessons from business process re-engineering. International Journal of Logistics Management, 9(1), 15-23.

16. Ruben Vrijhoef, L. K. (1999). The four roles of supply chain management in construction. European Journal of Purchasing & Supply Management,6(3), 169-178.

17. Eriksson, P. E. (2010). Improving construction supply chain collaboration and performance: a lean construction pilot project. Supply Chain Management, 15(5), 394-403.

18.Cheng, J. C. P., Kincho H. Law, Hans Bjornsson, Albert Jones, & Ram D. Sriram. (2010). Modeling and monitoring of construction supply chains. Advanced Engineering Informatics, 24(4), 435-455.

19.Behera, P., Mohanty, R. P., & Prakash, A. (2015). Understanding construction supply chain management. Production Planning & Control,26(16), 1332-1350.

20, Xue, X., Xiaodong Li, Qiping Shen, & Yaowu Wang. (2005). An agent-based framework for supply chain coordination in construction. Automation in Construction, 14(3), 413-430.

21.Min J, Bjornsson H.(2008).Agent-Based Construction Supply Chain Simulator (CS2) for Measuring the Value of Real-Time Information Sharing in Construction[J]. Journal of Management in Engineering, 24(4):245-254.

22.Shin, T. H., Sangyoon Chin, Su-Won Yoon, & Soon-Wook Kwon. (2011). A service-oriented integrated information framework for rfid/wsn-based intelligent construction supply chain management. Pipeline Technique & Equipment, 20(6), 706-715.

23.Kim, Y. W. , Han, S. H. , Yi, J. S. , & Chang, S. W. . (2016). Supply chain cost model for prefabricated building material based on time-driven activity-based costing. Canadian Journal of Civil Engineering, cjce-2015-0010.

24.Irizarry, J., Karan, Ebrahim P., & Jalaei, Farzad. (2013). Integrating bim and gis to improve the visual monitoring of construction supply chain management. Automation in Construction, 31(5), 241-254.

Appendix A Raw data

Table A.1 Basic situation data of China's construction industry after processing

index	2016	2015	2014	2013	2012	2011	2010	2009	2008
Real estate development enterprise operating profit (100 million yuan)	4646	3523	3734	6295	4233	4442	5102	4356	3432
Total contracted construction industry construction industry total output value	56555	57374	107409	93766	86377	79489	71096	62616	54227
Construction steel structure industry output value (100 million yuan)	2543	2657	2614	2699	2468	2444	2296	2303	2000
Survey and design unit engineering survey income (100 million yuan)	447	425	447	527	480	501	443	377	337
Engineering design revenue of survey and design units (100 million yuan)	1934	1923	3281	2989	2602	2043	1796	1525	1400
Survey and design unit project contracting income (100 million yuan)	5776	5428	5702	10188	6767	6041	4704	3578	3218
Building materials wholesale goods sales (100 million yuan)	6809	6829	7753	7695	7039	6713	4981	4044	4431
Construction project supervision business income (100 million yuan)	1444	1414	1350	1347	1211	1143	999	787	657
New prefabricated building area (10,000 m^2)	11400	7260	3500	1500	1004	742	549	406	300
Proportion of new prefabricated buildings in construction houses	2.70%	1.73%	0.83%	0.37%	0.28%	0.23%	0.20%	0.17%	0.13%
Carbon emissions per unit of building energy consumption (Kg CO2/Kgce)	2.18	2.20	2.25	2.36	2.41	2.34	2.34	2.34	2.28

Appendix A

Table A.2 Basic information on the Japanese construction industry after processing

index	2016	2015	2014	2013	2012	2011	2010
The top 50 builders received the contract for the construction of the house (million yen)	9678105	9409719	8971411	8901782	7689512	7453410	7200700
Total residential building (100 million yuan)	160887	152411	154257	163493	148339	145496	143218
CO2 emissions from the residential phase of a new detached house (Kg/per household per year)	2784	2832	2844	2862	2857	2846	2962
Waste reduction and recycling during the production phase (Kg/M^3)	15.1	17.8	18.0	18.5	19.4	19.9	19.3
Architectural design business approximate expansion area	32543	38867	32196	37609	33309	32662	58136
Geological survey industry operating income (million yen)	70404	65373	69426	78288	70533	62846	59708
Material equipment supplier operating income (million yen)	761172	773453	829301	760968	667939	616751	583420
Consultant Operating Income (million yen	501544	465237	478360	525423	464633	427277	375673
Total number of new prefabricated houses	148528	143549	140501	146402	132244	126770	126671
Total number of new homes	967237	909299	892261	980025	882797	834117	813126
Newly delivered homes after long-term excellent residential certification	107202	102587	98137	114682	102972	102032	100850
Performance evaluation of building design by delivery number (household)	226997	200236	196021	231636	202960	197748	193581
Proportion of Prefabricated building	15.36%	15.79%	15.75%	14.94%	14.98%	15.20%	15.58%

Appendix B China Japan's prefabricated construction industry chain symbiotic coefficient

表 B.1 Co-occurrence coefficient of symbiotic system in china prefabricated building industry chain（2013-2016）

Symbiotic coefficient θ_{ij}^{m}	Developer Z_1	Project management unit Z_2	Component supplier Z_3	Design unit Z_4	Construction unit Z_5	Exploration unit Z_6	Material equipment supplier Z_7	Supervisory unit Z_8
Developer Z_1	-	0.40	0.53	0.45	0.33	0.28	0.38	0.33
Project management unit Z_2	0.60	-	0.63	0.55	0.43	-	0.48	0.43
Component supplier Z_3	0.47	0.37	-	0.42	0.31	-	-	-
Design unit Z_4	0.55	0.45	0.36	-	0.38	-	-	0.38
Construction unit Z_5	0.67	0.57	0.36	0.36	-	-	0.56	0.50
Exploration unit Z_6	0.72	-	-	-	-	-	-	-
Material equipment supplier Z_7	0.62	0.86	-	-	0.44	-	-	-
Supervisory unit Z_8	0.67	0.86	-	0.62	0.50	-	-	-

Appendix B

Table B.2 Co-occurrence coefficient between symbiotic units in China's prefabricated building industry chain (2009-2013)

Symbiotic coefficient θ_{ij}^{m}	Developer Z_1	Project management unit Z_2	Component supplier Z_3	Design unit Z_4	Construction unit Z_5	Exploration unit Z_6	Material equipment supplier Z_7	Supervisory unit Z_8
Developer Z_1	-	0.40	0.53	0.45	0.33	0.28	0.38	0.33
Project management unit Z_2	0.60	-	0.63	0.55	0.43	-	0.48	0.43
Component supplier Z_3	0.47	0.37	-	0.42	0.31	-	-	-
Design unit Z_4	0.55	0.45	0.36	-	0.38	-	-	0.38
Construction unit Z_5	0.67	0.57	0.36	0.36	-	-	0.56	0.50
Exploration unit Z_6	0.72	-	-	-	-	-	-	-
Material equipment supplier Z_7	0.62	0.86	-	-	0.44	-	-	-
Supervisory unit Z_8	0.67	0.86	-	0.62	0.50	-	-	-

表B.2 日本装配式建筑产业链共生单元间的共生系数（2010-2016）

Symbiotic coefficient θ_{ij}^{m}	Developer U_1	Project management unit U_2	Component supplier U_3	Design unit U_4	Exploration unit U_6	Material equipment supplier U_7	Supervisory unit U_8
Developer U_1	–	0.86	0.80	0.74	0.81	0.89	0.71
Project management unit U_2	0.14	–	0.40	0.32	–	0.56	0.29
Component supplier U_3	0.20	0.60	–	0.41	–	0.65	–
Design unit U_4	0.26	0.68	0.59	–	–	0.73	0.46
Exploration unit U_6	0.19	–	–	–	–	–	–
Material equipment supplier U_7	0.11	0.44	0.35	0.27	–	–	–
Supervisory unit U_8	0.29	0.71	–	0.54	–	–	–