Dissertation

学 位 論 文

THE PLANNING STRATEGIES FOR ACHIEVING SUSTAINABLE URBAN FORM BASED ON SPACE PRODUCTION THEORY

空間生産理論に基づく持続可能な都市形態を実現するための計画戦略に関する研究

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ABSTRACT

In view of the close relationship between urban form and sustainable urban development, choosing a scientific form to realize sustainable urban development has become one of the hot issues that the urban planning academic community pays attention to, and it is of great significance to the current urban space expansion. This article summarizes the measures and methods that Japan has made in the construction of sustainable urban forms. Based on the summary of development experience, it pays attention to the simultaneous sustainable development measures of Japanese urban construction in urban ecology, society, and economy. Based on the theory of space production, an ideal development model for sustainable urban forms is proposed, which makes useful explorations for the construction of sustainable urban forms in the future.

This PhD research is based on the theory of space production from Henri Lefebvre. Lefebvre believes that capitalist urban space planning and capital logic are interactive: urban space planning is always permeated with capital logic, and capital logic also restricts urban space planning. The urban space planning process is driven by capital logic, which embodies the rational entanglement of centrality and dynamic instrumentality. The technological rationality in urban space planning has created a technologically abstract urban space living state for human beings. This urban space living state is a dynamic, visualized, centralized, and consumerized living form. Many new spatial phenomena have occurred in the human thinking mode and practice based on this capitalized urban space survival form. In order to eliminate this kind of capitalization caused by urban space planning, it is necessary to advocate urban space reform and development.

The first research mainly focuses on urban ecological construction. With the rise of the concept of sustainable development, natural environmental protection has gradually become an important issue in urban construction. Water Sensitive Urban Design (WSUD) is an important sustainable development theory in the urban water environment, which has attracted more and more attention worldwide. At the same time,

as an island country, Japan attaches great importance to water resources and water environment and has achieved fruitful results in urban water resources management. Based on the WSUD framework, this research introduces Japan's practical experience from the perspectives of water source protection, flood control and waterfront space landscape, aiming to summarize Japan's experience and provide a new perspective. By explaining the water-sensitive design ideas contained in Japanese practice, this study expands the scope of WSUD, provides a meaningful research framework for Japanese researchers, and provides convincing information for water-sensitive design researchers around the world Case.

The second study mainly discusses Japan's attempts to build a sustainable urban form at the socio-economic level. In the context of developing high-efficiency production activities based on the global division of labour, the Japanese government has been exploring new possibilities for port construction to avoid direct competition with nearby Asian ports, while building an infrastructure network that serves the entire country to improve domestic industry Productivity. With the support of international trade logistics, Japan's raw material imports and production have expanded the supply chain of production in the domestic market. With the policies promulgated by the Japanese government, domestic production technology and existing production resources have begun to participate in the industrial chain connected to the port. At the same time, it promoted industrial development and the construction of port areas. This research focuses on the construction of port areas in Japan's land planning. Combining its development history and experience, it provides references for economic development and spatial planning guided by sustainable urban forms.

The third research focuses on urban population and social environment. In this research, from a macro perspective, we studied the impact of urban development planning on population changes in central urban areas. Regional development plans have different aggregation modes and different development structures for different functional areas. This difference was evaluated as a different development model. Kanazawa was used as a case study area, and the corresponding development plan was

determined by different development models. Set up three development modes of "concentrated central urban area development mode ", "decentralized central urban area development mode ", and "maintenance-oriented central urban area development mode ". Using genetic algorithms, under the guidance of three different development modes, calculation and analysis are performed. The population recovery, the degree of the land-use mix, and the degree of land-use specialization in the central urban area are three indicators. On this basis, a land-use planning support system has been developed.

Japan's urbanization development process has gone through several typical stages, and its urbanization development is mainly supported by the evolution of the industrial structure and the government's institutional selection. Among them, agriculture is the basis of urbanization, manufacturing and tertiary industries are the main driving forces of urbanization, and the government's reasonable policy choices are important external conditions for urbanization. From the perspective of spatial production theory, this article discusses the impact of urban development and capital structure changes on urban spatial production at different scales from the five levels of natural resources, industry, and society, focusing on the process of typical cases, assessing production efficiency and analyze its endogenous mechanism.

Keywords. Urban spaces, Sustainable Urban form, space production, Spatial planning

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CHAPTER 1. INTRODUCTION

1.1. Research Background

Urban life has become the symbol and cornerstone of our modern civilization. According to the United Nations, 55.3% of the world population lived in urban areas by 2018, and the ratio will further increase to 68.4% by 2050 (*UN World Urbanization Prospects* 2018). Such urbanization creates enormous social, environmental, cultural, and economic challenges like slum dwellers, insufficient infrastructure, increased pollution, and unplanned urban expansion, leading to reflections on the sustainability of modern urban form.

As Henri Lefebvre pointed out, "(urban) space is a (social) product," which means the urban space cannot be separated from its production process (Henri Lefebvre, 2014). David Harvey (1987, 1989, 2012) further indicated that the continuous urbanization that we have experienced originated from the development of capitalism and subordinate to the pursuit of surplus-value. Therefore, the urban space and urban form are determined by the capital logic, bringing problems like pollution, inequality, and unsustainability. An urban form that can create more inclusive, safe, resilient and sustainable cities is urgently needed.

The United Nations General Assembly (UNGA) has set up the Sustainable Development Goals (SDGs) in 2016, the 11th of which is "Sustainable cities and communities" for the more sustainable and resilient urban settlement (Lee et al., 2016). The concept of sustainable cities has motivated many scholars and urban planners to seek the sustainable urban form and the corresponding planning strategies (Jabareen, 2006; K. Williams, Burton, & Jenks, 2000). The compact city concept focus on high residential density with mixed land uses and efficient public transportation (Burton, 2000a; Jenks, 2019) ; while the movement of new urbanism emphasis returning to the traditional neighborhood form with walkable block and accessible public open space (Ellis, 2002; Katz, 1994). These concepts and strategies aim to achieve sustainable development by reducing fossil fuels, managing pollution, and protecting the natural environment.

However, a sustainable urban form is more than physical characteristics like natural resources, population density, and transportation, but involves the social-economic characteristics in the planning, construction, operation, and management process. Since an urban form is from its corresponding production process, revealing the production process is essential in understanding and achieving the sustainable urban form. Moreover, the meaningful logical mapping between Lefebvre's space production theory and the idea of sustainable urbanism lead to the discussion on sustainable urban form from Lefebvre's theory (Wiedmann & Salama, 2019).

Therefore, proposing the planning strategies to achieve sustainable urban form is an important research topic, closely related to its production process under the space production theory. Analyzing the production process and exploring the corresponding planning strategies is fundamental to the sustainable urban form, and Japan can provide valuable experience and reference as a country that experienced rapid urbanization and subsequent orientation shift to sustainable urban form.

1.2. Research Purpose and Contribution

Achieving a sustainable urban form is an essential area of contemporary urban development, which requires an in-depth understanding of urban space production and targeted planning strategies. Therefore, this Ph.D. dissertation aims to propose planning strategies for sustainable urban form based on the analysis of the space production process. This research can contribute to sustainable urban form from sustainable strategies in the elements of urban space production. According to the research aims, the following several objectives to be achieved:

1. Analyze the production process of modern urban form based on the space production theory, and examine the elements of urban form production and the operating logic.

2. Propose sustainable planning strategies for the material element in space production to promote the sustainable use of space resources through water resources management in Japan.

3. Propose sustainable planning strategies for the production elements in space production to promote the sustainable output of space products through the port area construction in Japan.

4. Propose sustainable planning strategies for the consumption elements in space production to encourage the sustainable organization of urban residents through a planning support system based on GA algorithm.

1.3. Literature Review

1.3.1. The Space Production Theory and the Capital Logic

The space production theory started from Lefebvre. In the famous *The Production of Space* (Henri Lefebvre, 2014), Lefebvre indicated that social space is the reproduction of social relations, and the production of urban space is the production of urban social relations. Space is not a production carrier but an object of production, a product of various ideologies. From the perspective of the urban development process, traditional space production is limited by the characteristics of the natural environment where the city is located. At the same time, the difference in the social structure becomes the source of unbalanced development in the differentiated modern space production. Space production has realized the transformation from “production of things in space” to “space itself” (Gottdiener, 1993).

Based on Lefebvre’s theory, David Harvey took these insights as the starting points for further formulation. Since the publication of *Social Justice and The City* (Harvey, 2010), Harvey has incorporated Lefebvre’s ideas and conceptions in his reflection on urban space, the capitalist production of space, and the theory of uneven geographical development. More recently, perceiving that the idea of the right to the city has experienced a resurgence over the last decade, Harvey resumed his reflections on

Lefebvre in the book *Rebel Cities* (Harvey, 2012), thereby updating the debate on the right to the city and the urban revolution.

The Production of Space is a landmark work in Lefebvre's thought process (Henri Lefebvre, 2014). He pointed out that the so-called capital logic is that production or living activities are carried out under the capital rules and are carried out in the capital form. The capital logic in urban space planning is that urban planning activities are subject to capital rules and are carried out following capital methods, making urban space planning more central, visual, and consumerized, showing the intervention and manipulation of technological rationality on daily living spaces. Examining the capital logic of urban space planning is to overcome the problems of urban space planning and restore the right of urban space.

These ideas of urban space and its capital logic inspired in discussion on urban development and capital. The subordination of the city to capitalist development and its incessant need for the production of surplus capital implies a process of constant urban growth based on destruction and reconstruction of cities and the profound social, environmental and political effects associated with this dynamic. For this reason, capital appropriates urban spaces to ensure the conditions necessary for the production-reproduction of capitalist relations (Elden, 2007).

Regarding space as a product under the dominance of capital opens up discussions about the production process. Urban space production is necessary for capital proliferation and creates a space structure and space system suitable for capital operation. Due to capital intervention, urban space production shows uneven development worldwide, exacerbating the gap between rich and poor among countries(Eyles, 1987; Harvey, 1987). At the same time, to resolve problems of overaccumulation, capital is spatialized through fixing investments, embedding in the land, and creating an entirely new landscape, which shows as the attempt to fix the space through construction and reconstruction (Harvey, 2001). In this process, the metropolis takes the central role in the capital operation and becomes the central scene of the crisis transition of the times, represented by the post-modern metropolis Los

Angeles. A capitalist political ideology is formed in such a background, which opened up post-modern urban criticism about the "third space" which criticized the destructive effect of technological rationality on urban planning (Soja & Chouinard, 1999).

Correspondingly, as another element of reproduction, space is also regarded as the object of consumption. Spanish scholar Manuel Castells (Mollenkopf, 1979) summed up the category of collective consumption and pointed out that urban space production allowed workers' consumption to evolve into collective consumption in the form of the state. British scholars Drake Gregory and Mike Dier used Lefebvre's dialectics of social space to interpret the consumption phenomenon of post-modern urban space. (Gregory & Urry, 1988) Such consumption phenomenon can be reflected in the relationship between consumption space and commercial brands in urban life. Commercial brands promote the construction of consumption space power, and consumption space power restricts the formation of commercial brands (H. Lefebvre, 2003). And the alienation of consumption results in the homogeneity and fragmentation of urban space with a highly repetitive spatial form (车玉玲, 2010)

1.3.2. The Planning Strategies base on Spatial Production

As the concept of sustainable development gradually arouses more interest, how the theoretical framework of space production serves sustainable development has become a research topic that attracts attention. Scholars analyze the different types of space to find the key elements that can promote the city's sustainable growth.

One of the concepts is the "social spaces." The core point is that the development of urban social space is conducive to restoring the traditional living space, improving space quality, and thus high-quality and sustainable development (Gottdiener, 2010). Urban renewal and urban collective consumption are the main topics. Urban renewal mainly focuses on enhancing the vitality of the old urban areas, while urban collective consumption emphasis urban public space, including landscape parks, community squares, open blocks, and other civic spaces. These strategies are conducive to increasing the city's social participation and the probability of public space occupation, which is in line with Lefebvre's thinking of "urban rights." (Harvey, 2017) It is believed that the production of social space based on these strategies will eliminate spatial inequality and injustice and bring about sustainable urban development.

The "differential spaces" lead to another characteristic development strategy. Lefebvre proposed that cities are over-identical due to the single capital-driving space production. Therefore, differential space should promote the diversification and diversity of space production on contradictory space. According to Kroll (Milgrom, 2008), the urban spaces must adapt to the changing needs of residents, which accentuate the differences present in local contexts' particularities. Therefore, differences from the physical environment in colors, roads, and buildings to the residents' needs for medical care, education, and safety will highlight the geographical and cultural differences, break the power hierarchy of space production, and bring about high-quality urban spaces with differences (Andres, 2013).

Meanwhile, some scholars turn to the "symbolic spaces" for urban development. The symbolic space offers a significant shift from physical space planning to the geography and anthropology empirical contexts of space production (Aase, 1994). The symbolic space strategy symbolizes the specific economic, political, or cultural space, like shaping prominent landmarks, linguistic tropes in strategic planning, and remarkable public manifestations and events to form an experiential economy for development. (Dembski & Salet, 2010). Such strategies would raise awareness of the city's symbolic existence and achieve real change through consecutive policies. These are rather soft strategies that appeal to the human mind, which directed attention to a city with little in common with the visible landscape (Dembski, 2012).

1.3.3. The Sustainable Urban Form from the Perspective of Space Production

Cities worldwide have been striving to achieve sustainable urban forms to cope with their rapid urban growth. Different factors have been affecting the modern urban form. These factors include urban activities, freshwater sources, and it is affected by the development of the industries.

Sustainable development is inseparable from urban development. In the "Our Common Future" published by the World Commission on Environment and Development in 1987, sustainable development was formally proposed for the first time and defined as "development that not only satisfies the needs of contemporary people but does not endanger the ability of future generations to meet their needs" (Brundtland, Khalid, Agnelli, Al-Athel, & Chidzero, 1987) The rapid urbanization on a global scale makes sustainable development face severe challenges, and the form of sustainable cities has become the focus of attention of the natural sciences and social sciences. Studies have estimated that urban expansion in 2030 will reduce the global cultivated land area by 1.8% to 2.4% and that a quarter of the global cultivated land loss will occur in China (d'Amour et al., 2017). Urban development patterns and species evolution will also influence each other. The natural environment and urban social issues are intertwined and become the key to global sustainable development (Alberti et al., 2017).

The process of urbanization is not only the main cause of the global sustainable development challenge but also a potential solution (Brelsford, Lobo, Hand, & Bettencourt, 2017; Seto, Golden, Alberti, & Turner, 2017). Sustainable cities were first proposed at the second UN Habitat Conference in 1996, and a large number of international conferences and projects have since emerged. (Holden, Roseland, Ferguson, & Perl, 2008) The United Nations put forward 17 sustainable development goals in the "2030 Agenda for Sustainable Development", of which the 11th goal is to "build inclusive, safe, disaster-resistant and sustainable cities and human settlements." (Lee et al., 2016). In 2019, the first meeting of UN-Habitat proposed to achieve "support for inclusive, safe, resilient and sustainable cities and human settlements" and "strengthen urban-rural linkages to achieve sustainable urbanization". (Caragliu, Del Bo, & Nijkamp, 2013)

Unsustainable urban structures have long been seen as a cause of environmental issues (Curwell, Deakin, Vreeker, & Symes, 2005; Jabareen, 2006). They have a significant impact on forests, wildlife, endangered species, water quality, forest degradation, automobile use, open spaces, traffic, noise, global warming, and the replacement of natural cover with impervious surfaces, among other things. (Jabareen, 2006; Newton, 2000; K. Williams et al., 2000). As a result, a community pursuing sustainable development goals (SDGs) must pursue a sustainable urban form. Such a city adheres to the principle of sustainable growth, which is described as development that meets both current and future needs (Lu, Nakicenovic, Visbeck, & Stevance, 2015; Steiner, 2012).

There have been several proposals for sustainable urban forms. The compact city, the eco-city, neo-traditional construction, and urban containment are examples of these (Jabareen, 2006). In this research, the compact city and eco-city were chosen as a basis for achieving a sustainable urban-type within the study region, urban areas of Japan. The eco-city was also used as a base concept in this research since the compact city's long-term viability is still being debated. Compactness, compatibility, dependence, and suitability were selected as the four factors for determining the city's sustainability score while optimizing urban land use based on the compact and eco-city models (Burton, 2000b). These parameters are identical to those used in a previous report on LU allocation. While it is impossible to replace an actual city type with a newly optimized design, certain practices dealing with urban planning and land-use patterns, such as those in the current report, may be applied to create a sustainable urban type.(Jenks, 2000; Lauf, Haase, & Kleinschmit, 2016 ; Tannier, Bourgeois, Houot, & Foltête, 2016)

1.4. Dissertation Organization

The main body of this Ph.D. dissertation is divided into four chapters (**Figure 1.1**). The first component analyzes the elements in the space production process, which clarify the three critical elements of material, production, and consumption. Next, the second component takes water management in Japan as an example to discuss the implementation of water-sensitive urban design for materials of space production. Then the third component examines the regional industrial chain of international trade ports in Japan and discusses the product organization in space production. Finally, the fourth component proposes an urban planning support system based on the genetic algorithm in response to the urban decentralization trend in the consumption of space production.

DISSERTATION	PURPOSE	METHOD	CONTRIBUTION
Chapter 2 The Innovative Framework of Sustainable Urban Form supported by the Space Production Theory	Propose new framework of **sustainable urban form** based on the space production theory.	☐ Theoretic analysis	Establish a new framework for achieving sustainable urban form.
Chapter 3 The Measures of Water-Sensitive Urban Design in the Context of Japan's Sustainable Ecological Environment Construction	Discuss sustainable urban forms from **environmental construction** of **natural space.**	☐ Case study	Summarize the planning strategies for sustainable urban form regarding to water-sensitive urban design.
Chapter 4 The Impact of the Development of International Trade Port in Japan on the Formation and Evolution of Regional Industrial Chain Response to the Requirement of Sustainable Industrial Development	Study the **economic development** in **urban space** by discuss the evolution of industrial development in port cities.	☐ Case studies of fifteen port cities	Summarize the planning strategies for sustainable city form regarding to industrial chain development in port cities.
Chapter 5 The Construction of Urban Planning Supporting System using Genetic Algorithm Responding to Urban Decentralization from the Perspective of Population Change	Study the population change in **social space** under development programs responding to urban decentralization.	☐ Genetic algorithm ☐ Land attractiveness model	Develop planning support system & Explore population changes under development programs for sustainable urban form.

Figure 1.1 The framework of this Ph.D. dissertation

1.4.1. Space Production in the Practice of Japan – Motivation, Policies, Strategy, Mode and Enlightenment

This chapter deeply analyzes how space is produced in urbanization in Japan. The production of commodities involves several essential elements such as raw materials, production, distribution, exchange, consumption, and production relations, and these can also find appropriate correspondence in the production of space. Based on this analytical framework, a sustainable urban form needs to respond from all elements of space production, including adjusting urban density and population in exchange and distribution and optimizing energy use in production. Therefore, the specific planning strategy for sustainable urban form can be analyzed from the elements of spatial production following this analytical framework.

1.4.2. The Measures of Water-Sensitive Urban Design in the Context of Japan's Sustainable Ecological Environment Construction

Following the framework of Chapter 2, this chapter examines raw materials in space production. This chapter introduces relevant Japanese practices in the three main aspects of water source protection, flood control, and waterfront landscape. In general, Japan adheres to the WSUD principles and combines natural conditions, engineering technologies, and cultural traditions into the practices, forming WSUD with distinctive Japanese characteristics. Specifically, Japan emphasized forest conservation in terms of water source protection and adjusts the water environment at the urban scale through water supply facilities and water demand; adopted comprehensive flood control measures and created a series of valuable engineering measures; achieved a more natural landscape by creating nature-oriented rivers with regional material and various sections and guided the design of waterfront space through regulations.

This chapter was presented and published at the IOP Conference Series: Earth and Environmental Science, Xishuangbanna, China, titled *The Construction of Water-Sensitive Urban Design in the Context of Japan*.

1.4.3. The Impact of the Development of International Trade Port in Japan on the Formation and Evolution of Regional Industrial Chain response to the Requirement of Sustainable Industrial Development

Following the framework of Chapter 2, this chapter examines production in space production. This chapter takes the construction of Japanese ports and port cities to clarify the development path and organization model of Japanese trade ports. Lots of sustainable planning strategies can be learned from the development of the port cities in Japan. The construction of the port area should be based on developing the regional economy, integrating the existing development foundation, establishing a complete industrial chain, forming a unified operation as a whole, and improving production efficiency. Another important lesson is to focus on the formation of scale economies effect and industrial clusters, strengthen regional cooperation, strengthen regional advantages, establish a refined division of labor based on the industrial chain, organize production resources with innovative models, and form regional production complexes to improve regional competitiveness as a whole.

This chapter was published as a book chapter in S. Sintusingha (Ed.), *International Perspectives on the Belt and Road Initiative*. England: Taylor & Francis, with the title as *Competition and Precedence for BRI Ports: The International Trade Port's Formation and Evolution of Regional Industrial Chain in Japan*.

1.4.4. The Construction of Urban Planning Supporting System using Genetic Algorithm responding to Urban Decentralization from the Perspective of Population Change

Following the framework of Chapter 2, this chapter examines consumption in space production. This chapter studied urban development planning on population changes in central urban areas from a macro perspective. Kanazawa was used as a case study area and set up three development modes. Each development program is defined as a chromosome in the GA system, and an optimal development program is generated through the algorithm. The corresponding population change and land use structure are obtained through the spatial interaction model based on the obtained development program. Under the guidance of three different development modes, calculation and analysis are performed using genetic algorithms. On this basis, a land-use planning support system has been developed. The results reveal the possible migration of Kanazawa City under three different development modes.

This chapter was published as a journal paper in the *Journal of Urban Planning and Development* 146(4). doi:10.1061/(asce)up.1943-5444.0000631, titled *Construction of Urban Planning Supporting System Using Genetic Algorithm Responding to Urban Decentralization*: *Case of Kanazawa City*.

CHAPTER 2. SPACE PRODUCTION IN THE PRACTICE OF JAPAN – MOTIVATION, POLICIES, STRATEGY, MODE AND ENLIGHTENMENT

2.1. Introduction

Japan is one of the first countries in Asia to implement the National Comprehensive Development Plan (NCDP, Japanese: 全国総合開発計画). The NCDP was put forward and implemented in the context of the rapid economic growth since the 1950s with the emergence of "over-density" and "over-sparseness" of national land use. The content of NCDP mainly includes 1) managing natural resources such as land and water; 2.) preventing disasters like floods and wind disasters; 3) adjusting the scale and configuration of urban and rural areas; 4) configuring industries, transportation and communication facilities. Since the enactment of the National Land Comprehensive Development Law (Japanese: 国土総合開発法) in 1950, Japan has conducted six NCDP. For more than 60 years, the content of Japan's NCDPs has been adjusted with changes in national economic and social development, shifting from emphasizing economic development to emphasizing the quality of life of the people. It has played an essential role in optimizing spatial structure, narrowing regional gaps, controlling environmental pollution, and boosting economic vitality.

The ultimate goal of NCDP is to improve social welfare and comprehensively utilize, develop and protect national land from the perspectives of economy, society, and culture (陆书至, 1992). The existing researches have introductions to a single NCDP and comparative summaries of previous NCDPs. Comprehensive Policy Study Group (1963) introduced the background and base development model of the first NCDP (Japanese: 全国総合開発計画). Fukushi (1968) analyzed the background of the second NCDP (Japanese: 新全国総合開発計画), pointed out that the large-scale development project is the key to this plan, and explained the concept of the central axis of the Japanese archipelago. Zhao (1980) introduced the content of the third NCDP (Japanese: 第三次全国総合開発計画) and recognized that how to control large cities, build small and medium-sized cities, and promote the rational layout of industries is the main focus. Suzuki (1988) introduced the main content of the fourth NCDP (Japanese: 第四次全国総合開発計画) and pointed out that the plan proposed an "exchange network concept" based on the settlement circle, aiming to preserve the regional characteristics and promote mutual exchange between regions, further realizing the overall coordination and connection of the country. Mabuchi (2000) introduced the contents and characteristics of the fifth NCDP (Japanese: 21 世紀の国土のグランドデザイン) and pointed out that it is to form a multi-axial land structure by constructing four new national land development axes to realize the balanced development of the country. With the reformation of the land planning system, the sixth NCDP (Japanese: 国土形成計画) elaborated the five goals and the eight areas of policy directions(国土交通省国土政策局広域地方政策課, 2016).

In addition to introducing each comprehensive land development plan, some studies summarize and evaluate the previous plans. Nakamura (1989) evaluated the first four NCDPs and believed that these plans violated land plans' social improvement and comprehensiveness, concentrated on metropolitan and surrounding areas following market principles, and failed to optimize land space and effectively handle the environmental issues. Kiyotaka (1999) combed and summarized the first five NCDPs and believed that NCDPs successfully narrowed the regional gap and alleviated the "over-sparse and over-density" land space.

From the perspective of space production theory, the NCDP serves as the leading top-down planning guide in Japan, which can effectively reflect the changes in the space production process and reveal key elements in Japanese space practice. Therefore, this research starts with the NCDP in Japan, discusses the change process of the main ideas and the capital logic behind it, and then reveals the specific elements of Japanese space production.

2.2. Method

In 60 years, NCDPs have undergone constant adjustments and changes from goals to methods. This study started with the NCDP in Japan and divided it into three stages for discussion based on its socio-economic background and changes in the major planning strategies. The three stages are:

- Large-scale reconstruction and development after World War II (The first and second NCDP s, 1945-1976)
- Multi-polar decentralized land and exchange network (The third and fourth NCDP s, 1977-1997)
- Resident participation and independent regional development (The fifth and sixth NCDP s, 1998-2020)

According to the space production theory, the development of urban space will go through different stages with the continuous accumulation and spatialization of capital, (Harvey, 1978, 1987), which is determined by the inherent contradictions of capital. Therefore, such a division method refers to the development process and main characteristics of NCDPs on the one hand, and it also fits the evolution process of the capital logic behind NCDPs on the other hand.

This reseach would like to reveal how capital dominates the urbanization process at each stage and then shift to the next stage through the summary and comparison of different stages.

2.3. Results

2.3.1. Large-scale reconstruction and development after World War II

After World War II, Japan was faced with rapid economic recovery, increased grain production, industrial revitalization, and environmental governance. Therefore, in 1950, Japan formulated and promulgated the first basic law on land development: National Land Comprehensive Development Law (Japanese: 国土総合開発法), which is the first time to propose national land development plans at all levels. However, after World

War II, the main task of the Japanese government was to solve the need for the resettlement of veterans and restore industrial production, which postponed the balanced development of the country. In addition, there are many top-level design issues, including a vague relationship between national land planning and economic planning, the opposition between the economic authorities and the land development authorities, the divergent understanding of national land planning as a strategic plan, and the lack of a financial system that guarantees the implementation of land planning. Therefore, the National Land Comprehensive Development Law has not promoted and guided Japan's land planning work right since its enactment.

Until 1962, the first NCDP was formulated under the National Land Comprehensive Development Law. The first NCDP was formulated when Japan entered rapid economic growth dominated by private industry investment, mainly aiming to solve the unbalanced industrial layout, narrow the income gap between regions, and promote the balanced development of the economy. By establishing development poles, the first NCDP implemented a base-style development model to seek balanced development between regions and avoid excessive concentration of industrial distribution in the coastal zone. The concrete manifestation of the base-style development model is developing new industrial cities and special industrial construction areas. According to the New Industrial City Construction Promotion Law (Japanese: 新産業都市建設促進法), the Japanese government selected 15 cities and six areas for industrial development besides the original four major industrial areas along the Pacific coast. Until 2000, the Japanese government announced that the plan had reached the expected goal, which means the first NCDP has continued for more than 30 years. The development of large-scale heavy chemical industries in relatively backward areas has been reasonably dispersed in space, and the country's development has been balanced.

With the implementation of the first NCDP, Japan's economy has experienced rapid growth and became the world's second-largest economy by 1968. During this period, Japan’s population and industries have been further concentrated in the large cities around Pacific Rim. Economic growth has been dense in large cities with traffic congestion, housing shortages, energy shortages, insufficient water supply, and environmental pollution. The opposite is the sparse phenomenon of rural areas with the increasingly outflowing population, insufficient labor force, and difficulty maintaining basic living facilities and normal community life. In order to solve the problem of unbalanced resource allocation and related environmental and social welfare issues, the second NCDP is announced in 1969, which aims to promote the construction of transportation networks and build industrial bases through large-scale projects. The construction of modern transportation systems such as expressways and high-speed railways connecting industrial areas and local cities extends the industrial development to the entire country. However, during this period, the high-speed growth prevented the Japanese government from foreseeing risks and ran some unrealistic large-scale investment projects, leading to the over-density development of Tokyo and the skyrocketing land prices, which affected the regular operation of the economy. Many large-scale development projects in Japan were stranded by the oil crisis of 1973, announcing the end of the era of large-scale industrial development.

It can be seen very intuitively from these historical processes that the urban construction in Japan at this stage is dominated by industrial investment. From the perspective of space production theory, in the initial stage, capital is continuously invested in producing commodities to obtain profits, and the profits are reinvested in production to expand the production scale, which is the primary capital circuit (Harvey, 2001). The production of commodities requires a specific space, an "industrial city" or an "industrial area," which NCDP responded to through urban planning. Specifically, the base-style industrial development in the first NCDP and the large-scale investment projects in the second NCDP serve the primary capital circuit, convert natural space and farmland into industrial land to expand production, and bring rapid economic development and related space problems. From the perspective of space, these spaces are invested by governments and companies and further perceived as industrial space commodities, which is the process of industrial-type space production.

2.3.2. Multi-polar decentralized land and exchange network (1977-1997)

The global oil crises that broke out in 1973 and 1979 shocked Japan’s economy, making the Japanese government aware of the critical restrictive role of resources and energy and urging the Japanese government to rethink its development strategy and shift the resource-intensive industries to technology-intensive industries. However, the imbalance of resource allocation due to over-density and over-sparseness still has not been fundamentally resolved. In order to continue to promote balanced economic development, Japan announced the third NCDP in 1977, aiming to revitalize the local economy through development models such as "brain layout areas" and "technology-intensive cities" and control the concentration of population and industries in large cities. The third NCDP shifted Japan’s land development from economic development to infrastructure to improve people’s living standards. The "Idyllic City Concept" put forward by the Ohira Cabinet established the philosophy of people-oriented and nature-harmonious for the post-urbanization of Japan. Implementing the technology-concentrated city has contributed to the adjustment of Japan's industrial structure and regional economic revitalization, creating a new path for Japan's land development.

In the 1980s, the effect of Tokyo as a growth pole to drive the surrounding economic development was more pronounced and caused the concentration of Tokyo’s population and resources. The "big city defects" are very prominent with the population density remained high, the housing resources were insufficient, the traffic was congested. At the same time, the rapid changes in the industrial structure led to employment problems in local cities and surrounding areas. In addition, the internationalization of Japan's economy has further accelerated the phenomenon of emptied domestic industries. To alleviate the imbalance of economic development, Japan promulgated the fourth NCDP that integrates the entire nation's land through a land, sea, and air transportation system called “exchange network” in 1987.

Meanwhile, to form a multi-polar decentralized structure, Japan has strengthened the construction of " core business cities" around Tokyo and regional hub cities such as Sapporo, Sendai, Hiroshima, and Fukuoka. The construction of "comprehensive leisure and entertainment areas" is the critical development project in this period, the last project in land development supported by the Japanese government. With the collapse of the bubble economy in 1991, the fourth NCDP has exposed many problems and failed to realize most of its goals.

In general, the land development plan at this stage is still focused on infrastructure investment. However, unlike the previous stage, this kind of investment is not reflected in the further expansion of industrial areas but reflected in transportation infrastructures such as highways and high-speed railways. Although this topic has been covered, it is still dominated by industrial development needs in the second NCDP, and now it turns to the construction of living circles, the cooperation between regions, and the flow of production factors.

From the perspective of space production theory, the capital accumulated in the primary cycle will gradually decline profitability as production efficiency increases. In order to find a new way out, capital will invest and fix in space in the form of infrastructure construction, transforming the "production in space" into "produce space." Such infrastructure construction would increase productivity by improving factor transfer and technology, and the profits gained would be invested back into the construction, which is the secondary circuit (Harvey, 2001). The technology-intensive cities in the third NCDP and the exchange network in the fourth NCDP addressed capital logic in the secondary circuit and brought further economic growth. In the end, the pursuit of profit in the secondary circuit is reflected in the unrestricted growth of land prices, forming a real estate bubble and ultimately seriously damaging the economy. From the perspective of space, the focus of space commodities has shifted from production to distribution and exchange, which is reflected in drastic changes in prices as investment subjects.

2.3.3. Resident participation and regional independence (1998-now)

In 1998, Japan began to reflect on its own land planning experience and lessons over the past half a century and look forward to the coming 21st century. After more than 50 years of national land development, Japan’s comprehensive high-speed transportation system and the national land infrastructure grid have been formed, which marked the end of large-scale land development. The future land development can only be small-scale, partial, and supplementary development. In addition, after the collapse of the bubble economy, the Japanese economy fell into the worst long-term depression since World War II, and the economic situation no longer allowed state-led large-scale development as in the past. After thoroughly analyzing the challenge of economic globalization, population aging, decentralization momentum, and residents consciousness, Japan but removed the concept of “comprehensive national land development” and released a territorial plan named "Magnificent Blueprint for the 21st Century: Promoting Regional Independence and Creating a Beautiful Territory" (For consistency, it is still called the fifth NCDP here.) The fifth NCDP marked a radical change in the concept of Japan's territorial planning: 1) The main body of development changes from the state-led to local-led, from the government-led to residents-led; 2) the development behavior change from land development into land management; 3) the development scale change from large-scale to small-scale, from the overall development to improvement and supplement. The fifth NCDP is no longer a simple continuation of the past four NCDPs. However, it pays more attention to participation and cooperation, expands the axis of regional cooperation, forms a wide-area international exchange circle. However, implementation measures to realize the space concept of one pole and four axes remain not compelling enough.

After entering the 21st century, the problems of negative population growth and aging society in Japan have become more prominent, ushering in a thorough transformation from "land development" to "land formation." From the previous five NCDP, Japan’s territorial structure and industrial layout have taken shape, and its environmentally polluting industries have gradually moved away. The future goal is to adapt to the requirements of economic development in the new era, build a sustainable environment with greener living and convenient transportation. In this context, Japan has started a comprehensive survey in 2005, conducted discussions throughout the country, and listened to the proposals of prefectures and government-designated cities.

After several revisions, the final draft of the "Japanese National Land Formation Plan" was produced and approved in 2008. Although the sixth NCDP continued in the "one pole and four-axis" land structure and the transformation of land planning body, more innovative concepts and measures are promoted.

In pursuing the economic and social development of the country as a whole, the sixth NCDP believes that improving regional competitiveness is the primary economic development goal. At the same time, the population decline will inevitably bring about regional vitality decline, and a larger regional unit is needed for national planning strategy to improve the charm and competitiveness of the region and maintain the vitality of the entire country. This larger area unit is called "wide area." According to the regional population, economic scale, urban agglomeration conditions, and infrastructure conditions, the entire country is divided into ten wide-area regions and carried out "wide-area local planning." The 10 wide-area regions are: Hokkaido, Tohoku, Kanto, Central, Hokuriku, Kinki, China, Shikoku, Kyushu, and Okinawa.

The sixth NCDP believes that a wide area should not be an attachment of a metropolitan area and should have economic self-reliance. Moreover, a wide area will be self-reliant and mutually independent, replacing the past domestic competition structure with Tokyo as its apex. The concept of "independent" mentioned refers to the relative economic independence and cultural independence and development strategies independence. Each wide area is unique and cannot be replaced by other wide areas or even foreign areas. And the association and collaboration include collaboration and exchanges between wide areas and collaboration and exchanges between cities within a wide area.

Japan has completed the in-depth transformation of national land development at this stage, and regional and local autonomy has been placed in an important position. Emphasizing local characteristics, local differences, and residents' participation plays a more critical role in this stage, making land development gradually shift to a bottom-up model. From the perspective of space production theory, Japan has entered the final circuit of capital. As the second circuit continues to accumulate, it is difficult for capital to find profits under homogeneous spatial conditions. Therefore, it turns to differential space and improves labor reproduction through tertiary industries such as culture, medicine, and education.

The final circuit is reflected in the emphasis on residents' needs in each specific space and the independence and differentiation of each wide area in the fifth and sixth NCDP. From the perspective of space, more attention is paid to the consumption process of space commodities. Capital provides differentiated space commodities for different regional residents and provides a distinctive daily living space experience. In this process, residents' participation and grassroots autonomy have received attention.

2.3.4. The space production under the capital circuit and the corresponding sustainable planning strategies.

Figure 2.1 summarizes the development process of Japanese NCDP and the capital circuits behind it. At different stages, capital pursues profits in different ways and reinvests profits into the circuit, forming different space requirements, reflected in the form of NCDP.

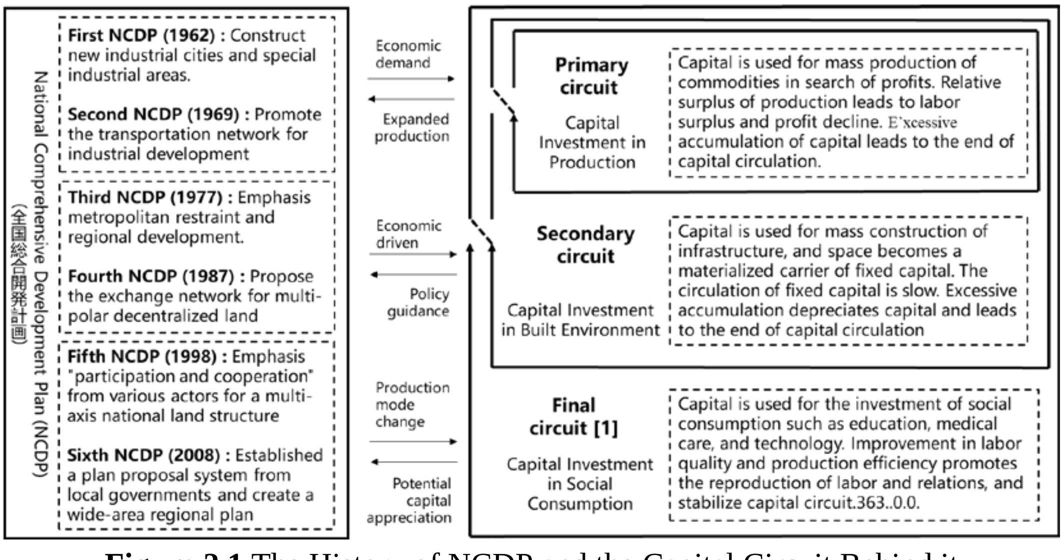

Figure 2.1 The History of NCDP and the Capital Circuit Behind it

After 60 years of development, Japan’s capital has followed its laws to complete three circuits from commodity production, built environment to social consumption, and the NCDP is the starting point to determine Japan’s territorial structure and urban form. Although this process is also shaped by external factors, government guidance, and local will, capital logic still dominates the evolution of the overall process.

From the perspective of a more specific space commodity, it has also undergone vital changes under the control of capital logic. From the production of new space through urban expansion to infrastructure investment to promote the value of space, then to develop differentiated space commodities, each essential element of the production of space commodities is involved.

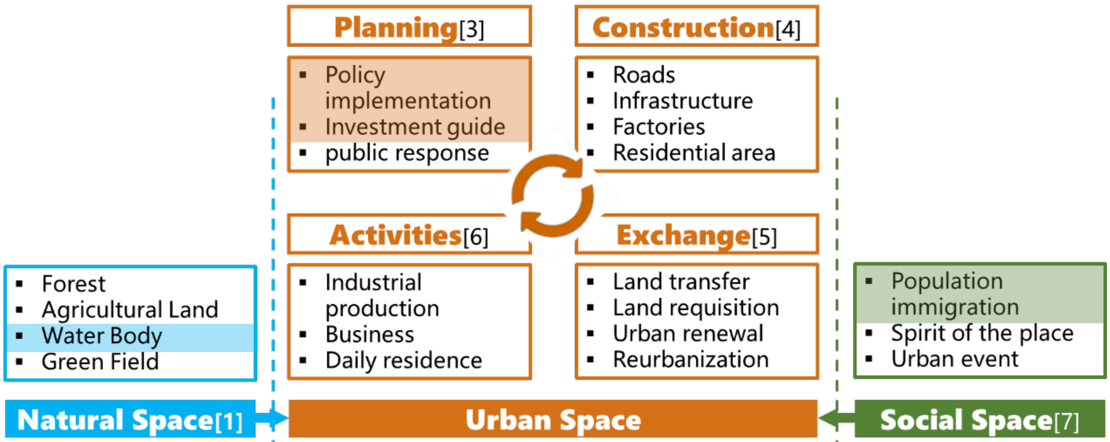

Figure 2.2 The essential elements of space production.

Regarding urban space as a commodity produced, the specific correspondence of the production process of general commodities can be seen in space production. **Figure 2.2** shows the process of urbanization. The space production process takes natural space as raw material and produces spatial commodities through production, distribution, exchange, and consumption. The profits obtained from it became the accumulation of capital, further promoting urbanization and shaping a city's production relations.

The appropriate correspondence in space production would lead to a new perspective of urbanization. Raw materials in the urbanization process are the natural spaces that are constantly requested to be occupied, which shape the natural form of the city. While the production process is organizing and constructing urban space, which transforms the space into specific land use such as commerce, residential or industrial areas. Furthermore, the distribution process refers to the planning and regulatory management process, which distributes different space products to form the urban form under planning. Then the exchange process includes land acquisition and land use, from acquiring raw materials to getting the land rent. Finally, the consumption process is the daily life of urban residents, including the collective demand for infrastructure and public services. The production relationship is the social structure between all the above parts, reflecting the city's social form.

From these analyses, many urban phenomena can be identified as the problem in the space production process. The increase in land prices in residential areas and land rents in commercial areas aim to bring profits to capital investment. The emergence of urban villages and slums corresponded to low-income groups falling into poverty and failed to consume spatial products. The process of de-centralization corresponds to the overproduction and underconsumption of space commodities. Moreover, environmental problems come from the destructive use of space resources. Therefore, for the solution of urban problems, we should also start with the production process of space commodities and adjust different elements through corresponding planning strategies to achieve the sustainability of the entire process.

Based on this analytical framework, a sustainable urban form needs to respond from all elements of space production, including adjusting urban density and population in exchange and distribution, optimizing energy use in production, encouraging differentiated development in consumption. Therefore, the planning strategy for sustainable urban form can be analyzed from all levels of spatial production. Specifically, regarding the raw materials, planning strategies should focus on nature, including ecological features, water, soil, and air. Regarding production, planning strategies should focus on the economy, including the capital, labor, management, policies, and regulations. Regarding production relations, planning strategies should focus on society, including population, knowledge and technology, history, and culture. These constitute the main focus of sustainable urban form.

2.4. Conclusion

The research is delivered to deeply analyze how space is produced in the urbanization in Japan and identify the key elements in the space production process. The six NCDPs are taken to show the historical trajectory of the capital circuits under the space production theory. This chapter systematically analyzed how capital enters and shapes urban space in the three different stages in Japanese urban development based on the theoretical system of space production, including the large-scale reconstruction and development from 1945 to 1976, the multi-polar decentralized land and exchange network project from 1977 to 1997, and the resident participation and regional independence from 1998 till now. Under this macro picture, this chapter indicates that several essential elements such as raw materials, production, distribution, exchange, consumption, and production relations can find appropriate correspondence in space production.

Based on this analytical framework, a sustainable urban form needs to respond from all elements of space production. Therefore, the planning strategy for sustainable urban form can be analyzed from all levels of spatial production. Specifically, nature, economy, and society are identified as three main aspects, and sustainable urban forms can be organized from these three aspects. This chapter provides a basic theoretical framework for follow-up research, and will further discuss how specific sustainable planning strategies will be implemented on this basis.

CHAPTER 3. THE MEASURES OF WATER-SENSITIVE URBAN DESIGN IN THE CONTEXT OF JAPAN'S SUSTAINABLE ECOLOGICAL ENVIRONMENT CONSTRUCTION

Water Sensitive Urban Design (WSUD) is a critical sustainable development theory in the urban water environment, which is attracting more and more attention worldwide. Meanwhile, as an island country, Japan attaches great importance to water resources and water environment, and have achieved fruitful result in urban water management. Based on the framework of WSUD, this research introduces Japan's practical experience from the perspectives of water source protection, flood control, and waterfront space landscape, aiming to summarize Japan's experience and provide a new perspective. By explaining the thoughts of water sensitivity design contained in Japanese practice, this research expands the scope of WSUD, provides a meaningful research framework for Japanese researchers, and provides compelling cases for researchers on water-sensitive design around the world.

3.1. Introduction

Water Sensitive Urban Design (WSUD) is a robust Low Impact development-based system for managing urban water environments. The goal is to achieve coordinated urban built form and urban water cycle growth, protect ecological water supplies, and ensure the urban ecological environment's resilience(Wong, 2006b). WSUD theory offers the possibility of simultaneously achieving urban sustainability, preserving water supplies, recovering urban habitats, and adapting to climate change in the face of challenges such as climate change, urban population explosion, and water pollution. The WSUD theory is widely regarded as a basic theory of future urban growth and urban planning. In Australia, the United States, France, Singapore, and other nations, the WSUD theory is regarded as a basic theory of future urban planning and urban water climate management(Thurston; Wong).

In the late 1980s, WSUD was proposed as an urban planning pattern (Coutts, Tapper, Beringer, Loughnan, & Demuzere, 2013). However, the concept of Water Sensitive Urban Design (WSUD) has been evolving, and no unified definition has been developed (Coutts et al., 2013). Sustainable social growth and management of the urban water system are essential components. Its main goal is to conserve water supplies while also ensuring the city's natural ecosystem is resilient and to achieve organized urban development patterns and urban water cycles in the end.

According to the Joint Steering Committee for Water Sensitive Cities, in delivering clause 92(ii) of the National Water Initiative of Australia, "*WSUD is the integrated design of the urban water cycle, incorporating water supply, wastewater, stormwater and groundwater management, urban design, and environmental protection. It represents a fundamental shift in the way water and related environmental resources and water infrastructure are considered in the planning and design of cities and towns, at all scales and densities*."

3.2. Method

Since its introduction, there have been many studies on WSUD. However, WSUD is essentially the local practice of low-impact development in Australia (Group & Council, 1990), and its primary goals and principles mainly include the following four points (France, 2002):

- Maximally maintain the original natural water bodies in the urban environment, such as ponds, streams, lakes, and rivers, maintain the original terrain features and natural drainage routes, maintain appropriate underground aquifers, prevent excessive erosion of waterways, slopes, and embankments, and protect the overall balance of natural processes and the water cycle.
- Maximally protect the permeable grounds such as the original waterfront plants and soil, combined with ecological water treatment facilities, reduce

sediments and pollutants in surface runoff and improve the quality of stormwater runoff entering the city receive water sources.

- Combine the planning and layout of buildings, roads, and sites with rainstorm collection, transportation, and treatment systems to reduce urban water demand.
- Combine the public space planning and landscape treatment with storm drainage routes and storm management measures to protect biodiversity and establish multi-purpose ecological storm drainage corridors.

These four points in Australia's research and practice can be the key to understanding the core idea of WSUD.

There have been several studies on WSUD since its inception. While WSUD was created to manage the water supply system (drinking water, surface runoff, water health, water recovery, etc.), the primary issue was rainwater management (Hoyer, Dickhaut, Kronawitter, & Weber, 2011). The scope and connotation of WSUD have steadily increased as related planning, and management structures have improved, as has the most recent advancement of hydrological management measures and technologies. At this time, holistic conservation of the urban water ecosystem and long-term hydrological system management are actively engaged.

Recently, WSUD research has primarily focused on three areas: natural geography, ecosystems, and socioeconomics. Non-human activity factors that influence hydrological conditions, such as landscape, slope, and elevation, are often included in relevant natural geographic research (Kuller, Bach, Ramirez-Lovering, & Deletic, 2017). Soil, greening, water quality, water quantity, rainwater recharge(Brebbia & Popov, 2009), water resilience(Brebbia & Popov, 2009), ecological diversity (Coutts et al., 2013), environment, and runoff control are all investigated in ecosystem research. Previous research on the socioeconomic level focused on urban transportation(Wella-Hewage, Alankarage Hewa, Pezzaniti, & Technology, 2016), urban site creation and construction (Lerer, Arnbjerg-Nielsen, & Mikkelsen, 2015), public knowledge, public engagement, and the development of a hydrophilic lifestyle, as well as supervision and management. Previous research on the socioeconomic level focused on urban transportation(Kuller et al., 2017), urban site growth and construction [8], public knowledge, public engagement, and the construction of a hydrophilic lifestyle, monitoring and maintenance, risk assessment(Sharma, Cook, Tjandraatmadja, Gregory, & Technology, 2012), and social stability, among other things.

Meanwhile, the majority of WSUD research has focused on more minor scales, such as urban space, locations, feature planning, design schemes, blocks, urban areas, and segmented watersheds (Lundy & Wade, 2011). Few studies have been conducted on a national scale, and the research topics have included Australia and other countries (Donofrio, Kuhn, McWalter, & Winsor, 2009). Using Australia's overall water climate and watershed management as entry points, Coutts Andrew-M and colleagues examined the design priorities, design material, and technical system of WSUD. The transpiration and oasis effect, vegetation cooling through shade and evaporation of water, and the reduction of surface temperature are three important aspects of WSUD's impact on climate. Transpiration and oasis effect, vegetation cooling effect by shade and evaporation of water, and reduction of surface temperature are three important topics of WSUD's impact on climate (Coutts et al., 2013).

In Japan, research on WSUD has also made some progress. Hidetaka and Kinouchi (近森秀高 & 木内豪, 2005) have given a comprehensive introduction to the concept of WSUD. Kana et al. (Hotta, Shiraki, & Ishii, 2016) introduced the WSUD practice in Melbourne, which mainly focused on the impact of greening on the urban water cycle. In comparison, Takanori introduced the WSUD practice about residential area landscape and planning in Germany (福岡孝則, 笠真希, 吉武舞, & 鈴木敦子, 2016) and the US (福岡孝則 & 加藤禎久, 2015). On this basis, the development and evaluation of water reclamation technology for the 21st-century urban water cycle system has been studied by Hiroaki et al.(田中宏明, 2001). There are many studies in Japan focusing on WSUD topics like water resources (Kojiri, Hamaguchi, & Ode, 2008), watershed management Haidary, Amiri, Adamowski, Fohrer, and Nakane

(2013), and urban water cycles Asano, Maeda, and Takaki (1996). Although not clearly stated, they can all be included in the discussion under the framework of WSUD.

Regarding the WSUD idea, Japan put forward the concept of “nature-oriented type rivers” in 1990, and has conducted more than 100 projects nationwide by 2012 祖田亮次 and 柚洞一央 (2012). With such research and practice advancement, the Japanese government has absorbed its core idea and proposed targeted policies and plans. In *National Comprehensive Water Resources Plan*, the following three targets have been raised:

- Establishment of sustainable water use systems
- Conservation and improvement of the water environment
- Revival and fostering of a water-related culture

Considering the natural conditions in Japan, the Plan incorporates WSUD issues into policy formulation from the perspective of *resource* development 国土庁 (1999), emphasizing: *“It is essential that policies on water resources are implemented in a planned manner based on a long-term and comprehensive viewpoint. Therefore, in order to demonstrate long-term prospects of water supply and demand, and clarify the basic direction of water resources development, preservation, and utilization, the Water Resources Department of MLIT has compiled the National Comprehensive Water Resources Plan.”*

Despite the fact that WSUD has been the subject of various studies and activities in Japan, the constant evolution of the WSUD definition has resulted in few reviews that include works from Japan in the WSUD context. As a result, this paper will examine Japanese research in the WSUD system from three perspectives: capital, disasters, and architecture, with the aim of giving readers a thorough understanding of the WSUD in Japan.

3.3. Results

3.3.1. Water Source and Urban Water Supply

As the source of water resources in a river basin, the water source area plays a vital role in protecting and managing the entire river basin's ecological environment. The water source area's ecological protection is the most critical part of water source protection in water source conservation.

With the growth of the economy and therefore the acceleration of urbanization, the public and government have paid more attention to the water source area and, therefore, the surrounding ecological environment. Between them, the first problem to be solved is erosion, and therefore the greening of the water source area can play a valuable role in conservation and soil. Similarly, the forest soil has a specific purification effect on certain harmful components in natural rainwater and plays a role in purifying the water in the water supply due to its geological structure's particularity. The increased water-holding capacity can also radiate water into the downstream watershed, serving as a comprehensive center for drought and flood control, as well as watershed regulation and storage.

Therefore, from a macro perspective, there is a critical correlation mechanism between the ecological protection of water sources and the river basin's overall development. A necessary means of restoring the water source area's ecological balance is to establish a plant-led sustainable ecosystem. The difference in the types and scales of surface vegetation directly affects the depth of underwater seepage, affecting the water source land's water retention capacity.

According to WSUD, the continued growth of cities presents challenges to the security of water supplies from the standpoints of land use and water resource use. Simultaneously, the safety of water supplies is closely linked to the urban water system infrastructure and, as a result, the balance of water demand. As a result, WSUD must provide studies on everything from water supplies to water system infrastructure to water demand.

3.3.1.1. *Water Resource Environment in Tokyo*

Tokyo is Japan's capital and, therefore, the country's largest city. The total area is 2,191 km^2 (as of October 1st, 2016), or 0.6 percent of Japan's total land area. Tokyo has a population of 13.63 million people (as of January 1st, 2018), accounting for around 10% of Japan's total population. Tokyo's population and, as a result, economic activity centers are concentrated in the city's suburbs.

With the gradual formation of a mature society, in the context of the declining birthrate in Japan, environmental problems have become increasingly prominent, causing widespread attention within Japan and the international community. As the political and economic center of Japan, Tokyo is Japan's most representative international city. Social capital and scientific research resources are highly concentrated in the Tokyo area, representing the most advanced technology level in Japan. Its water demand and water source management are inductively representative. As a result, using Tokyo as a search area will reveal the organization of Japan's urban water management.

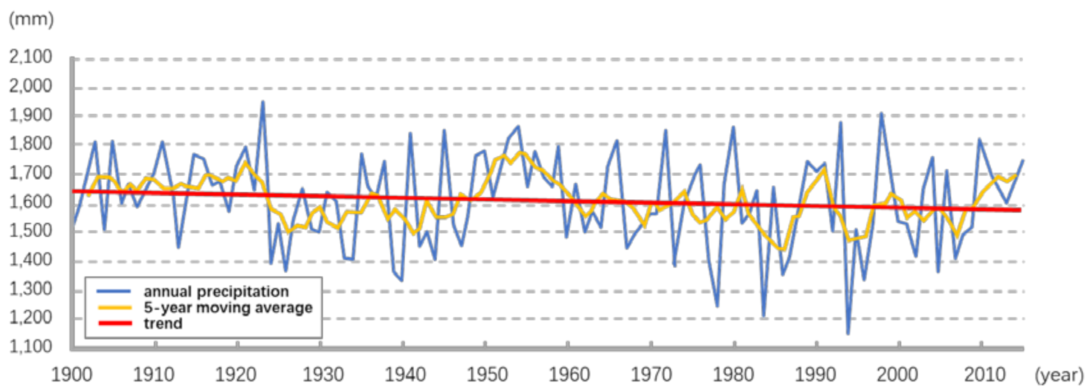

Figure 3.1 The amount of precipitation in Tokyo from the 1900s

The water supply chain sources mainly consist of the storage of water conservancy facilities and surface water runoff. With the background of global climate change, the amount of precipitation has decreased since the 1900s (**Figure 3.1**). This situation affected the water supply methods mentioned above, thus caused a shortage of water supply.

In terms of Tokyo's potential water system, Japan has always placed a high value on protecting natural water supplies and, as a result, the ecological climate. Although advocating environmental sustainability, it is hoped that the whole water supply will be maintained, and therefore the water quality will be improved. Promoting the construction of rainwater infiltration devices, enhancing the waterfront climate, new water quality regulations, and " water source forests" are among the proposed water supplies, water quality, and environmental protection initiatives. Water source forests are the most direct intrusion within the water source region among them.

Figure 3.2 depicts the protection and management area of the Tokyo water system Forest, which covers a total area of 21,624 hectares. Rainwater collection, water source management, sediment loss control, and water quality protection are primary functions of the water source forest. The upkeep and conservation of water source forests are essential for environmental protection and ensuring water system sources, and they should be encouraged even more.

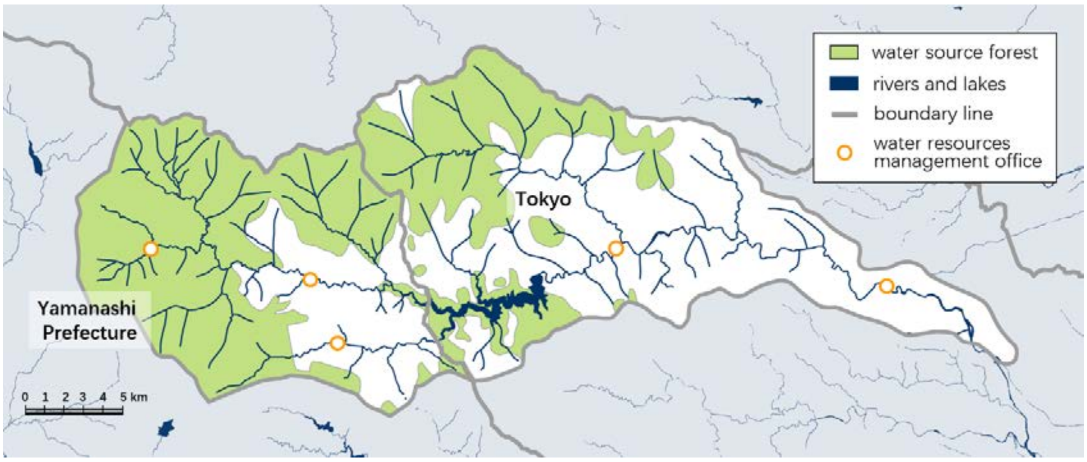

Figure 3.2 The Water Supply Forest in Tokyo

3.3.1.2. *Water facilities in Tokyo*

Tokyo's primary water supply remained the Tama River until the early 1960s. Tokyo started to use the Tone River water system and built and constructed the Tone River water supply as a result of the rapidly rising water demand. Currently, the Tonegawa and Arakawa River systems provide 80% of Tokyo's water supplies, while the Tama River system provides about 20%(Lossouarn et al., 2016). Besides, due to the recent trend of less rainfall, it has become clear that the Tone River system’s supply capacity has already fallen by about 20% from the time of planning. Furthermore, unusual weather has become more common in recent years around the world, and global climate change will have a direct effect on water systems in the future, such as water supply and water quality.

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and, as a result, the Japanese Water Resources Agency established new water sources in Tokyo, namely the " Basic Plan for Water Resources Development in the Tone River and Arakawa Rivers." Several ventures, including the Urayama Dam, the Kita Chiba Waterway, and the Takizawa Dam, have recently been completed (国土交通省, 2017).

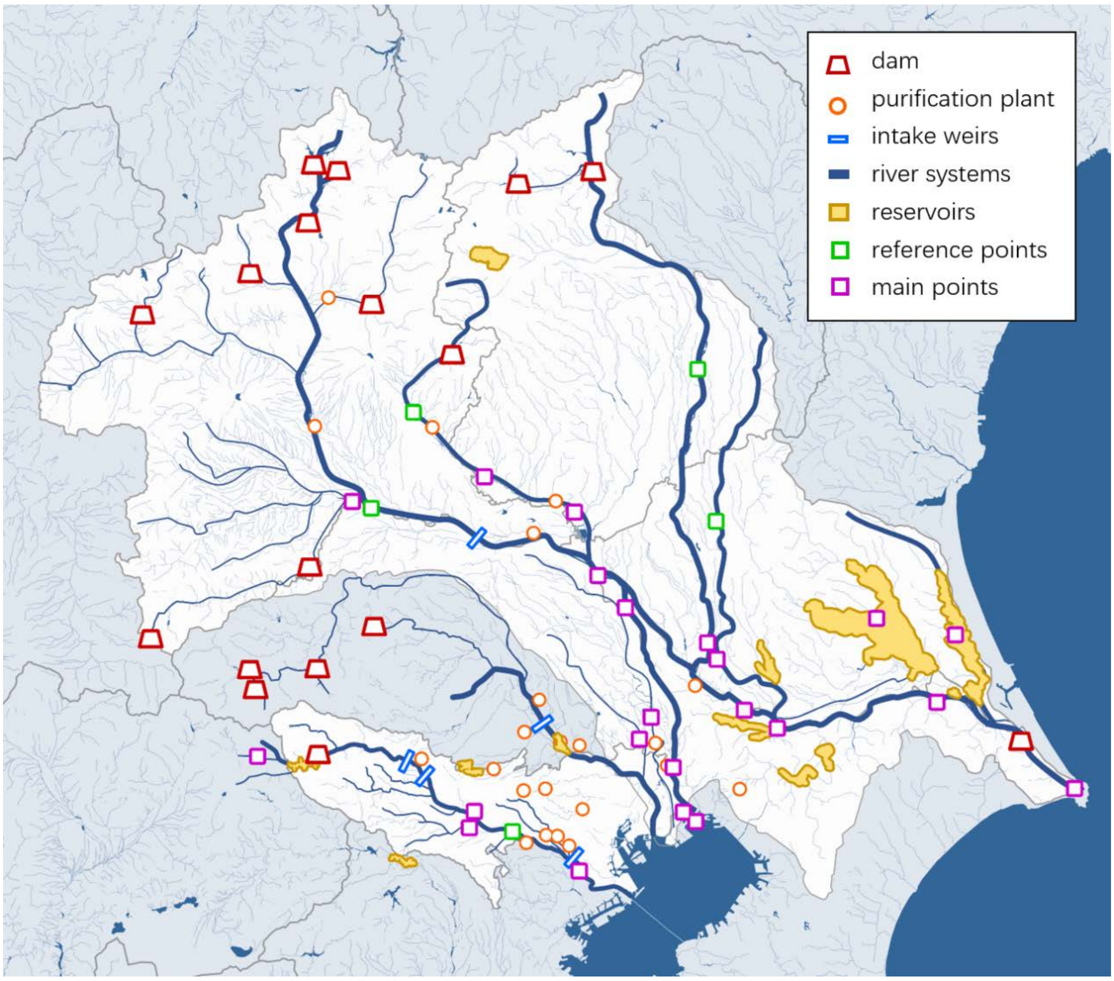

Figure 3.3 The water facilities in the Tokyo Metropolitan Area.

Raw water is pumped from the Tone and Tama rivers to the Higashimurayama water purification plant in this system(**Figure 3.3**). Simultaneously, raw water from the Tama river is frequently replenished at the Asaka water purification plant through natural flow, allowing for raw water exchange. Water from the Tone and Tama rivers is typically used in the water system, with a small amount of water from the Tama River system, such as the Okochi Reservoir, being used to store water. During the summer, however, the highest water demand may be confronted with the Tone and Tama river water quality incidents. In these dry times, water from the Tama River is essential.

This water system has directly modified Tokyo's water cycle course and has become an integral part of the Tokyo metropolitan area's water system, according to the WSUD. Via regional and seasonal water supply deployment, Tokyo's water facilities have achieved the twin goals of conservation and water system.

3.3.1.3. *Water supply and water demand in Tokyo*

The Tokyo Metropolitan Government Bureau of Waterworks is one of the world's most well-known large-scale water operators, in charge of Tokyo's entire water supply network. Water is provided by the Bureau of Waterworks to the Tama area's 23 wards and 26 cities and towns. The service area is 1,239.27 km2, with a daily water demand of 13,401,324 people. The total water distribution amount per year of Tokyo is 1,541 million m^3as of October 1st, 2017 (TokyoMetropolitanGovernment, 2018). As of October 1st, 2017, Tokyo's total annual water distribution volume was 1,541 million m3. The Tokyo Metropolitan Government currently had 630 million m3 of raw water on hand every day in 2018.

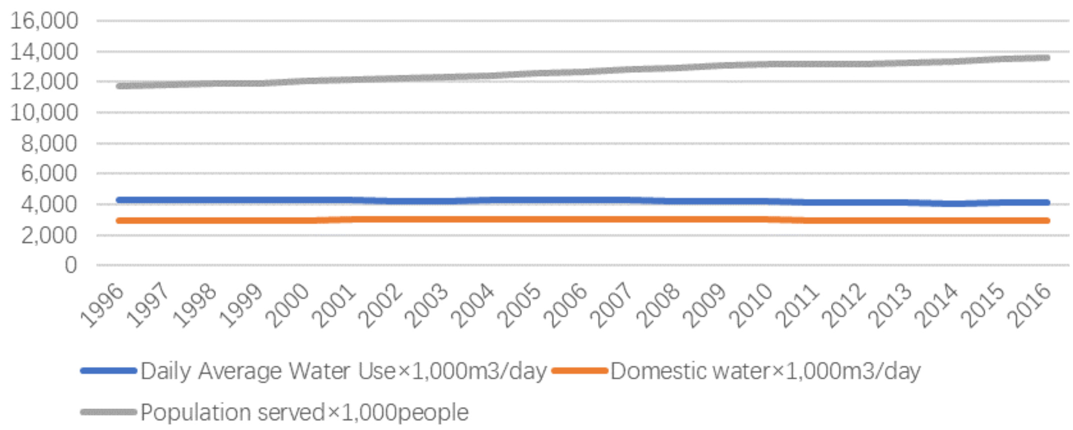

Figure 3.4 Daily Average Water Use and Population Served (Wards and 29 Cities/Towns)[1][2]

Water demand is one of the most important factors in determining the water supply system's operational capability. It will change in response to changes in population, habits, environment, and socioeconomic conditions. Water demand in Tokyo has increased as the city's population has grown. During periods of increasing growth, it is unpredictably changing social and economic development patterns, climate change, natural disasters, and demand, causing future water demand to shift unexpectedly. The graph depicts Tokyo's average water intake and population serving over the last 20 years (**Figure 3.4**).

Given that water storage systems will be used for another 50 to 100 years, it is important to consider water supply demand for as long as possible in order to ensure a steady supply of water. After building an alternative water purification plant, the aging water purification plant will be sequentially renewed on a series-by-series basis. When renewing the water purification plant, in order to ensure a stable water supply during the renewal period, the aging water purification plant will be sequentially renewed on a series-by-series basis after establishing an alternative one. It will take approximately 25 years for the maintenance and the renewal of the water purification plant. As a result, when forecasting water demand in the *"Tokyo Waterworks Facility Reconstruction Basic Concept"*, the Bureau of Waterworks will take population patterns for the next 25 years into account (東京都水道局, 2016).

As a result, the average daily water consumption, which is the amount of water used by customers, will remain at the same level as it is now and peak in the 2018's. Based on the data experienced so far, the maximum daily water distribution could reach

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[1] *After the integration of Okutama City into Tokyo in April of 2010, the Tokyo Metropolitan Area is composed of 23 Wards and 29 Cities/Towns. That means that before 2009, it consists of 23 Wards and 28 Cities /Towns.*

[2] *The figures of the population served shown in the table represent the data on October 1st of each fiscal year. The population served in FY2016 may be amended upon the census.*

approximately 600 million m^3 at peak times, taking into account fluctuations and leaks in the water supply. Based on the difference between demand and ability, the Bureau of Waterworks seeks to restructure the water distributing area to an appropriate size by improving new water supply stations and expanding by renewing decrepit facilities. Meanwhile, the reservoir capacity in water supply stations will also be improved to aim to supply water for 12 hours of the planned maximum water distribution amount per day to respond to hourly variation in water usage and in case of emergency.

Water demand is the root of urban water problems and a gradually covered topic by WSUD in recent years. The Tokyo metropolitan area’s water demand provides an excellent example for other regions, showing the importance of water demand when implement WSUD with the construction and renewal of water facilities.

In general, Japan's experience has shown the critical importance of water supplies, water supply infrastructure, and water demand, and the country has reacted from the perspectives of forest protection, water resource distribution, and demand estimation. From land resources to engineering buildings, these have been the research directions of WSUD in recent years. Research on water supplies and water supply is the foundation for more planning and design to build an urban environment where people and water live in harmony.

3.3.2. Flood Control and Disaster Prevention

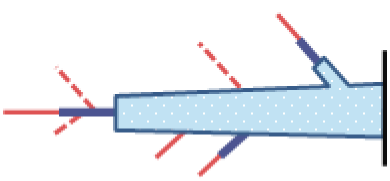
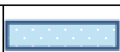
Flood control has been an important issue for public administration since rivers’ flooding has caused significant damage to people since ancient times. However, in recent years, environmental issues have been highlighted, and in rivers, hydrophilicity has become more critical than flood control. The river that has become a concrete revetment for flood control is restored to a natural revetment or a state close to it to lower the fence between people and the river, regaining familiarity with the river and preventing water pollution and becoming an organism. Citizens’ desire to recover a gentle river has increased.

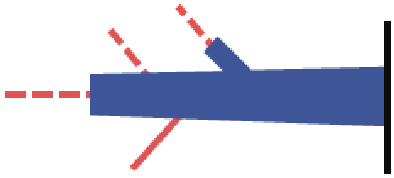
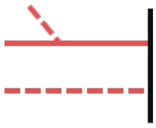
Japan’s rainy climate and the mountainous terrain have formed steep and flashy rivers, which have regime coefficients up to an order of magnitude higher than for continental rivers, bringing lots of floods (Oguchi, Saito, Kadomura, & Grossman, 2001). According to MLIT, about 50% of the Japanese population and about 75% of assets concentrate in flood vulnerable areas in the alluvial plains, which account for only 10% of its total land area (河川環境課水防企画室, 2016). Flood disasters caused by torrential rainfall will bring tremendous damage to these areas, making flood control measures important parts in river basin management.

Under the *Disaster Measures Basic Act*, *River Act*, and *Flood Protection Act*, Japan has formed a system from “crisis response” to “emergency measures and recovery,” and then “disaster prevention” around the occurrence of a flood. The system covers measures from patrolling rivers, reporting damage status, delivering flood warnings, emergency restoration measures, post-disaster recovery measures, and then to river improvement, provision of the river information system, and construction of disaster prevention stations (Takeuchi, 2002).

Japan has developed a framework around floods that includes "crisis response," "emergency measures and recovery," and finally "disaster prevention" under the Disaster Measures Basic Act, River Act, and Flood Protection Act. The system includes initiatives such as river patrolling, damage reporting, flood alerts, emergency repair, post-disaster recovery, and river enhancement, as well as the provision of a driver information system and the installation of disaster mitigation stations (河川環境課水防企画室, 2016).

Table 3.1 Separation on river management in Japan

Water system	Pattern diagram	River types		Manager
Primary water system (109)		First-class river Ministerial control section		Minister of land, infrastructure, transport and tourism;

		Designated section		Prefectural governor
		Mutated river		Mayor of a municipality
		Ordinary river		Local government organisation
Secondary water system(2711)		Second-class river		Prefectural governor
		Mutated river		Mayor of a municipality
		Ordinary river		Local government organisation
Single water system		Mutated river		Mayor of a municipality
		Ordinary river		Local government organisation

3.3.2.1. *Comprehensive flood control measures in urbanized areas*

Many parts of Japan, especially the Tokyo metropolitan region, are experiencing rapid urbanization. Taking Kanagawa prefecture as an example, rural land, including forest and farmlands, accounted for 90% in the Tsurumi River basin in 1958 but had decreased to about 15% in 1997. One consequence of rapid urbanization is the growing concentration of population and property in low-lying lands, which have historically been subject to flooding.

On the other hand, the rapid urbanization and suburbanization have brought about a more severe trend of artificialisation of river basins, which has weakened the natural capabilities to retention and detention. Asphalt and concrete on the urban surface make it difficult for stormwater to penetrate underground naturally. As a result, the majority of stormwater stays on the land and fills urban rivers and depressions faster than in rural areas, raising the likelihood of urban flooding. Besides, the flow of rivers in urban areas is generally deficient. Still, when typhoons hit, the rainwater in the catchment area concentrates and flows out in a short period, becoming urban floods, and submerging subways or urban underground shopping centers, paralyzing the city's functions. In short, urbanization has increased the danger of urban-type flooding by concentrating floods in a shorter period of time.

Various facilities and systems have been established to protect residents from flood damage, including widening channels and embankments, building detention basins and dams, and diverting water through floodways. However, these conventional river improvements that mainly rely on levees and retarding basins are neither suitable nor enough for the urbanized area. There is an urgent need for a comprehensive approach that combines:

- **River measures**, including river channel improvement and construction of dams, retarding basins and discharge channels responding to floods, and so on;
- **River basin measures**, including the retention and detention facilities designed to maintain and enhance capabilities of river basins, and land-use planning that maintains urbanization control areas;
- **Damage mitigation measures**, such as the establishment of warning and evacuation systems or promoting awareness of local residents.

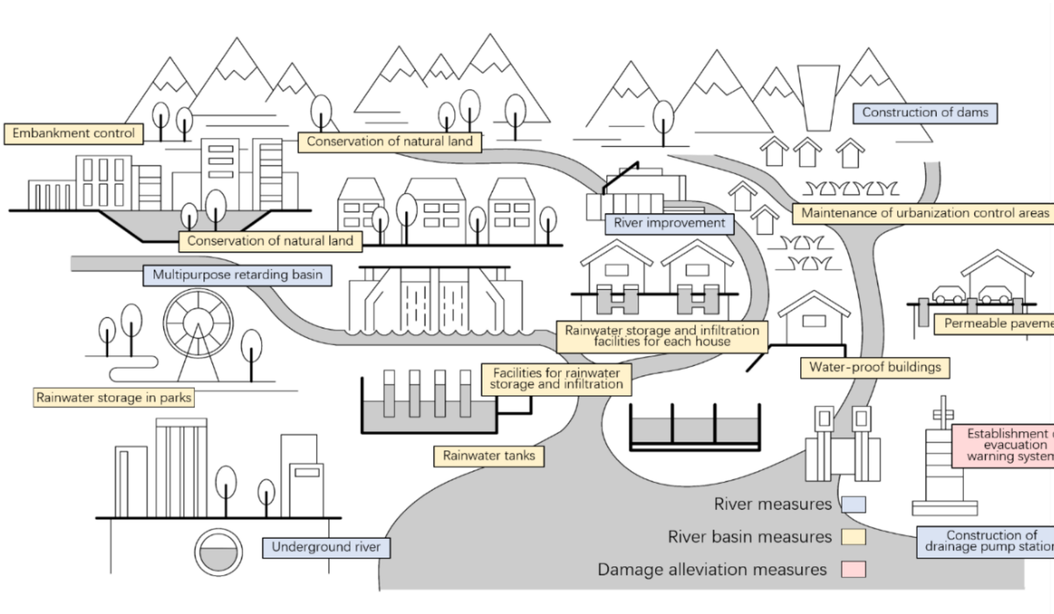


Figure 3.5 Comprehensive Flood Control Measures in River Basin

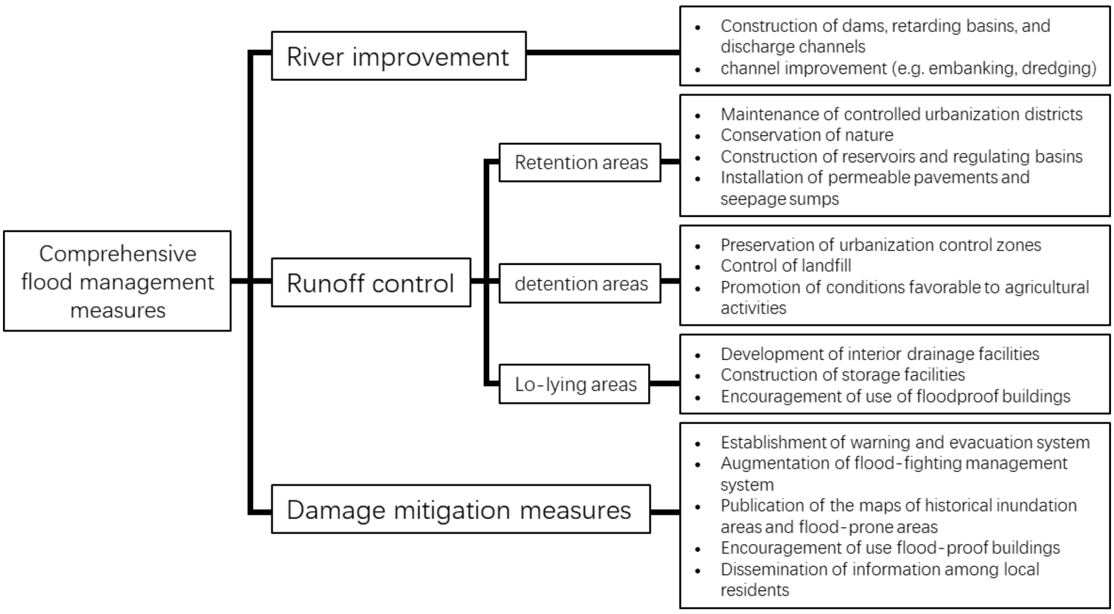


Figure 3.6 Comprehensive Flood Control Measures in River Basin

The above-mentioned comprehensive flood control measures are extensive and internally related, and many of them can be regarded as the direct application of WSUD principles in the field of disaster prevention. Based on the perspective of WSUD, Japan has made many academic explorations and engineering practices regarding its circumstances.

3.3.2.2. *Super Levee development project*

There is no tolerance for embankment failure along major rivers that pass through densely populated and property-rich urban areas. Since 1987, large levees known as "high-standard levees" or "super levees" have been built along these rivers(H. Nakamura, Kato, & Shiozaki, 2013). Super levees are high and deep (300-500 m) levees that are used to construct urban structures and traffic facilities. They also act as urban regeneration, which justifies the building costs by increasing the value of the developed lands (**Figure 3.7**).

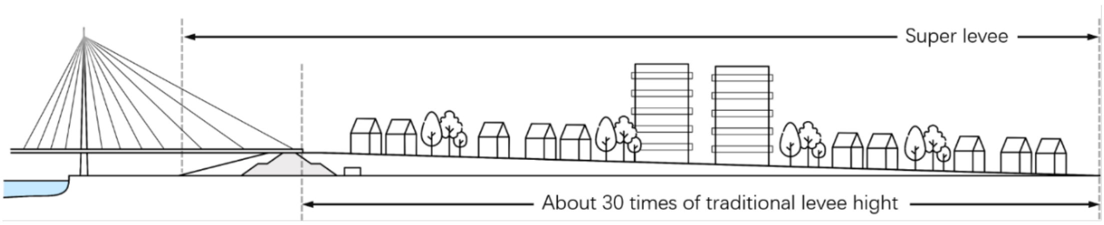


Figure 3.7 Concept of Super Levee

In alluvial lowlands, super levees are the last line of defense against a typical flood. The concept of a super levee stems from the fact that even in the event of a catastrophic flood, destruction can be minimized if levees remain intact. Furthermore, wider levees can efficiently cope with flooding, seepage, and earthquakes. Consequently, Super levees are far superior to traditional levees. Furthermore, gently sloping super levees aid in the smooth connection of the city to the shore (**Figure 3.8**).

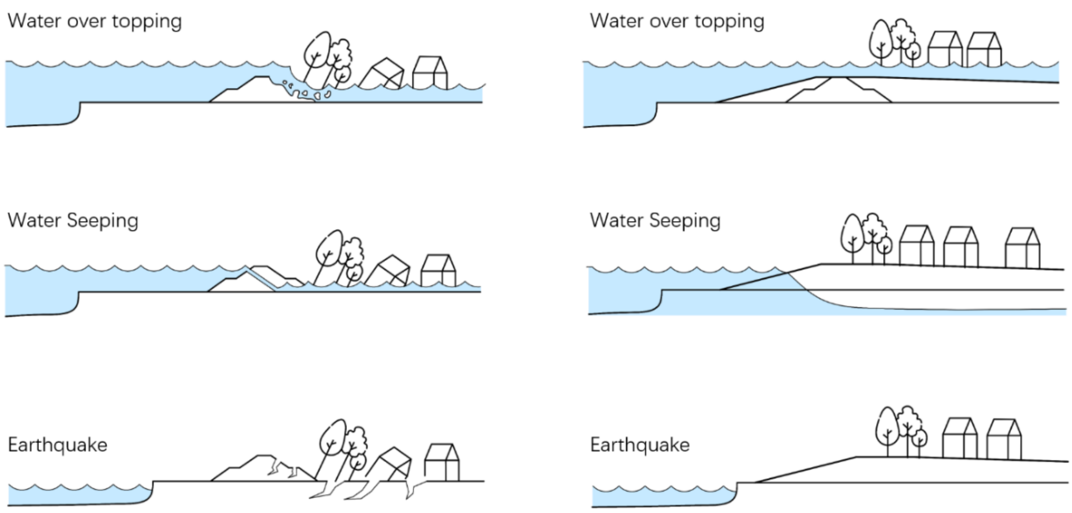


Figure 3.8 Comparison of Super Levee and Ordinary Levee on Water Overtopping, Water Seeping, and Earthquake.

The community side of super levees, such as residential land and parks, can also be used efficiently. The room provided by super levees also allows for a beautiful and comfortable living atmosphere. People may reach the riverbank in a more natural manner without having to move across a clearly defined dividing line. Residents of the city will remain close to nature by achieving harmony between the natural and urban environments. As a result, super levees allow the construction of a healthy and scenic community that is integrated with the river.

The super levee also integrates with non-point developments, such as urbanization development, in the hinterland. These levees, which will prove superior in coping with unexpected urban-type floods, are being constructed for river sections where unexpected effects would be considerable, such as the Tone, Edo, Ara, Tama, Yodo, and Yamato Rivers in Tokyo/Osaka Metropolitan Area.

The super levee project incorporates urban space and flood protection engineering initiatives as a direct measure to cope with the flood, which can realize the roles of flood resilience and disaster mitigation and provide a brand-new kind of urban-type as a meaningful WSUD exploration of urban design.

3.3.2.3. *Rainwater storage and infiltration facilities*

Where upgrading the river channel to avoid flood disasters is difficult due to progressive urbanization, the river administrator should improve rainwater storage and infiltration facilities, specify the urban rivers and catchments, develop catchment flood disaster countermeasures, and other realistic measures as comprehensive flood control measures.

Considering the hydrologic cycles and water environments in the river and its basin, rainwater storage and infiltration technology, which is a runoff control measure against the runoff increase due to urbanization, is not only for flood control but also for water conservation and restoration of sound water circulation system. It is also an effective means recommended by Rainwater Storage and Infiltration Technology Association (雨水貯留浸透技術協会, 2001). Groundwater recharge, spring regeneration, an increase in river flow at standard times, efficient use of rainwater, improved water quality, improved heat island phenomenon, and habitat protection are all benefits of rainwater storage and infiltration (Marsalek et al., 2008).

The rainwater storage method aims to temporarily store rainwater in the facility and control the amount of discharge. Furthermore, the rainwater infiltration method is to infiltrate rainwater underground and store it as groundwater. These methods can be roughly divided into

- **Regulating pond** is a method of temporarily storing rainwater in dams and excavations, adjusting the discharge amount to cut off the peak runoff, and is the most common rainwater storage method.
- **Pond storage** refers to ponds such as agricultural ponds and garden ponds that have a regulated capacity.
- **A low-bed flowerbed** is a method of temporarily storing rainwater in a low-bed-shaped depression with a floor of 30 to 50 cm.
- **Park storage,** playground **storage, open space storage, parking lot storage, schoolyard storage, and rooftop storage** are methods that temporarily store rainwater when heavy rainfall occurs at each location.
- **Combined storage** is a method that combines regulating reservoirs, park storage, playground storage, and open space storage in a stepwise fashion.
- **Underground storage** is a method of temporarily storing rainwater in underground tanks and tunnels.
- **Seepage well, seepage pond,** and **suction well** are methods of infiltrating and storing rainwater underground using shallow wells, reservoirs, and culverts, respectively.

At the beginning of the comprehensive flood control measures, large-scale storage facilities aim to collect and control rainwater over a wide area in only one place, but schoolyards, parks, ridges are used afterward, forming a decentralized method in which the sufficient space in the urban area has the storage effect only during heavy rains (

Figure 3.9). In recent years, regulating ponds will be integrated with parks and sports facilities and function as amenity ponds, ecological ponds, and waterside amenities. Hence a coordinating pond that cooperates with the area can be created (忌部正博, 2005; 忌部正博, 屋井裕幸, & 高祖成一, 2008).

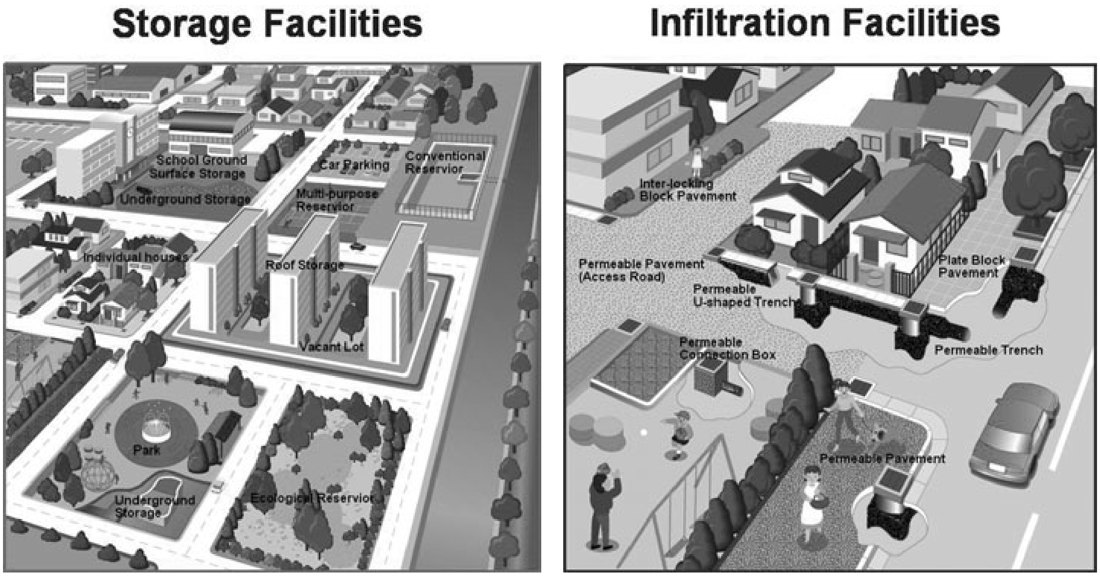


Figure 3.9 Typical Rainwater Storage and Infiltration Facilities in Japan (忌部正博 et al., 2008)

In addition, Kasukabe City is building an underground artifactual waterway, which is one of the world's largest underground water facilities, to ensure the safety of the Tokyo metropolitan area. Floods in the Tokyo metropolitan area can be avoided by joining the five major rivers, including the Nakagawa, Kuramatsu, and Tone, and draining water directly into the Edogawa River. The 6.3kilometer-long facility is made up of five silo-shaped water storage spaces of various sizes that are 50 meters underground (**Figure 3.10**).

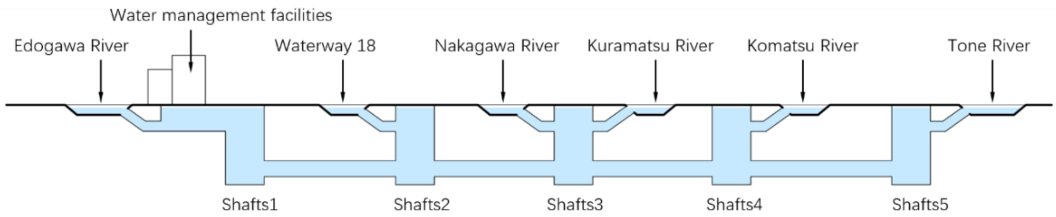


Figure 3.10 The Metropolitan Area Outer Underground Discharge Channel

Infiltration facilities such as infiltration trenches and water-permeable pavements are delayed in usage compared to storage facilities. However, methods for evaluating the infiltration capacity of the ground and the facilities' infiltration capacity were established after that (雨水貯留浸透技術協会, 1998), and it is possible to perform a functional evaluation. Initially, it was feared that sediment or fallen leaves in rainwater would cause clogging and cause a decline in the infiltration function. In the follow-up survey of facility installation, it has been confirmed that there is almost no functional deterioration even without maintenance, such as cleaning 安藤義久 (1982).

Since Japan is vulnerable to flooding, WSUD flood mitigation measures are a critical issue. The Super Levee and rainwater facilities are a specific development and practice of Japan in WSUD, while extensive flood management initiatives in urbanized areas serve as a comprehensive strategy. With global climate change on the rise, Japan's expertise in urban design in coping with flood disasters is worth promoting and referencing.

3.3.3. Waterfront Landscape Planning

The waterfront landscape is another essential part of WSUD. The waterfront landscape has a relatively noticeable landscape ecological effect, mainly reflected in the flowing beauty and ecological impact of the water body, the waterfront plant community’s richness, and the diversity in landscape color. Moreover, the water body is the medium for exchanging the material energy of the riparian zone and the organisms on land, improving the urban microclimate. The waterfront environment’s diversity and complexity directly affect the surrounding environment. Hence, the waterfront landscape should be developed and designed reasonably to utilize the urban waterfront environment for its ecological function fully.

The history of waterfront landscape planning in Japan started at the end of the 20th century. In 1990, Japan launched the “nature-oriented river work” to guide ecological projects for nature-oriented rivers. Through improved engineering construction measures and the application of biological construction materials, Japan achieved artificial landscape environments close to nature landscape in many river restoration projects 齐实 (2001). Along with the concept of “nature-oriented planning and design of rivers” proposed in 1993, the MLIT focused its technical research on restoring ecology and protecting the natural ecology of rivers, reservoirs, and coasts by systematic ecological natural environment construction (Thyssen, 2001). In 1997, the River Law adopted by the Japanese Council focused on the river management project with nature-oriented construction methods to ensure the sustainable development of natural river ecosystems (崔伟中, 2003).

At the beginning of the 21st century, Japan proposed a forward-looking river management policy. The development of a river-centered ecological city becomes a basic standard for modernizing Japan into a beautiful ecological living environment and rich living conditions. Natural engineering measures, which protect biodiversity, aquatic biodiversity, and the natural ecosystem of the co-exist and reproduce spaces, are adopted to achieve the goal of “creating a healthy life and environment in harmony with nature.” Under the guidance of the new river management policy, Japan has entered a new era of ecological river construction. The related engineering technology and basic theory are gradually updated and improved

3.3.3.1. *Nature-oriented River restoration*

Creating a nature-oriented river refers to the river management process that includes the entire river’s biological activities, considers the harmony among local lifestyles, history, and culture, preserves the original habitat, growth, breeding environment, and diversity of the creatures, and create unique river landscapes. (国土交通省, 2008).

Traditional river renovation projects usually use stony embankments to artificially determine the river’s cross-section and force the river to intercept and straighten, resulting in a series of problems such as the river's faster flow and erosion of the river bed and higher peaks of the flood. However, the nature-oriented river restoration starts from an ecological perspective, emphasizing the restoration of the river's ecological function, creating the river's landscape function, and ensuring harmony between the residents and the river.

In Europe, Switzerland and Germany started to implement river restoration projects as early as the 1950s. Regarding this idea, Japan put forward the concept of "nature-oriented *type* rivers" in 1990. By 2002, a total of 28,000 river management projects adopted this model (渡邊彩花, 内藤太輔, 森吉尚, 宮本健也, & 後藤勝洋) Among the 5,500 river restoration projects implemented nationwide in 2002, about 70% of the projects adopted this concept. The differences between "Nature-oriented *type* rivers" and traditional river restoration are shown in **Table 3.2** (足立考之, 1993).

Table 3.2 Comparison of Nature-oriented Rivers and Traditional Rivers Restoration

Content	Traditional type	Nature-oriented type
Aims	Flood control / Drainage	Ecological protection
Standard	National unified	Regional specific
Efficiency	Engineering efficiency first	Natural influence first
Production	Mass production	Customized production
Maintenance	Less maintenance	Emphasis on maintenance
Materials	Mass production	Regional materials
Watercourse	Mainly straight lines	Mainly natural curves
River shape	Manual decision	Free formation
Section	Standard sections	Diversified sections

Based on the perspective of WSUD, there are several vital characteristics of nature-oriented type rivers:

- **River Beach Usage.** Due to the remarkable attributes of seasonal floods, the compound sections are widely used in Japan, with sweeping river beaches used as a flood section during the flood period. While most of the time, these river beaches are out of the water surface at the average water level, which can be used as various hydrophilic spaces. Starting from the Edo River and Tama River in Tokyo, the river beach land is used as a green space and park, becoming the first Nature-oriented river project. Since then, ecological restoration projects were developed in Japan, including side water purification facilities, wetland restoration facilities, fish habitats, aquatic botanical gardens, and hydrophilic platforms abound.

- **Slope Protection**. The other most implemented method among the nature-oriented type rivers is the naturalization and diversification of slope protection. The primary purpose is to change the condition that the rigid slope protections are hard for plants and insects are to inhabit. By changing the material used, the slope can restore aquatic plants in the waterfront part and create aquatic habitats for fish and shrimps. Such processes of restoring natural river diversity also greatly improved the river landscape. According to the gradient, structure, and material, Koichi Yamamoto divided the nature-oriented slope projects into seven types: stone masonry slope, natural stone slope, retaining wall, snake cage slope, grid filling, rockfill slope, plant slope. (山本晃一, 2003). These types can be used flexibly according to different situations and ecological aims.

- **Traditional Work**. The traditional river work, such as willow branches slope, sunken wooden beds, and snake cages, is restored since these methods are all considered to be closer to nature. Simultaneously, the use of natural materials such as stones, stakes, willow branches, and bamboo has also significantly been promoted.

- **Waterfront Line**. According to the river's characteristics, restore the shoreline's natural curve as much as possible in areas where conditions permit. One of the notable projects is the Kushiro River Project (F. Nakamura, Ishiyama, Sueyoshi, Negishi, & Akasaka, 2014). Initially a wetland, the Kushiro River implemented a linearisation project in the 1970s, resulting in ecological degradation and eutrophication. In 2010, a 2.4km long restoration project was launched, which removed the rigid dike and restored the river's original curve. After the project, the river has become more complex and diverse due to the different depths and flow rates and forms a wetland system at the expanded flooded area. In the case that cannot change the entire river line, try to restore the river bed as much as possible, like the representative project on the Sakai River. According to the waterfront, bends are set in the scouring part and the silting part separately for changing the water flow.

- **BioTop & Riverbed**. A pond-like terrain on the waterline is formed through engineering measures, which are connected to the mainstream river to create a relatively stable water flow environment that can be used by aquatic organisms. There can be either emergent plants or submerged plants around the bay, making it a suitable place for fish and birds to inhabit (木村一郎 et al.) This method of artificial habitat construction is called "BioTop." In the riverbed design, creating gulf streams and forming shallows and abysses are effective methods for constructing habitats based on fluid mechanics, which are commonly used in nature-oriented river projects.

- **Wetland Rehabilitation**. Rehabilitating a natural wetland system using fluctuating water levels is the most common method of nature-oriented river projects. Most of the Grade 1 rivers have formed natural wet areas on the sweeping river beach with lush reeds and other plants.

- **Riverside Forest Rehabilitation**. Considering the natural ecosystem's continuity, it is a continuous aquatic-terrestrial ecosystem from the riverbed, beach, and embankment to the outside of the embankment. Hence the riverside forests should be preserved or rehabilitated to create a natural ecosystem. Riverside forests can increase the diversity of the ecosystem and become a beautiful waterfront landscape.

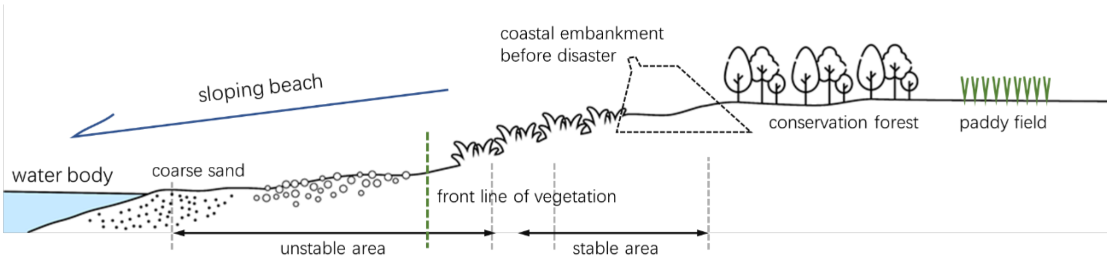


Figure 3.11 The typical compound sections of river in Japan

Figure 3.12 The restoration of natural waterfront shoreline (リバーフロント研究所, 2009)

Figure 3.13 A Bio-Top project used for floodplain regeneration (リバーフロント研究所, 2009)

Based on 15 years of experience in implementing the "Nature-oriented *type* Rivers" project and summarising the problems that have emerged, in October 2006, the MLIT of Japan proposed a new project model, namely the "Nature-oriented Rivers." The key to the transformation from "Nature-oriented *type*" to "Nature-oriented" is to free the concept of "type." The removal of "type" includes getting rid of unified shapes and methods and getting rid of demonstration projects and representative projects. It also includes shifting from the river conservancy construction project to river management, from the restoration of individual sections to the restoration of the whole river, from independent river conservancy projects to integrating with local life, history, and culture.

3.3.3.2. *Waterfront Space Design*

The waterfront space satisfies the needs of modern people with its superior hydrophilicity and adaptability. The attraction of the waterfront space lies in its visual, psychological, and physical stimulation: the changeable water shape and the colorful light effects would inspire thinking and imagination; the fresh air would adjust spirit and emotion; the symbiosis of animals and plants would remind people the richness and loveliness of nature. The very different feelings and impressions in the waterfront space's activities make it an indispensable part of modern cities.

The waterfront space design is a diverse intersection of urban design, architectural design, and landscape design, an organic combination of multiple projects and investments. Therefore, the planning and design of the waterfront space should be dynamic, guiding each development and construction activity through flexible methods to ensure the initial intent. On this premise, the waterfront space design in Japan proposed flexible control methods. It has formulated detailed design guidance and management regulations for environmental elements, forming a complete management system and working procedures.

- **Building Height.** The height control of waterfront buildings is the primary part of urban waterfront design. An appropriate height control guidance can ensure an open, rich, and aesthetic of the waterfront's visual space. It includes two aspects: one is the height relationship between buildings. Generally, the waterfront buildings are mainly low-rise, and the height gradually increases as the building position backs off. It is to provide viewing conditions for more residents while enriching the landscape levels along the waterline. The other is the relationship between the building and the surrounding landform environment. Generally, the building group's contour line and the environmental background should highlight the environmental characteristics and create a beautiful rhythm change.

- **Roof Form.** In a densely built street space, the lower part of the building has a closer relationship with people and form a "street wall." The urban waterfront space has the characteristics from both street space and wide water surface, making the skyline formed by the street wall essential. As a superior visual condition, the roof form plays a decisive role as flexible planning control methods. Such control includes the roof volume, the architectural style, the overall relationship between buildings, advertising, and equipment. Moreover, more strict and detailed regulations for the high-rise buildings play a leading role in the landscape.

- **Building Layout.** As a direct component of "street walls," building spacing and building planes can directly affect waterfront space division. The waterfront planning of Kobe City uses two indicators, namely the vacancy ratio and the gap ratio, to control the building layout. The vacancy ratio should be between 3/10 and 4/10, and the gap ratio should be less than 7/10 to ensure the visibility and hierarchy of the waterfront landscape (Giovinazzi & Giovinazzi, 2008). Meanwhile, the high-rise buildings facing the water should have a pleasant background for the sightseer. Usually, a building is divided into the upper, middle, and lower sections, and the upper and middle sections are controlled by the construction area and the horizontal diagonal to prevent a vertical building facade from affecting the landscape of the waterfront space

- **Exterior Wall**. The distance between the exterior wall of buildings and the waterside space can affect the waterfront space experience. Hence, the exterior wall's location and the back-off requirements above a certain height are controlled to intimate the open and approachable waterfront space. Such control varies greatly from cities, ranging between 3 and 50 meters (Seguchi & Malone, 1996). The planning of Tokyo's Rinkai Fukutoshin Seaside Park is considered an example of landscape control with detailed regulations on exterior walls.

- **Open bottom.** The open bottom is a control measure when the waterfront area is in the city center with limited land and high building density. It requires the high-rise buildings to open the ground floor as public activity spaces to increase the waterfront space capacity and openness. Besides the standard ground-floor-overhead treatment, a brand-new concept of "inner courtyard" introduces the atrium into the waterfront planning, aiming to create an organic combination of "natural, artificial, and human" public environment.

- **Greening.** Greening can make up for the artificial environment's shortcomings, increase landscape levering, and enrich the environment. Therefore, greening is an indispensable control element in the planning of waterfront space. Landscape regulations generally specify the seasonal greening, color relationship, greening with slope protection, and several ideas and suggestions.

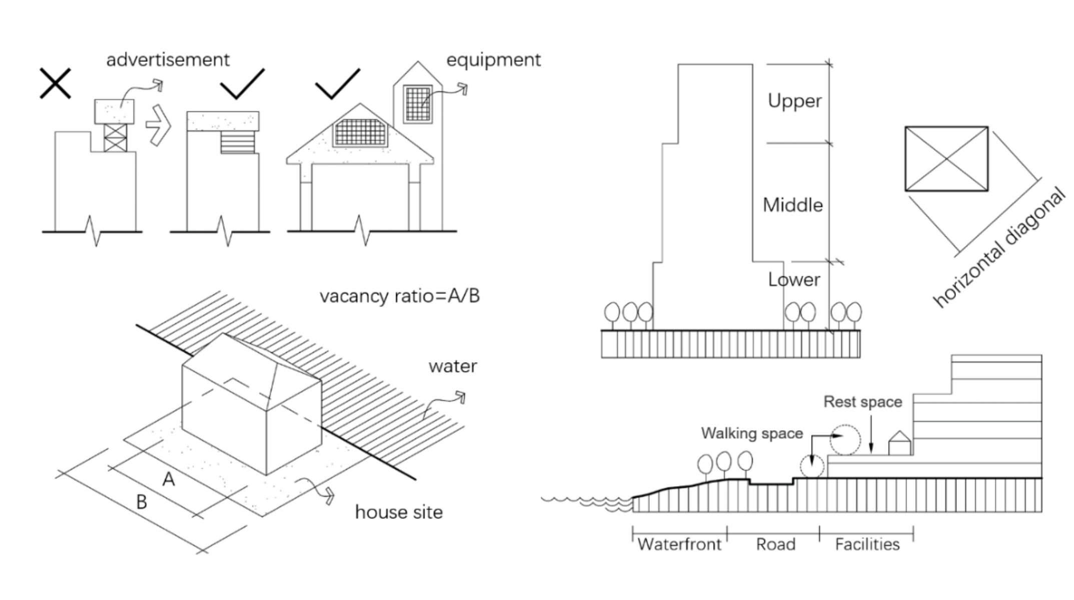


Figure 3.14 Example of typical Japanese waterfront space design regulations (金广君, 1994)

In terms of specific landscape design, Japan has provided many excellent examples of WSUD. As an effective combination of Japanese characteristics and universal concepts, the nature-oriented river design is one of Japan's most outstanding results in the practice of WSUD. At the same time, Japanese architects and landscape designers also contributed many excellent waterfront landscape design cases. In general, the basic principles of WSUD have been very well practiced in Japanese landscape design.

3.4. Conclusions

The Water-Sensitive Urban Design (WSUD) research framework is used to incorporate related Japanese practices in the three key aspects of water source safety, flood management, and waterfront landscape in this study. In general, Japan follows the WSUD concepts and incorporates natural environments, engineering technology, and cultural values into its activities, resulting in WSUD that is uniquely Japanese.

Japan, in particular, has placed a focus on forest conservation in terms of water source safety, as well as adjusting the urban water environment through water supply facilities and water demand. On this basis, Japan introduced extensive flood control measures and developed a set of useful infrastructure measures, such as super levees and rainwater storage facilities, in response to the occurrence of flood disasters. On a smaller scale, Japan created a more natural landscape by constructing nature-oriented rivers with regional materials and parts, as well as enforcing regulations that guided the design of waterfront space.

For the study of WSUD, Japan provides many precious examples. The natural geographic characteristics determine that rivers are closely connected with the city, while the high urbanization rate makes the river treatment in cities more complicated. No matter the construction of Super Levees, the construction of Underground Discharge Channel, or the compound utilization of river beaches, all reflect Japan's unique thinking and design, which are worthy of further in-depth research and discussion in the field WSUD.

There are several studies in the field of water environment that cover all applicable topics, and we only discuss a small portion of the subject related to water sensitivity, so there will undoubtedly be some gaps. At the same time, we concentrate on basic engineering activities while ignoring a number of Japanese policy decisions. Furthermore, regarding Japan's unique decentralization system, the local governments and various NPOs also play essential roles in river management and urban design, which is difficult to discuss due to limited space. In general, we hope to provide readers with an overview of WSUD in Japan, and we intend to expand on the related sections in the future study.

Water-Sensitive Urban Design is an essential part of Low Impact Development in the era of climate change. As people pay more and more attention to environmental protection, this field is bound to usher in considerable development. We hope that Japan's experience can help humanity meet the challenges of this century.

CHAPTER 4. THE IMPACT OF THE DEVELOPMENT OF INTERNATIONAL TRADE PORT IN JAPAN ON THE FORMATION AND EVOLUTION OF REGIONAL INDUSTRIAL CHAIN RESPONSE TO THE REQUIREMENT OF SUSTAINABLE INDUSTRIAL DEVELOPMENT

With the background of the rapid advancement of the Belt and Road Initiative, the attitude of the Japanese government and business community towards the Belt and Road Initiative is undergoing a negative to objective change. This change has created the need for long-term effective Sino-Japan cooperation in the future. Under this premise, maritime transportation is an essential way for trade links between China and Japan. Due to the influence of geopolitics and other factors, Japan has long-term development history and a profound development foundation in the field of port trade and has also formed a characteristic model of the combination of ports and inland industrial chains. This chapter takes the construction of Japanese ports and port cities as an example to clarify the development path and organization model of Japanese trade ports and provide a reference for future maritime trade cooperation between China and Japan based on the Belt and Road Initiative.

4.1. Introduction

In the emerging Asian region, where infrastructure investment needs are high, China's Belt and Road Initiative has drawn attention.

In the meantime, Japan has so far promoted infrastructure investment in emerging Asian countries directly through bilateral institutions such as the Japan International Cooperation Agency (JICA) and the Japan Bank for International Cooperation (JBIC), or indirectly through multilateral institutions such as ADB and the World Bank. Since 2015, Japan has launched a stance that emphasizes "quality" infrastructure investment and is deepening cooperation with the US-Australia under the concept of "free and open Indo-Pacific."

From a political perspective, the Abe administration launched the "free and open Indo-Pacific" strategy in 2016. It captures the dynamism created by the intersection of the "two continents" of Asia and Africa and the "two oceans" of the Pacific Ocean and the Indian Ocean and maintains and strengthens a free and open maritime order based on the rule of law. It is said to be a strategy. Specifically, from East Asia to South Asia, the Middle East, and Africa, we will promote infrastructure development and connectivity, revitalize trade and investment, improve the business environment, develop human resources, and It is said that the country is built with respect for ownership. The Japanese government says that the "free and open Indo-Pacific" strategy does not exclude China, but rather embraces it (庄司智孝, 2020).

From the business and corporate perspective, it has already been seven years since the concept of Belt and Road was launched. Perceptions and attitudes of Japanese companies of Belt and Road have changed along with changes in Japanese political circles and public opinion. Following the holding of the Belt and Road Summit in Beijing in May 2017, the attitude of the Japanese government began to change, and Japan announced that it would join the China-led Belt and Road conditionally. In December 2017, the Japanese government established the "Guidelines for Private Economic Cooperation" and allowed Japanese companies to participate in the Belt and Road business in the three fields of energy conservation/environmental cooperation, industrial sophistication, and utilization of logistics. When Prime Minister Li Keqiang of China visited Japan in May 2018, Japan's Ministry of Economy, Trade and Foreign Affairs, and China's National Development and Reform Commission/Commercial Affairs Department signed a memorandum of understanding regarding Japan-China third-country market cooperation. Support Japan-China business cooperation related to Belt and Road. Furthermore, in October 2018, the "Japan-China Third Country Market Cooperation Forum" was held in Beijing when Prime Minister Abe visited China. Promoting Sino-Japan cooperation in third-country markets has become a primary policy stance on the Belt and Road of the Japanese government.

From the perspective of Japan, China is located in a very dynamic Asia-Pacific region with abundant mineral resources, agriculture, culture, and other resources. China believes that international economies have mutually complementary relations, and good cooperation can achieve new cooperative development and common prosperity (江原規由, 2014).

The relaxation of the Japanese government's attitude towards the Belt Road initiative has directly affected the attitudes of Japanese companies, and the active cooperation between companies has further promoted the cooperation between Japan and China. Although Japan is not currently a country along the Belt and Road, it is strategically a part of China's promotion of the Belt and Road. China and Japan have a stable and close economic and trade relationship. Whether in infrastructure, energy, trade, or financial and monetary fields, China and Japan can use the "Belt and Road" platform to establish a solid foundation for long-term cooperation.

With this precondition, China and Japan are always looking for the best channel for trade cooperation. In the world, marine transportation has always been the main way for countries to trade. About 80% of world trade is based on maritime transportation, and a large part of them are mainly transported by container ships. Since 2000, the expansion of the international production network has led to the development of supply chains, triggered by China's accession to the WTO and the progress of regional integration centering on ASEAN. As a result, ocean-based international transportation centered on container transportation has grown dramatically.

Japanese Maritime Center researcher Hiroko HONZU analyzed the impact of the Belt and Road Initiative on the world shipping market and China's shipping industry. She pointed out that China has the third-largest commercial shipping scale in the world and has a huge impact on the world shipping market. The impact of the Belt and Road Initiative, especially the 21st Century Maritime Silk Road, on the global maritime market is to increase trade volume, promote the growth of transportation demand, and build a maritime logistics network to promote the maritime market. The impact of the "Belt and Road" on China's shipping industry is to promote the cooperation, mergers, and reorganization of domestic shipping companies and to promote Chinese companies' investment, acquisition, and financing of overseas ports. (本図宏子, 2016)

The Belt and Road Initiative mainly focuses on infrastructure development such as ports, roads, railways, and airports, but Japan is also actively promoting infrastructure exports as a national policy. Chinese construction companies are backed up by a substantial domestic market, and their management scale is also becoming huge. Not only is its lower price, but the quality has also grown in recent years, making it a rival to Japan in the medium to long term. On the other hand, the construction of Japanese overseas ports is steadily advancing. Given the massive demand for infrastructure in Asia, Japan has many business opportunities.

In particular, the port and shipping industry has strong internationality and strong international ties between companies. The port development is not only about the port, and there are many cases of comprehensive development of the industrial area and urban development in the hinterland of the port, so the port construction creates more business opportunities for both Japan and China.

At the domestic level, Japan currently has a resource background that can serve long-term maritime trade development and already has the conditions to join the One Belt One Road initiative. In terms of port construction and port city development, Japan has formed a unique development model due to its unique geographical environment and resource. The content of this chapter will focus on the unique model of the construction of Japanese ports and port cities to reflect the domestic response of Japan to further Sino-Japan trade cooperation in the future.

Under the background of economic globalization, the development of industrial and manufacturing industries in emerging countries represented by the BRIC countries continues to affect the world industrial pattern. Since the 1990s, with the economic development of China, South Korea, Singapore, and other countries, the trade pattern in the coastal areas of Japan has correspondingly changed. As a gateway to exchanges with other countries, the trading port has always occupied a crucial strategic position in the development and construction process of the continental countries of Europe and Asia. Hence building ports and airports is becoming an important trade strategy. In this process, Japan gradually lost its advantage in foreign trade, which significantly changed the development of Japanese port cities as well as the trade pattern of East Asia.

Since the 1950s, the planning and construction strategy of the Japanese port trade area gradually changed, resulting in a development model based on regional industrial development. With the economic miracle in the post-World War II era, the Japanese government established four representative industrial zones, the Keihin Industrial region (Tokyo), the Chukyo Industrial Zone (Aichi), the Osaka-Kobe port Industrial Zone (Osaka), and the Kitakyushu Industrial Zone (Fukuoka). These industrial regions integrated industrial and port trade resources of existing urban areas and rapidly formed into new port economic development regions, which contributed greatly to Japan's economic development. Since the 1970s, the major industrial structure of Japan has changed from basic industrial manufacturing to a tertiary industry dominated by finance and services. With the acceleration of globalization, competition between port areas became more intense, and Japan lost its original advantages in international trade competition (LV & ZHANG, 2006). At the end of the 20th century, in order to improve the international competitiveness of the national ports, the Japanese government began to adopt a series of targeted strategies to integrate existing port resources to improve the shortage of port infrastructure and reduce inefficient competition. At the same time, the Japanese government implemented a targeted National Strategic Special Zones policy to strengthen the scale of coastal port cluster construction and transform from simply developing industrial manufacturing to developing modern service industries and high-tech industries (Yeh, Hsu, Su, Chen, & Liu, 2009).

The port can be regarded as the local industry and infrastructure of urban life, which is an important factor in the international competitiveness of a place or a city. Taking Hokkaido Port as an example, in the course of historical development, a series of policies such as the opening of Hakodate port and the establishment of shipping bases have had an important impact on the development of the region. At the same time, Hokkaido is located on the East Asia-North America route, surrounded by Sakhalin and Tumen River regional development and other economic projects. The superior geographical location laid the foundation for the implementation of the port development plan from a global perspective. In terms of the geographical environment, Japan's urban-port relationship is different from land-locked countries. Maritime transportation connected the port area and the domestic transport system and promoted the development of the region. On the other hand, the rapid development of internationalization and containerization has changed the function of international logistics ports in Japan.

The China-Japan-Korea Circulation and Logistics Joint Report (2006) summarizes the overseas transfer of Japanese manufacturing industries and the distribution of domestic transportation methods and their evolutionary process. The system of an efficient logistics network through maritime transportation has been built to support the efficient international division of labor with East Asia and improve the overall transshipment function of the terminal by improving the transshipment efficiency of small-volume cargo in some international ports. Compared with the changes in container transportation in neighboring countries, it is apparent that the port developments of Asian countries relate to the export of their own products and also involve the import efficiency of goods from other countries, with the intention to promote large-scale construction process and transshipment goods preparation. However, the limitations of the Japanese port administration have made it impossible to effectively grasp the international situation and to respond to changes (Sintusingha, Wu, Lin, Han, & Qin, 2021) flexibly.

In terms of port administration, Japan has for a long time implemented local decentralization and citizen co-construction policies in port construction. This practice made it difficult to respond to changes in the international situation and has produced many single-function port facilities (立法と調査, 2010). The Keihin Port Shared-vision (2009) identifies a diversified supply and demand chain management concept based on globalization and consumer demand, discusses the new trends of logistics and transportation reform in the Keihin Port area, and clarifies the main functions of major urban ports such as passenger transportation, sightseeing, disaster prevention, and urban public service. This program played an important role in the reform of Japanese port administration agencies. Moreover, Japan's port policy has constantly been changing according to the development of the post-war economy. Based on changes in the pattern of foreign trade, many policies and laws have been promulgated to adjust the relationship between the development of Japanese ports and the ports of Asian countries (海事交通研究, 2008).

With this development and transition, the government of Japan has been exploring new port city construction models based on: the original port advantage economy to develop superior coastal industries; the combination of inland production resources; extension of existing industrial chains; and the formation of new industrial clusters to promote the development of regional economies. The relatively mature industrial chain and the scale economy innovation model that was formed in the port area continue to bring new possibilities to Japan's economic construction.

The research on Japan's port cities recognizes the fundamental patterns of port cities development and evolution, establishes a correct understanding of the international logistics port construction in Asia. We can use these existing development experiences as a reference and provide theoretical support for the practice of port construction for China's BRI.

4.1.1. BRI and the development strategy of overseas port cooperation

Since his inauguration at the end of 2012, China's President Xi Jinping has been promoting the establishment of an economically stronger Asian community, bringing in the historical and cultural ties between the countries along the ancient Silk Road and investing in major infrastructure projects in the region. With this background, the "Belt and Road Initiative" (BRI) was promoted (Bi & L., 2015).

The BRI involves 65 countries and regions, with a total population of 4.5 billion or 62.5% of the world's total, accounting for 28.6% of the world's total economic output.

The strategic concept of this initiative emphasizes the "community of interests" of mutual benefit for all countries. Studies have shown that the more international cooperative cities, the faster the development and the higher level of openness in urban economy development (LIU, TANG, & Astronautics, 2006).

China's Ministry of Foreign Affairs and the Ministry of Commerce jointly issued the "Vision and proposed actions outlined on jointly building Silk Road Economic Belt and 21st-Century Maritime Silk Road", which proposed strengthening the construction of coastal cities such as Shanghai Tianjin, and Ningbo[3]. This roadmap focussed on improving the competitiveness of the 15 coastal port cities, which is of great significance to the effective implementation of the BRI strategic decision and the development of China's economy. It is expected that the 15 port cities play a decisive role in the speed of regional development.

As the key node in the development of shipping, logistics, trade, and other industries, coastal ports are an important infrastructure for a country or region to integrate into the process of economic globalization and integrate regional and even global economic resources. To meet those criteria, the implementation process of the BRI must ensure the full potential of the strategic fulcrum of China's coastal ports, optimize the port's development planning, expand the port's comprehensive functions, and strengthen its interconnection with other ports, land transportation hubs and logistics systems along the route.

The proposed "21st-Century Maritime Silk Road" initiative consists of two main sea passages leading to the Indian and Pacific oceans. The western route starts from the Chinese coastal port to the South China Sea to the Indian Ocean and extends to Europe. The route connects between and supports the coastal economic belt of China, the China-Indochina Economic Corridor, the China-Brazil, Bangladesh-China-India-Myanmar Economic Corridor, and forms the China-Indian Ocean-Africa-Mediterranean blue

[3] Other cities include Zhoushan, Guangzhou, Shenzhen, Zhanjiang, Shantou, Qingdao, Yantai, Dalian, Fuzhou, Xiamen, Quanzhou, Haikou and Sanya

economic channel. The southern route starts from the Chinese coastal port through the South China Sea to Oceania and the South Pacific island countries, forming the China-Oceania-South Pacific blue economic channel (**Figure 4.1**).

According to the development status of the ports along the BRI corridors during 2007-2018, the construction of the two routes is advancing rapidly. At the same time, the two new channels have also been proposed. The first is the Maritime Silk Road that starts from China and extends through the Pacific Ocean to Latin American. And the second is the Silk Road on the ice that crosses the Arctic. The construction of the west and south routes, which serve as the main axes of "the Maritime Silk Road", takes priority with the ice and the China-Latin America Pacific routes to complete the vision.

Figure 4.1 Oversea ports cooperating in the BRI

The decisive status of BRI port cities and the trade links between them have raised several new topics on port city development, and the strategies and policies of Japan's port cities can provide valuable experience for it.

4.1.2. The current situation and dilemma of Japan trade

Japan is a country with a relatively small area, a large population, and limited resources. However, Japan achieved miraculous economic development and became a global economic power that is closely related to the excellent natural conditions of the port area, which contributed significantly to the development of the maritime industry. Depending on this condition, Japan became a foreign trade-based country with an established export-oriented economy in which raw materials are imported to overcome domestic resource shortage.

4.1.2.1. *Trade dependence of Japan*

A country's trade dependence depends on many factors with economic scale and geographical attributes the decisive factors (Harris, America, the Caribbean, & Littlefield, 2008). While Japan changed from a small economy to a world power, the country's trade dependence has not changed much, especially when its neighbors have made great economic progress in total trade volume. Generally speaking, both the developed and the developing countries adopted export-oriented development strategies to promote the development of the local economy. Diverging from these traditional development patterns, Japan adopted measures to protect its domestic enterprises instead of promoting foreign capital influx. Although foreign investment restrictions have been gradually relaxed in recent years, non-economic systems and customs, as well as higher corporate tax rates, still limit the scale and role of foreign capital in industrialization.

4.1.2.2. *The transformation from air to maritime transportation*

In the 1960s and 1980s, air transportation was the fastest of Japan's delivery channels but also with the highest cost. After the 1990s, with the increase of routes and economic growth, air transportation costs decreased while sea transportation speed increased. Compared with pure air transportation, the new mixed transportation method that combined sea and air transportation eliminated the cost disadvantage with improved speed. In 2004, with the increase in the volume of goods shipped to the United States from Asia, the logistics throughput of the two major ports in the West Coast of the United States exceeded the port load, resulting in some conversion from maritime logistics to aviation logistics.

From the perspective of the logistics practitioners, the demand side applied a series of measures responding to the changes in the production environment and efficiency of logistics. While it is important to maintain the competitiveness of commodity prices, at the same time taking measures to reduce logistics costs is also necessary. Enterprises adjust the emphasis of logistics and supply chain management according to logistics efficiency and take measures to curb aviation transportation in consideration of cost reduction. The policy tolerance for maritime transportation also increases the utilization rate of maritime transportation.

While from the perspective of the supplier side, the use of maritime transportation has accelerated the transportation speed, shortened the period of preparation for ordering and delivery, and greatly improved the timeliness. At the same time, with the increase of shipping frequency and the increase of routes, the transport capacity has been expanded and the logistics network systems are continuously improved. The advantages of air transportation in offshore Asian routes are further reduced and the maritime transport time is shortened.

4.1.2.3. *The declining international competitiveness of Japanese port*

Since the 1990s, the competitiveness of Japan's major trading ports has begun to show varying degrees of decline. Measured by the number of port container freight changes, compared to international major trading ports, the container throughput of Japanese ports is losing its advantage in quantity. In terms of container throughput of major ports in the world from 2012 to 2016, Shanghai, Singapore, Shenzhen, Ningbo-Zhoushan and Busan are the top five major container freight ports in the world[4]. Among them, Shanghai Port reached 36537kTED and 37133kTED in 2015 and 2016, and showed a growing trend. At the same time the port with the largest throughput in Japan, Tokyo Port has not reached 5000 TED in total dropped in the international ranking to 30 in 2013, and continues on a certain downward trend. The container freight throughput of other major ports in Japan also showed varying degrees of decline.

[4] “The Top 100 Ports of 2014 of Containerisation International”: 2015-2016, “The Top 100 Ports in 2016 of Lloyds List Containers” Unit: kTED (Twenty-feet Equivalent Unit, international standard unit).

As for the main reasons for the decline in the competitiveness of Japanese port trade, some studies observe that, in the process of development, due to monopoly management, price protection, port approval, customs clearance process and other reasons, the utilization cost of Japanese ports is still high compared with other international ports of the same type. Secondly, the economic growth and consumption increase of other emerging countries in Asia have influenced the adjustment of Japan's domestic industrial structure (Japan Industrial Research Institute, 2002).

4.2. Results

4.2.1. Japan's new port strategy

To answer to the rise of Asian competitors pre and post the commencement of BRI, Japan has been exploring new port strategies on both trade policies and port city construction. These explorations lead to complete industrial chains and regional economy connections, which can be a reference for BRI about developing economically vibrant ports.

4.2.1.1. *The trade policies of Japanese ports*

Faced with the dilemma of the declining international trade competitiveness, the Japanese government began to seek new development paths and possible breakthroughs for the port area. At the end of the 20th century, in order to promote the development of regional industries and trade, and cope with the increasingly significant employment problems, the Japanese government established the Naha Free Trade Zone in 1988 and the Midtown Bay Newport Special Free Trade Zone in 1999, collectively known as Okinawa Freedom. This trade zone is the only free trade zone in Japan. In order to attract capital and enterprises to enter the Okinawa Free Trade Zone, the Okinawa County Government has adopted a number of preferential measures in the implementation of the tax policies for the industry, established the bonded area system and carried out targeted taxation and financial incentives for enterprises. Taking the bonded area system as an example, products for export can be stored, processed, produced and displayed in bonded places without duties and consumption tax.

Meanwhile, imported foreign products can also be stored, quality inspected, reprocessed, classified with the tax-free policy, and enter the domestic distribution networks according to market demand.

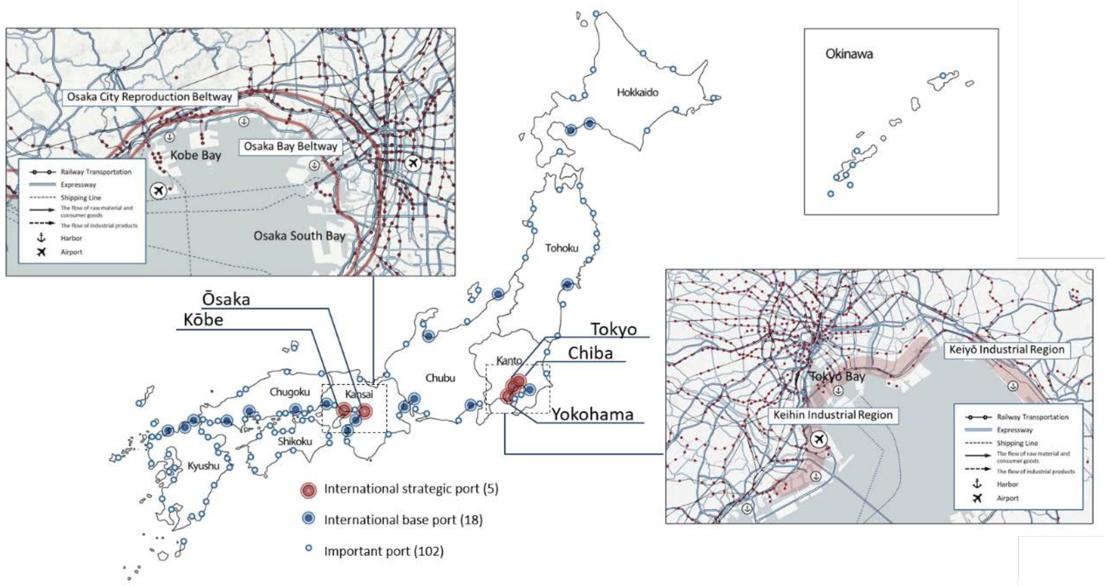


Figure 4.2 The distribution of Japan's main ports (data source: Ministry of Land, Infrastructure, Transportation and Tourism)

In terms of trade port management policies, according to the statistics published by Japan Ministry of Land, Infrastructure, Transportation and Tourism, Japan has 994 ports by April 1st 2017, including five international strategic ports, 18 international base ports, 102 important ports, and 808 local ports and 61 regular ports (**Figure 4.2**). Accordingly, Japan's national airports are also divided into basic airports, local airports, regular airports and shared airports. The grading system improves the efficiency of operation and management, which is also conducive to the cooperation between the airport and the maritime port. Thus a complete logistics and transportation system combining aviation and shipping was formed in Japan since 2010. The location of the port is highly relevant to the domestic public transportation network. The international strategic port is mainly located in densely located areas of railways and highways, and the international base port is located by the main structural road network. The perfect transportation system provides a good foundation for the development of port trade and the extension of the industrial chain.

4.2.1.2. *The construction of Japanese ports*

In order to strengthen the pivotal role of Japan's major ports in international trade network, and further redress the problems of few free trade zones, complicated restrictions, complex bonded relationships, and cumbersome procedures, the Japanese government simplified the process of transhipment from ports to the inland airport and established online platform to manage port transportation since 2010. In order to improve the continuity of land transport routes, the international ports are located at the place with more geographical advantages in terms of distances difference between Japan and South Korea. At the same time, the Kansai International Airport is used to realize the composite transportation system consisting of aviation, shipping and land.

The areas that have been selected as the representative port include the Shizuoka Port, which is the neighbouring economic supporting prefecture, and the Keihin Port, which is the international container strategic port, and the Kushiro port, the Shibushi Port, as the international strategic port, and Onahama port as the international coal transporting port.

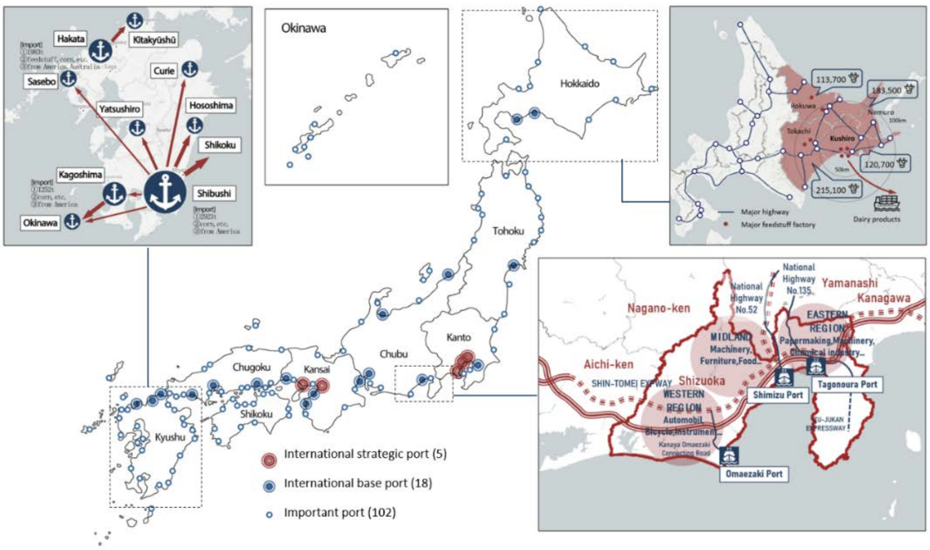


Figure 4.3 The industrial chain structure of Japan's Ports (data source: Ministry of Land, Infrastructure, Transportation and Tourism)

A) The port of Shizuoka Prefecture

Shizuoka Prefecture is located in the central part of Japan, with a 519 km coastline (data from the Japan Ports Authority of the Transport Ministry). It has had many important ports since ancient times. So far, Shizuoka Prefecture built 12 local ports and a newly built international port "Shimizu Port", two important ports "Tagonoura Port" and "Omaezaki Port". Industrial raw materials from North America, South America and other parts of Japan imported through Tagonoura Port and transported to Shizuoka Prefecture and surrounding areas such as Nagano Prefecture and Yamanashi Prefecture to provide more affordable raw materials for local manufacturing. The Shizuoka government established some primary production bases in the vicinity of the port area. These facilities reduce transportation costs thus improve production efficiency. After primary processing, the raw materials are transported to the secondary production bases around Shimizu Port and Omaezaki Port for further processing and packaging. Afterwards, the products are transported to domestic market or exported to North America, Europe and other regions. Based on this process, some complete industrial chains and industrial clusters have been established in the port area of Shizuoka Prefecture. The major industries in western region are automobile manufacturing, bicycles and musical instruments. The central part is mainly occupied by electrical machinery, furniture and food. In the east, papermaking, machinery and chemicals are the most dominant industries (**Figure 4.3**).

B) Keihin Port

Keihin Port is the largest centre for foreign container cargo trade in Japan and the largest automobile business centre in eastern Japan. It is a comprehensive international strategic port in eastern Japan which provides strengthened support for the residents' life, industry and energy supply in the metropolitan area. As the ranking of Japanese ports in international container shipping volume has been decreasing in recent years, Keihin Port, as an important trading nodal station in East Asia, adopted a series of measures to reorganize and strengthen regional functions since 2011. In the meantime, these measures strengthen the competitiveness of inland navigation, rail and road transportation, expand suppliers' benefits and increase North American based routes. Building on existing routes to North America, Japan expands Asian routes and enhances transportation capacity to strengthen the port functions.

C) Kushiro Port

In 2011, in order to achieve the low-cost and stable transportation of goods essential to the citizens quality of life, the Ministry of Land, Infrastructure, Transportation and Tourism of Japan positioned 10 ports in Japan including Kushiro Port as cargo import bases and international bulk cargo port. Public investment combined with private investment promoted the expansion of warehouses and the construction of feed stuff factories. As the second mainstay of the western port area's development, based on the large-scale ship maritime transportation, the Kushiro Port is expected to achieve an annual throughput of more than 1.3 million tons and a 10% cost reduction within five years.

As an important node of the inland industrial chain in Hokkaidō, Kushiro Port is closely integrated with the regional major traffic network (**Figure 4.3**). With its superior natural resource conditions, the western part of Hokkaidō has established a feed stuff production area which mainly serves the eastern livestock industry. Meanwhile, livestock industry clusters formed in eastern area including Rokuwa, Nemuro, Tokachi. At the same time, the feed stuff products from the western region are transported to and support the eastern livestock production area. After further processing, the downstream products are transported to various regions or exported through Kushiro Port and thus a complete industrial chain is established.

D) Port of Ohamacho

Ohamacho Port promoted the joint transportation of large vessels following the international bulk cargo strategic port policy. This measure reduced the cost of maritime transportation by 40%. At the same time, the soil sediment produced by the mooring site is used for the land-reclamation project in the eastern port area. As the core node of the Fukushima Prefecture's thermal power generation industry, Ohamacho Port takes imported coal to support the production of a number of thermal power plants in the port area and inland areas. Therefore, the Fukushima Prefecture established a production centre for thermal power generation industry in Kantō area.

E) Port of Mizushima

The cargo throughput of Mizushima Port ranks fifth in Japan. The steel, petroleum refining, petrochemical, automobile, and feed stuff industries are distributed around the port. The volume of export-oriented manufacture is about 4.4 trillion yen (2008). The related industries are located as a centralized layout pattern in the port area. The production and processing of raw materials provides support for the downstream manufacturing industry, reduces logistics costs and improves regional production efficiency.

F) Shibushi Port

Shibushi Port is the port with the largest crop input volume in Kyushu. At present, there are three storage companies and six feed stuff factories behind the public wall of the port buoy berth, forming the largest feed industry terminal in Kyushu (**Figure 4.3**). In order to achieve stronger international competitiveness for the local feed stuff products, Shibushi Port adopted a series of policies to promote the cooperation between private and public investments since 1998.

4.2.1.3. *The construction of Japan's major trade ports*

A) Tokyo Bay Area

The Tokyo Bay is located on the Pacific coast of central Honshu. The east and west sides of Tokyo bay are the Boso Peninsula (Chiba Prefecture) and the Miura Peninsula (Kanagawa Prefecture). The two peninsulas are enclosed and form an 80 km coastline in the Tokyo Bay area. Tokyo Bay promoted the development of the Tokyo metropolitan area to form the pattern of "One Capital, Three Prefectures" which including Tokyo, Saitama, Chiba and Kanagawa. The total area is 13,562 km^2 and the total GDP is about 15482 billion yen (2018).

Tokyo Bay has a dense port group, and the six internal ports have a good division of labour and cooperation. According to the overall planning, Tokyo Port is an import port mainly focussed on domestic trade; Yokohama Port is an international trading port that handles heavy industry products as the main export production; Chiba Port's major industries are energy imports and industrial export; Kawasaki Port is a specialized port for industrial enterprises, which mainly undertakes raw material import and production export; Kisarazu Port is mainly engaged in tourism development, and Yokosuka Port is a Military port. This division of labour avoids unnecessary competition in the Tokyo Bay area and improves logistics and regional development.

According to the data from Tokyo Bay Airway Office, the port cargo throughput in the Tokyo Bay area has reached 40% of Japan's total import and export volume, and the import volume of crude oil reached 30% and LNG reached 50% of the total amount. Japan's domestic production of oil, natural gas and other energy sources, industrial raw materials such as ore and crops such as wheat, soybeans are imported through the Tokyo Bay area. In the meantime, a healthy development pattern of the industrial chain has been established with the export of automobiles and electronic products.

The Tokyo Bay area has international trade advantages and sufficient hardware support for port capacity (**Figure 4.2**). Tokyo provides a strong development support as a regional centre city, and regional integration also achieved integrated development, these factors make the Tokyo Bay area become an international shipping centre of the whole Japan and influences world trade pattern.

B) Osaka-Kobe International Port Area

The Osaka-Kobe Port, which consists of Osaka and Kobe ports, is an international container strategic port that has kept pace with Tokyo Port. In terms of total trade volume and scope of influence, Osaka-Kobe Port's container import and export throughput reached 4.22 million TED in 2014. The radiation range includes Toyama Prefecture, Gifu Prefecture, Aichi Prefecture and the entire Western Japan region. Therefore, it is the second largest centre of Japan's economic and industrial activities.

The transportation infrastructure of the Osaka-Kobe Port is well-developed. The road transport centres on the bay area as a circular pattern. There are two coastal trunk lines, the Osaka Bay Beltway and the Osaka City Reproduction Beltway, which connects with Kobe and Osaka ports, and formed a road transportation network that radiates through the entire area and becomes an important anchor point for the Japanese national road traffic network. In terms of rail transit, the density of the Osaka area railway station reached 1.12 per km^2, which exceeded the average level of Tokyo metropolitan area, providing an excellent rail transit foundation for the entire port area. At the same time, the Osaka-Kobe Port area contains a number of international air transport bases including Kobe Airport, Kansai Airport, Yao International Airport and Osaka International Airport, providing sufficient support for the port's trading environment. The Osaka-Kobe Port has formed a function of import and export trade base on this sound transportation system. Meanwhile, it has effectively connected major cities in Japan and has gradually become one of Japan's main trading ports (**Figure 4.2**).

4.2.2. Japan's domestic transportation system for port cities

As a mountainous island nation, Japan's geographical conditions call for an efficient domestic transportation system. The well-developed railway and road transportation system of Japan empowers the development of port cities and regional economies, and eventually plays a supportive and supplementary role for international trade. During the development of the port cities along BRI, this kind of transportation infrastructure connecting the inland should also be valued.

4.2.2.1. *Railway transportation in Japan*

Japan's railway began at the end of the Edo Period. The first railway was built in 1872 and various forms of railway system have been established across the landlocked area in Japan while the urban railway transport system was still in its embryonic stage (佐藤誠, 2003).

Since the end of WWII in 1945, Japan's railway industry has entered a new period of development. The Shinkansen, which was launched in the 1960s, made the development of Japanese railways one of the most superior railway systems in the world. The Japanese railway system includes four types, Shinkansen, JR line, subway, and train. Subway and train are operated by local governments. After the innovation of privatization in 1987, the operator in charge of daily management and operation was transferred from Japan national railways (JNR) to Japan Freight Railway Company.

Before the 1950s, railway transportation was the main mode of inland logistics transportation in Japan, with a history of more than 140 years. In 1950, the total volume of rail freight in Japan took 52.2% of the total volume of logistics and transportation, which has shrunk under the competition of road transportation. Nowadays, The inland areas mainly rely on railway transportation to support the oil-based energy imports. The total oil volume transported by railway in Japan in 2008 was 711 tons, of which the traffic volume of Nagano, Gunma and Tochigi accounted for 60% of the total railway oil in 1950 (Ministry of Land, Infrastructure, Transportation and Tourism, 2013). At the same time, agricultural products, livestock husbandry and manufacturing products from domestic regions are transported throughout the country by the railway system and shipped to ports for export. According to the structure of Japan's railway network, the main railway axis that runs through the inland area bears a large proportion of railway transportation with routes radiating from the main axis to the surrounding area, forming a series of rail transportation.

4.2.2.2. *Road transportation in Japan*

Japan's road network mainly consists of highways, national and local roads with road transport beginning in the 1950s. Before that, the main transportation carrier in Japan was the railway. After WWII, Japan's economic recovery brought the rapid development of the automobile industry and related manufacturing industries, and the scale and volume of road transportation continued to grow. Since the 1960s, the economy entered a period of high-speed growth. With the increasing production and the consumption, the production structure undergone modernization reforms. At the same time, the storage sector has been greatly reduced, due to the demand for more timeliness. As an important supporting foundation for road transportation, road system directly affects the development of regional logistics and transportation industry.

In the early stages in development, the progress of road system construction is not sufficient to satisfy the growing demand for road transport. In 1956, only 23% of the national roads in Japan were completed. In 1966, Japan promoted the plan to build a 7,600 km national highway. Under this plan, highways parallel to the coastline are preferentially built than routes that cross the inland mountains. In 1987, the plan was revised to target a road length of 14,000 km and the total length of the completed construction has reached 8,730 km by March 2005. To solve the problems of inefficiency and fee imbalance caused by monopoly, in October 2005, reforms of corporatization and privatization were carried out on the Japan Road Corporation Company (JR), the Capital Expressway, the Osaka-Kobe Expressway, and the Honshu-Shikoku Bridge Expressway Company.

According to the structural characteristics of the road network, the higher ranked six-lane road is mainly built around the Tokyo metropolitan and the Osaka-Kobe port areas, forming important nodes for road transportation. The other roads centred on the metropolitan area and presented a grid-pattern layout, forming an integrated traffic road grid which radiates throughout the inland. By 1987, automobile transportation accounted for 90.8% of the total 3.5 billion tons of total domestic transportation, while railway transportation accounted for only 1.48%. The construction and development of the road system provides an excellent development background for regional industrial production in Japan and provides great conditions for Japan's economic construction.

4.2.3. Challenges and Opportunities from BRI

As an export-oriented economy, international trade and the external environment are vital to the Japanese economy. After the global financial crisis in 2008, Japan's total import and export trade was hit hard and shifting from a surplus to a deficit. Japan's Total Imports recorded an all-time high of 81.3 USD billion in 2012, and Total Exports recorded an all-time high of 74.3 USD billion in 2011. At the same time, as Japan's largest and second-largest trading partners, import and export trade with China and the United State experience a slow recovery (**Figure 4.4**).

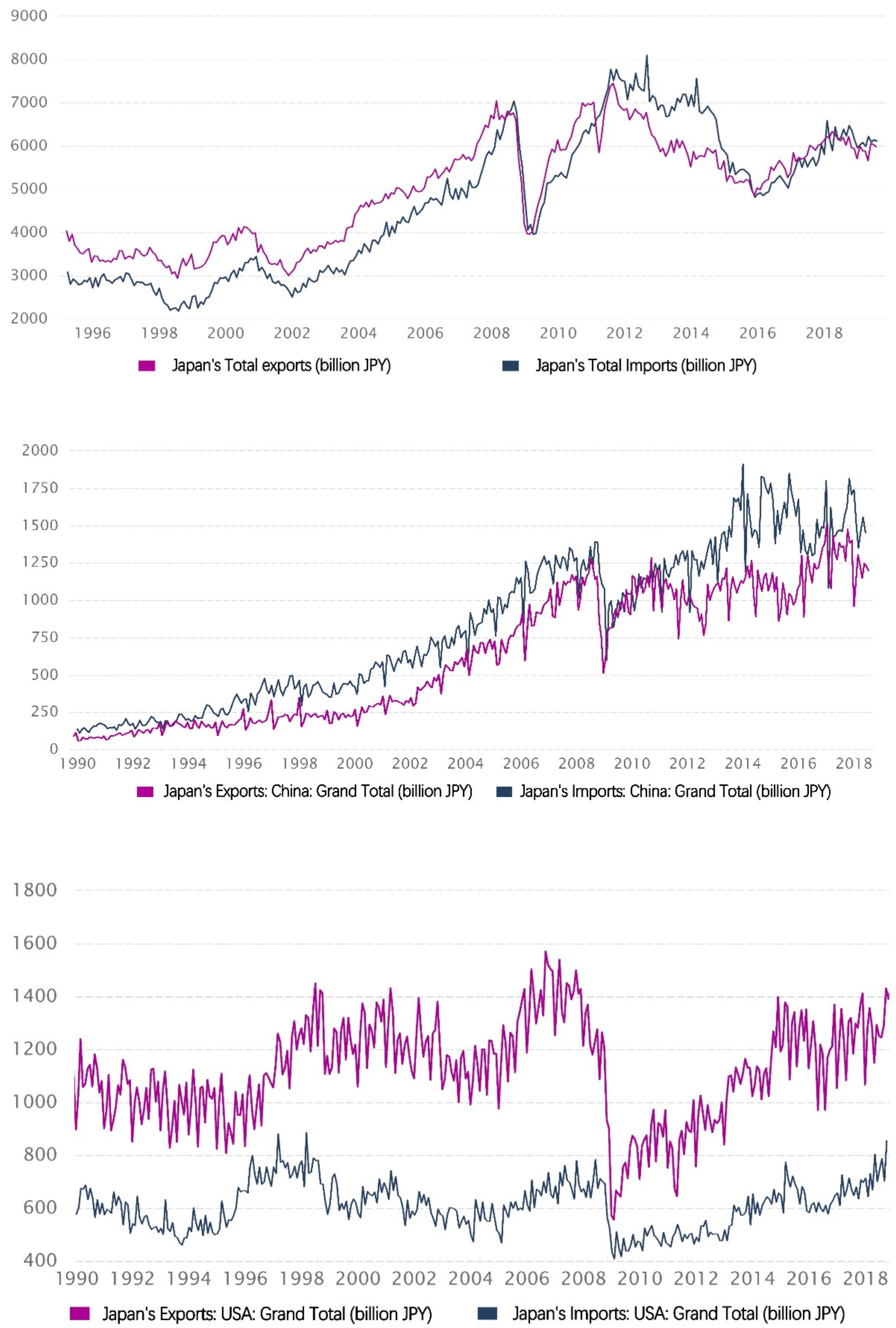


Figure 4.4 The Exports and Imports of Japan (data source: Ministry of Finance)

If focus on port trade, the situation is also gloomy. Since the 2008 financial crisis, Japan's overall port throughput has stagnated, while cargo throughput with China and the United States is slowly shrinking. Japan's new models of port cities needs better external conditions to support its development (**Figure 4.5**).

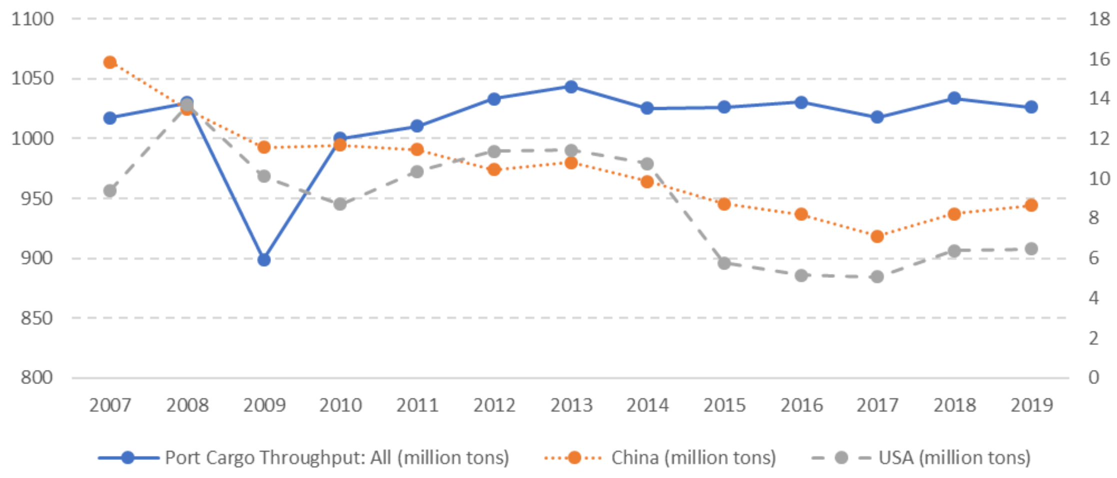


Figure 4.5 The Port Cargo Throughput of Japan (data source: Ministry of Finance)

As an important economy that has not to join the BRI, such situation is both a challenge from Asian competitors and a great opportunity. The completed infrastructure construction and regional industrial chain in the port cities can serve as the basis of international port trade in response to the BRI. And the close economic and trade exchanges between Japan, China and other Asian countries are also possibilities to expand and develop next port city models.

4.3. Conclusions

With the world's third largest economy and the second largest foreign exchange reserves, Japan has long historic operations and deep accumulations in the areas along the BRI and has a corresponding influence on regional affairs. As an important neighbour of China, it has naturally become an important potential BRI participant in the development of the BRI market.

As an important pole in the world economic structure, Japan is currently in an important period of economic development. As important infrastructure to support the domestic industrial development, port areas play important roles in the urban construction. More than just a part of the transportation junction, the port area is serves as an urban area with independent policy system, consumption mode, construction mode and undertake important transitional functions connecting production areas and trade zones. Nowadays, although the traditional manufacturing industry in Japan still maintains a certain level of competitive advantage, there are problems such as insufficient growth space. Therefore, in the perspective of the overall industrial structure, the support of the manufacturing industry for economic growth is gradually decreasing, and the development of emerging industries delayed (Qian-Xi Li, Okamoto Shinichi, 2007). Many ports in Japan can adopt diversified industrial patterns, not just logistics functions. In addition, for some ports that do not have the advantage of trade development in the location, they can make full use of coastal resources, develop innovative emerging industries, win competitive advantages through differentiated strategies, and strive to create liveable cities suitable for the current stage of development. The following experiences can be learned from the development of the port cities in Japan:

The construction of port area should be based on the development of the regional economy, integrate existing development foundation, establish a complete industrial chain, form a unified operation as a whole, and improve production efficiency. The industrial structure and specialization degree of various port cities in Japan are quite different. In the process of development, unique regional pillar industries have been formed. At the same time, pillar industries have brought new possibilities for regional economic development. There are also lessons of the port's role of radiation in the economic development of the surrounding areas.

Another important topic for the construction of port area is to focus on the formation of scale economies effect and industrial clusters, strengthen regional cooperation, strengthen regional advantages, establish a refined division of labour based on the industrial chain, organize production resources with innovative models, and form regional production complexes to improve regional competitiveness as a whole. Regional industrial clusters are manufacturing, and sales to form a complete industrial chain. The aggregation effect can also bring strong and sustained competitive advantages and promote regional industrial development. At the same time, industrial clusters can also bring better support institutions to the region, promote regional infrastructure construction, and bring more development opportunities to the city.

Japan is facing challenges and opportunities brought by the Belt and Road Initiative. The realization of the BRI requires Japan's accumulated port city development experience, and it is also an opportunity for Japan to deeply integrate into Asian trade pattern and revitalize port trade. Hope our introduction to the experience of Japanese port area can help in the process of BRI.

CHAPTER 5. THE CONSTRUCTION OF URBAN PLANNING SUPPORTING SYSTEM USING GENETIC ALGORITHM RESPONDING TO URBAN DECENTRALIZATION FROM THE PERSPECTIVE OF POPULATION CHANGE

In this research, from a macro perspective, we studied the impact of urban development planning on population changes in central urban areas. Regional development plans have different aggregation modes and different development structures for different functional areas. This difference was evaluated as a different development model. Kanazawa was used as a case study area, and the corresponding development plan was determined by different development models. Set up three development modes of “concentrated central urban area development mode”, “decentralized central urban area development mode”, and “maintenance-oriented central urban area development mode”. Under the guidance of three different development modes, calculation and analysis are performed using genetic algorithms. The population recovery, the degree of land-use mix, and the degree of land-use specialization in the central urban area are three indicators. On this basis, a land-use planning support system has been developed.

5.1. Introduction

The central area of a traditional historic city is often a significant representation of city characteristics. However, with the growth of urbanization came the relocation of vast populations to urban suburbs, the aging of society, the rise in commercial vacancy rates, the decline in urban land use, the emergence of suburban trade, and other social phenomena. The issue of the city's core is hollowed out has gained a lot of attention, and the idea of urban decentralization has gained a lot of traction.

Many cities prior to modern times were compact cities due to the limitations of vehicle commuting radius. The popularity of automobiles became a major force driving the spread of cities after the nineteenth century, and the city gradually lost its compact nature. Meanwhile, as industrialization progresses, urban space becomes increasingly congested, and the initial urban area is unable to support additional industries and populations. Cities have the potential to expand to the suburbs as transit and communication technologies advance. As a result, some city dwellers started to relocate their residential functions to the outskirts of the city and suburbs, away from their workplaces. The total urban population remained stable or slightly increased at this stage, but a substantial number of people moved from the city center to the suburbs.

Urban decentralization has resulted in a waste of existing capital in urban centers, causing the central urban region to deteriorate, urban land to be underutilized, and suburban land to be continually covered by ineffective building methods (Audirac, 2005). Dealing with environmental destruction caused by urban population and industrial concentration, as well as urban development and suburbanization, boycott planning, and urban vacancies, has become one of the major goals of the urban planning program.

The compact city is a term for a city's form as well as a representation of urban space. Gert de Roo and Donald Miller's book " Compact Cities and Sustainable Urban Development " described compact cities as having four characteristics (Lanzendorf, 2001): (a) high population density, high job density; (b) multiple land-use types; (c) good spatial layout and urban design; and (d) proper urban management.

5.1.1. Compact City

The idea of the " compact city " arose from a slew of economic and social issues brought on by the growth of European and American cities. After that, the American Planning Association turned it into a "smart development" approach, emphasizing the importance of a healthy lifestyle and public space built on a human scale.

Jane Jacobs' 1961 monograph "The Death and Life of Great American Cities" focused on the city's diversification, ushering in a period of reflection on previous urban planning(Gonzalez, Hidalgo, & Barabasi, 2008; Jacobs, 1992). George B. Dantzig and

Thomas L. Saaty published the first monograph on this hypothesis in 1973, followed by a series of similar studies to validate its empirical validity (Dantzig & Saaty, 1973).

The Commission of the European Communities (CEC) proposed the "CEC (1990) Green Paper on the Urban Environment" in 1990, which described "Compact City" as "a way to solve the problem of housing and environmental problems" and considered it to be consistent with the necessity of sustainable development. Since then, the "compact city" hypothesis has been gaining traction.

In response to the sprawl of American cities, New Urbanist scholars suggested the creation of compact neighborhoods with an urban living environment in the early 1990s. Mike Jenks, Elizabeth Burton, and Katie Williams of the Brookes University School of Architecture in the United Kingdom published "The Compact City: A Sustainable Urban Form" in 1996, which arranged the theoretical consensus and differences in the compact city theory in a systematic manner. Combining and summarizing information helps to advance compact city theory and its implementation in practice (Jenks, Burton, Williams, & Symes, 1997; Kiyonobu, 2007).

Kiyonobu's 2007 book "The Planning and Design of Compact Cities" combined existing issues about high-density, compact cities and sustainable growth into a collection of new theoretical perspectives (Kiyonobu, 2007). In related academics, there is no common term for the idea of compact cities. The study of compact cities is primarily concerned with urban sprawl and the decline of urban vitality.

The secret to "compact cities," according to Handy, is moderate and practical mixed urban land use. Only by combining various forms of land use will the benefits of a compact city be fully realized (Handy, 1992). The benefits of a compact city were explained by Michael Breheny. He demonstrated that fostering more compact cities would significantly reduce transportation energy use and, as a result, emissions (Breheny, 1995). The heart of a compact city, according to Katie Williams, is a high efficiency of various construction with a common composing key element, which is encouraged by urban planning programs and policies (K. Williams, 1999).

According to Elizabeth Burton, a higher-density urban form encourages social equity. Improved public transportation, decreased social inequality, and greater access to hospitals are among the advantages, although reduced living space and a shortage of affordable housing are likely to be the key drawbacks (Burton, 2000a). A compact area, according to S. Rueda, is a trend of urban spatial development with higher density (Rueda, 2000).

The "compact city" development model is known for its diversity. Diversity will aid in the city's redevelopment and help the city center flourish once more. Despite the various reasons for compact cities, compact cities can be understood as a city type with high density, mixed functions, diversity, and public transportation, according to the current consensus.

The compactness of urban form is a term used in the United States and Europe to define the density of cities, the degree of incorporation of different urban functions in living areas, and so on. As a result, density, land use, and transportation should all be considered.

- **Density** - There is a high population density as well as a high housing density. Since the risk of environmental problems rises as population density rises, the role of architectural and urban space design in preventing problems and improving environmental quality becomes more relevant.
- **Land use** - A complex and heavily used resource within a specific living area. Even if a single feature, such as housing or manufacturing, has a high density, it cannot be defined as compact, and different applications must be integrated within a certain range.
- **Transportation -** Low reliance on automobile traffic. The successful implementation of public transit will minimize reliance on automobiles and change the shape of cities.

The concept of a "compact city" is intended to solve problems that occur as a result of urban decentralization in general, such as the waste of existing resources in urban areas or inefficient development in suburban areas (Audirac, 2005). The compact city is a realistic urban form goal that distributes population density between urban cores and suburbs while avoiding urban voids created by shrinking cities. We can retain a compact city form, preserve a high-density and lively city center, and fight the trend of urban decentralization by rising population density, improving land attributes, and changing transportation methods.

5.1.2. Genetic Algorithm

J. Holland, an American academic, suggested the Genetic Algorithm (GA) in the 1970s. It's a type of optimization algorithm that's widely used to find the best solutions to combinatorial or multi-objective optimization problems(Johnson et al., 2014a). In the course of biological evolution, the genetic algorithm builds on the natural selection theory of "survival of the fittest, survival of the fittest," as well as genetic recombination and gene mutation.

The genetic algorithm has four main components: control parameters, such as population size, maximum iteration number, mutation rate, and crossover rate; chromosome coding method; fitness function; genetic operator, such as selection operator, crossover operator, and mutation operator; and genetic operator, which includes selection operator, crossover operator, and mutation operator. The genetic algorithm is based on the Schema Theorem, which is a mathematical theorem. The Schema Theorem ensures that the number of dominant gene fragment patterns in the genetic algorithm grows exponentially, allowing individuals with high fitness in the genetic algorithm to be well extended and grown (Sampson, 1976).

A chromosome is a string in which the solution occurs in a specific mode of coding as the genetic algorithm progresses. A gene is a character in a string that represents a variable in the problem-solving solution. A chromosome is also an organism, and a population of genetic algorithms is made up of these individuals. The population represents all of the chromosomes in a given iteration, and they all have the best solution.

The genetic algorithm's abstraction of the solution to the real problem is realized by chromosome coding, allowing the machine to deal with the real problem. Chromosomes can be encoded in a variety of ways. The two most popular encoding methods for genetic algorithm chromosomes are real-coded and binary-coded. The first chromosomal coding approach used in genetic algorithms is binary coding(Dong, Zanchetta, & Thomas, 2010).

It represents the chromosome with the fewest characters possible, which is the encoding method that maximizes the length of the chromosome such that the precision that can be expressed is increased. At the same time, binary coding preserves the chromosome pattern as much as possible, allowing the population to contribute to diversity. As a result, binary coding can be used to solve the maximum value problem for continuous functions with multiple variables.

Of course, binary coding has flaws, such as its long chromosome representation, which makes calculating the optimal solution of the search much more difficult, and the binary code can lose feature knowledge with the solution, which is not conducive to the design of the genetic operator (Johnson et al., 2014b). By mapping the gene to a real number in the range of 0 to 1, as well as implementing an efficient interpolation process, real number coding can effectively solve these problems (Piwonska, Seredynski, & Szaban, 2013).

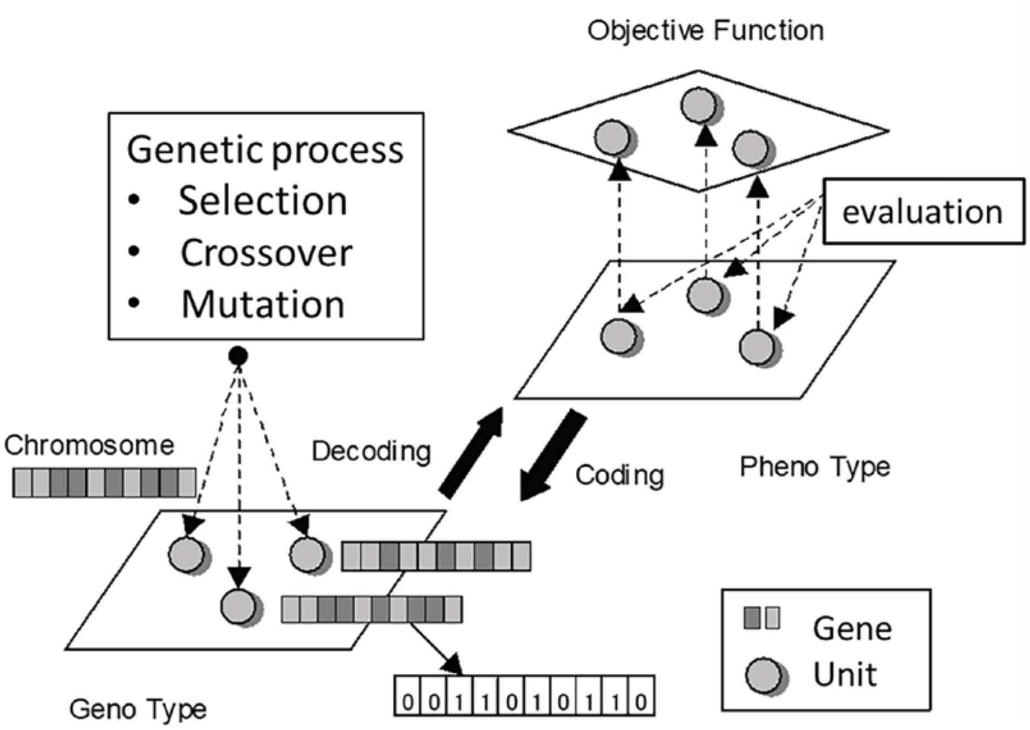


Figure 5.1 The basic framework of Genetic algorithms

5.2. Method

The main aim of this research is to create a land-use planning support structure that focuses on demographic changes in the central urban area as a result of various development modes. Genetic algorithms (GA) are used to find the best development program based on various development modes and to assess demographic changes. The entire system is divided into two parts: the GA subsystem and the evaluation subsystem, with the evaluation subsystem further subdivided into the population ability prediction subsystem, the population redistribution subsystem, and the development mode classification subsystem.

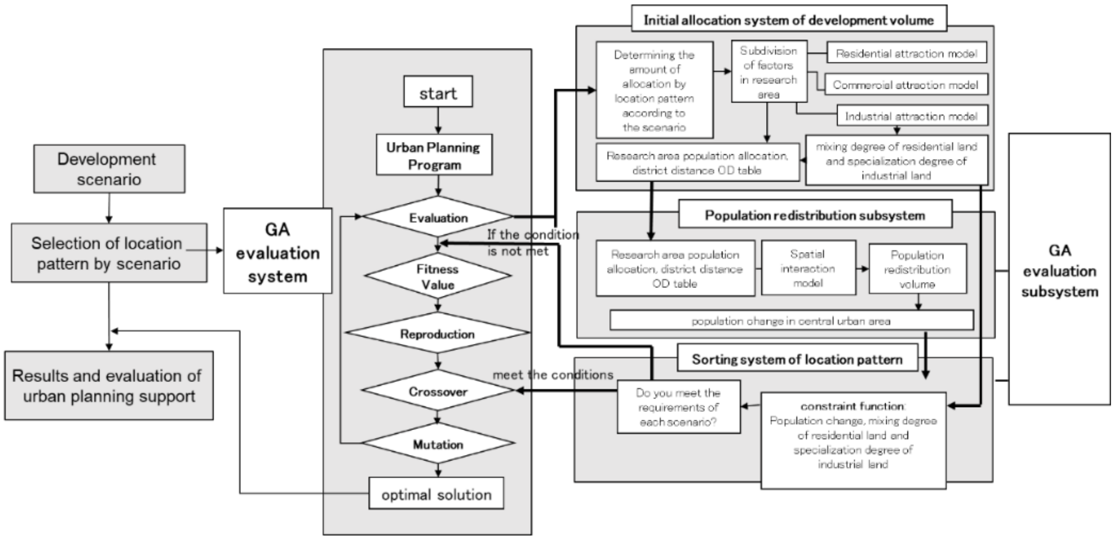


Figure 5.2 Framework of the land-use planning support system

The "Development Mode" is the pre-defined land-use development mode provided by the planner in this report. Three types of development modes are suggested for consideration, namely "Concentrated Central Urban Area Development Mode," "Decentralized Central Urban Area Development Mode," and "Maintenance-oriented Central Urban Area Development Mode," which would be referred to as "Concentrated Mode," "Decentralized Mode," and "Maintenance-oriented Mode," respectively, based on different needs.

- **Concentrated Mode** refers to the concentration of residential, commercial, and industrial areas in the central metropolitan region. The land is densely packed, the relation between residence and employment is relatively solid, and the central urban area's role is relatively complete. This Mode is an example of the compact city model in action.

- **Decentralized Mode** means the fragmented distribution of residential, commercial, and industrial areas, low land-use compactness, low connectivity between residence and jobs, and relatively dispersed functions in the central urban area. The compact city model is the polar opposite of this Mode.

- **Maintenance-oriented Mode** has no tendency. The current distribution of residential, commercial, and industrial areas is maintained rather than a more centralized or decentralized one. This is a manifestation of the city's current form.

Meanwhile, the " Development Program " refers to an actual development plan that includes the ratio of residential, commercial, and industrial land in each urban area. The land-use status can be controlled and evaluated by adjusting the development ratio in different areas. Different regions' growth rates are classified into three categories: high development rate (H), medium development rate (M), and low development rate (L).

The system aims to generate an optimal development program that is most beneficial to population recovery in the central urban area. Due to the diversity of development programs from the various combination of development ratios in each region, GA is used to search for the optimal development program.

Since the GA is a heuristic algorithm that needs constant iterative optimization according to the assessment of development program, this research constructs three indicators named "population change in central urban area" (PC), "mixing degree of residential land" (MD), and "specialization degree of industrial land" (SD). Each development program generated by the GA will be evaluated by the three indicators and compared with the requirements of the development model.

The system's operation procedure is as follows.

- **Initialization.** The device will produce some initial development programs at random for the preset development volume and encode them as chromosomes. For more details, see Section 5.2.1.

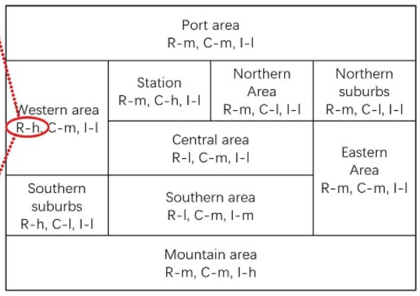
- **The population capacity prediction system.** The weight of residential, commercial, and industrial land in different urban areas is calculated based on the current state of the city and existing geographic details, and the initial construction t volume is allocated. The findings are used to measure the population potential of each metropolitan area. For more details, see Section 5.2.2.

- **The population redistribution system.** Based on the current state of the city and the population capacity obtained previously, the spatial interaction model is used to redistribute the population in various urban areas. See Section 5.2.3. for more information.
- **The development mode classification system.** Each development program's three indicators (PC, MD, and SD) are determined to see if it meets the development mode criteria. Maintain the development plan that satisfies the requirements. For more details, see Section 5.2.4.
- **Iteration.** If no development program meets the criteria, the GA method performs the crossover and mutation process of the development program before iteration ends.

5.2.1. Basic settings of the GA subsystem

In order to find the best development program, GA is used as the central algorithm. In order to process the crossover and mutation operation, GAs must encode the creation software into chromosomes. Finally, the algorithm finds the most adaptable chromosome combination. The low/medium/high development ratio is encoded as three different alleles, 0, 1, and 2, respectively, in this analysis, with the development ratios of different urban regions serving as the gene. The real ratio of growth varies from one area to the next. **Figure 5.3** depicts the chromosome encoding.

Land Use	Residential										Commercial	Industrial
Region	City Center	Sub-center					Suburbs		Surrounding Area			
District	Central	Eastern	Western	Northern	Southern	Station	N-Suburbs	S-Suburbs	Port	MOUNT		
Ratio	H M L	H M L	H M L	H M L	H M L	H M L	H M L	H M L	H M L	H M L		
Chromosome1	0	1	2	2	0	0	1	2	0	2	...	...
Chromosome2	2	0	1	1	0	2	1	1	1	2		
...	...											
Chromosome10	2	2	2	2	0	0	0	1	1	2		



	Central			Eastern			Western			Northern			Southern			Station			N-Suburbs			S-Suburbs			Port			MOUNT		
	H(%)	M(%)	L(%)	H(%)	M(%)	L(%)	H(%)	M(%)	L(%)	H(%)	M(%)	L(%)	H(%)	M(%)	L(%)	H(%)	M(%)	L(%)	H(%)	M(%)	L(%)	H(%)	M(%)	L(%)	H(%)	M(%)	L(%)	H(%)	M(%)	L(%)
Residential	8.4	5.6	2.6	13.8	10.0	6.8	11.5	8.8	5.3	13.1	10.8	7.3	22.3	19.2	16.5	23.4	20.0	17.6	12.3	9.8	6.9	12.5	9.6	6.5	6.6	3.6	0.7	5.8	2.6	0.8
Commercial	9.9	6.2	3.7	13.8	10.0	6.5	8.2	5.4	2.5	13.1	10.8	7.4	20.9	17.2	14.9	36.2	33.1	30.7	11.2	8.5	5.7	6.4	3.8	0.9	7.4	4.6	1.9	4.0	0.1	0.1
Industrial	7.0	4.8	1.3	7.6	4.8	2.0	10.1	7.1	4.7	5.1	2.4	5.1	38.2	35.7	32.4	26.2	23.8	20.3	14.2	11.9	9.0	3.1	0.1	0.1	10.9	7.1	4.7	5.3	2.4	0.7

Figure 5.3 Relationship between chromosome coding and regional development ratio.

To assess the fitness of each development program and provide a guide for subsequent selection, crossover, and mutation processes, a fitness feature is required. The feasibility of a development program is closely linked to the initial development amount in this report. If a generated development program differs from the initial development amount, it fails to meet the basic criteria and should be eliminated from the selection process.

There are three major categories of land use m in the city studied: residential ($m = 1$), commercial ($m = 2$), and industrial ($m = 3$). The fitness feature of the development program for the initial development number LQ^m, a development program c, and corresponding development volume AL_c^m is:

$$F_c = \sum_m |LQ^m - AL_c^m|$$

Equation 5.1 The fitness feature of the development program.

The likelihood of the creation model c being chosen in subsequent inheritance and mutation processes is proportional to its fitness:

$$P(c) = \frac{F_c}{\sum_c F_c}$$

Equation 5.2 The likelihood of the creation model c being chosen

A new generation of chromosomes is produced for evaluation using the standard selection, crossover, and mutation processes.

5.2.2. Population capacity prediction subsystem

The key assessment goal of a development program is the land use functions of different regions, as well as population movement between regions, which are all directly linked to the region's attractiveness to the population. Each metropolitan area must be assigned a particular development volume, and the effect on the population must be assessed.

Based on residential, commercial, and industrial land areas in each country, this study established the population ability prediction subsystem to describe the attractiveness of the population, including the employment population and the resident population. In subsequent subsystems, the population potential is used as a measure of the region's overall attractiveness. **Figure 5.4** depicts the workflow.

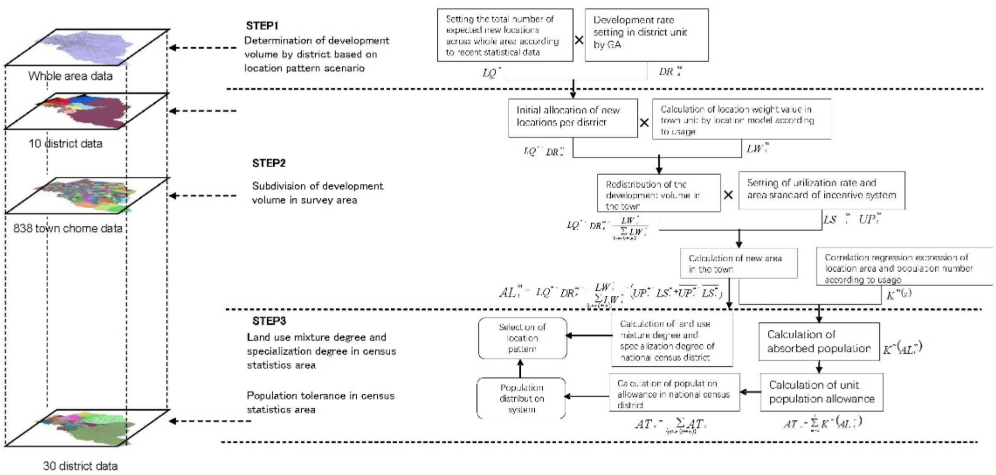


Figure 5.4 Process of the population capacity prediction subsystem

The production ratio for different functions m is encoded in the chromosome for each urban area n and is denoted as DR_n^m. The development volume AL_n^m of region n is determined by the development ratio DR_n^m:

$$AL_n^m = LQ^m * DR_n^m$$

Equation 5.3 The development volume of a region

There are a number of subregions i for each area n, which serve as the basic unit for statistical analysis and production volume allocation. Actually, various subregions would be more or less appealing to the new production volume LW_i^m. Each subregion's production volume can be further divided.

The attractiveness of each subregion LW_i^1 for residential functions is determined by population density, land price, and other factors. For example, living in a prosperous service sector is convenient, while higher population density, higher industrial density, and proximity to a railway station are less appealing due to air pollution and noise pollution. According to previous research (Mimura & Osaragi, 1999), the following regression equation describes the attractiveness of residential land:

$$LW_i^1 = DE_{pop} * \beta_1 + L_p * \beta_2 + L * \beta_3 + NUM_2 * \beta_4 + NUM_3 * \beta_5$$
$$+ D_{cen} * \beta_6 + D_{sta} * \beta_7 + D_s * \beta_8$$

Equation 5.4 The attractiveness of residential land

Parameters: According to Mimura et al.'s studies, β_1=0.1, β_2=0.492, β_3=0.1, β_4=0.1, β_5=0.148, β_6=0.02, β_7=0.02, β_8=0.02.

Similarly, the attractiveness of each subregion LW_i^2 for commercial functions is determined by factors such as public facilities and road density. We have the following regression equations based on previous studies (Horita, Sato, Kobayashi, & Takatsuka, 1999; Kataoka, Hagishima, & Satani, 1997; Satani, Hagishima, & Kataoka, 1997; Takatsuka, Sato, Kobayashi, & Horita, 1999):

$$LW_i^2 = DE_{res} * \beta_1 + D_{sta} * \beta_2 + D_{cen} * \beta_3 + F * \beta_4 + P_{com} * \beta_5$$
$$+A_{com} * \beta_6 + A_{ur} * \beta_7 + Z_{com} * \beta_8$$

Equation 5.5 The attractiveness of commercial land

The attractiveness of each subregion LW_i^3 for industrial functions is also influenced by road density, water price, and other factors (Kobayashi et al., 1997):

$$LW_i^3 = DE_{res} * \beta_1 + D_{sta} * \beta_2 + D_{har} * \beta_3 + D_{mar} * \beta_4 + L * \beta_5$$
$$+R * \beta_6 + F * \beta_7 + G_{ind} * \beta_8 + L_p * \beta_9$$

Equation 5.6 The attractiveness of industrial land

We can use the variables to measure the attractiveness of each subregion for each form of land use using these regression equations. Every subregion's production volume will be proportional to its attractiveness:

$$AL_i^m = LQ^m * DR_n^m * \frac{LW_i^m}{\sum_{\{i:i\in n\}} LW_i^m}$$

Equation 5.7 Subregion's production volume

The volume of production would also be influenced by government policies. An adjustment factor is applied since the government offers incentives for various subregions. The ratio of landowners who choose to use government incentives in the subregion *i* for the land feature *m* is UP_i^m, with the corresponding growth area coefficient being LS_i^m, and the ratio of those who choose not to use has $\widetilde{UP_i^m}$ and $\widetilde{LS_i^m}$. The final volume of creation is:

$$AL_i^m = LQ^m * DR_n^m * \frac{LW_i^m}{\sum_{\{i:i\in n\}} LW_i^m} * \left(UP_i^m * LS_i^m + \widetilde{UP_i^m} * \widetilde{LS_i^m}\right)$$

Equation 5.8 Subregion's creation volume

The number of all subregions is the creation volume of each area n:

$$AL_n^{\mathrm{m}} = \sum_{\{i:i\in n\}} AL_i^m$$

Equation 5.9 Area’s creation volume

The construction volume can also be used to estimate population size. In general, a higher rate of growth would result in a higher population potential. There are different regression equations for each land feature based on previous research (Uetake, Kawakami, Utsu, & Kameyama):

$$K_i^1(x) = 0.0217x + 76.92$$

$$K_i^2(x) = 0.0834x + 69.34$$

$$K_i^3(x) = 0.0243x + 9.82$$

Equation 5.10 The construction volume of different function

Each subregion's population capacity i is the sum of each land feature, and each region's population capacity n is the sum of each subregion:

$$AT_n = \sum_{\{i:i\in n\}} \sum_m K_i^m(AL_i^m)$$

Equation 5.11 Subregion's population capacity

So far, the subsystem can measure the development volume of different land functions of different regions AL_n^m, as well as the population potential AT_n, based on the development ratio set in the chromosome. The population ability will serve as the attractiveness in the spatial interaction model in the population redistribution subsystem, and the production volume will decide the subsequent indicators.

5.2.3. Population redistribution subsystem

Because of regional rivalry, population ability alone is insufficient for credible results in population migration. The population redistribution subsystem in this study is based on spatial interaction models (SI models). The SI model is used to simulate the population migration trend based on actual population migration in order to obtain the population shift in the central urban region.

The spatial interaction model is a mathematical model that uses spatial relations to quantify the relationship between human activities and facility distribution. Models of spatial interaction concentrate on cross-regional exchanges such as population movement, merchandise trade, transportation, and communication.

The basic data in this study comes from the population migration OD table and the geographic distance OD table. Using the maximum entropy principle to estimate specific parameters and re-adjust the population migration, the subsystem uses the population migration in the statistical data as the initial condition and the population potential obtained in 5.2.2. as the constraint conditions, as shown in **Figure 5.5** Process of the population redistribution subsystem.. The demographic changes in the central urban area are the subject of this research.

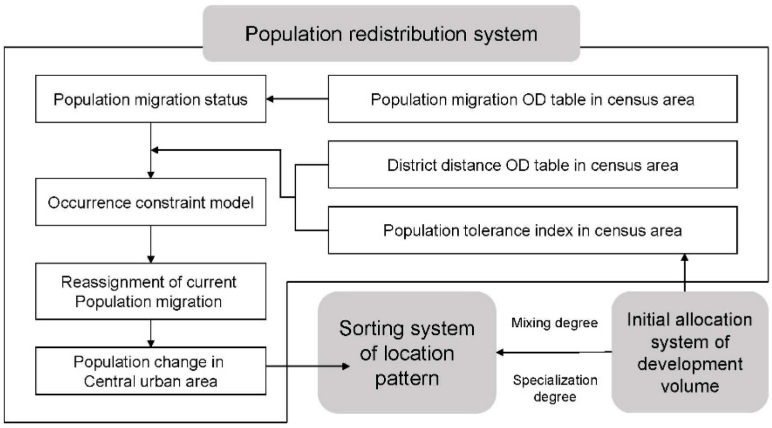


Figure 5.5 Process of the population redistribution subsystem.

The production-constraint model is one of many possible variations of the spatial interaction model. The production-constraint model requires that outflows in each region remain constant, but there is no cap on inflows in each region, which is appropriate for population redistribution.

The flow volume between two regions T_{ij} is proportional to the outflow sum $O_i$of the region i the attractiveness D_j of the region j, and the distance between the regions d_{ij} for any two regions i and j:

$$T_{ij} = A_i O_i D_j f(d_{ij})$$

Equation 5.12 The flow volume between two regions

The adjustment factor A_i is specified to ensure that each area's outflow remains constant:

$$A_i = \frac{D_j f(d_{ij})}{\sum_j D_j f(d_{ij})}$$

Equation 5.13 Adjustment factor

The flow is affected by the distance between the regions in the form of an exponential function:

$$f(d_{ij}) = d_{ij}^{-\beta}$$

Equation 5.14 The exponential function of distance influence

The attractiveness of each area is determined by its population capability. For the j region:

$$D_j = AT_j$$

Equation 5.15 The attractiveness of each area

Historical data can be used to calculate the distance between the area d_{ij} and the population outflow O_i. The maximum entropy theory can be used to estimate the parameter β that maximizes the likelihood of occurrence of the data and the corresponding modified population migration T_{ij} using the model given by P. A. Williams and Fotheringham (1984). The demographic changes in the central urban region can be calculated by adding the changed inflows and outflows.

5.2.4. Development mode classification subsystem

The three indicators for the chromosomes representing the development program can be obtained using the population capability prediction subsystem and the population redistribution subsystem. Section 5.2.3. provides information on demographic change in the central urban area:

$$\Delta P_n = \sum\nolimits_m (T_{mn} + T_{nm})$$

Equation 5.16 Demographic change in the central urban area

The proportion of residential land in the central urban area is referred to as the mixing degree of residential land. If the original land number is AR_n^m and the new construction volume is AL_n^{m} for the area n and function m from Section 5.2.2. , then:

$$A_n^m = AL_n^{\mathrm{m}} + AR_n^m$$

Equation 5.17 New construction volume

And the ratio between residential, commercial, and industrial land determines the mixing degree of residential land:

$$T_n = \begin{cases} \frac{A_n^1}{A_n^2}, & A_n^1 < A_n^2 \\ \frac{A_n^2}{A_n^1}, & A_n^1 > A_n^2 \end{cases} + \begin{cases} \frac{A_n^1}{A_n^3}, & A_n^1 < A_n^3 \\ \frac{A_n^2}{A_n^3}, & A_n^1 > A_n^3 \end{cases}$$

Equation 5.18 The mixing degree of residential land

The disparity between the proportion of industrial land in the central metropolitan area and the proportion of industrial land in all other regions is referred to as the specialization degree of industrial land.

$$I_n = \left|\frac{A_n^3}{A_n^{\neg 3}}\right| - \left|\frac{A_{\neg n}^3}{A_{\neg n}^{\neg 3}}\right|$$

Equation 5.19 The specialization degree of industrial land

A classification method based on the above indicators is the development mode classification subsystem. As shown in **Figure 5.6**, this subsystem tests the GA's development program chromosomes, sets up acceptable indicators' ranges through background records, classifies the obtained development program according to the development mode requirements, and retains the chromosomes that meet the requirements.

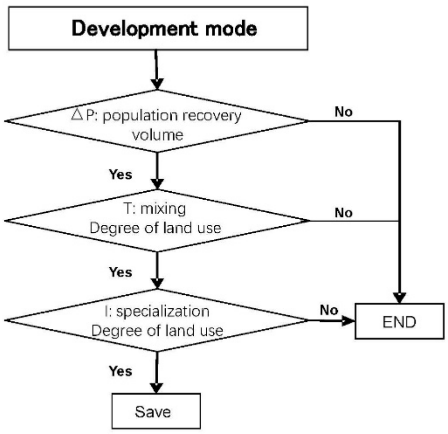


Figure 5.6 Process of the development mode classification subsystem

5.3. Results

5.3.1. Basic information of Kanazawa, Ishikawa

To check the method, this research system uses Kanazawa City in Ishikawa, Japan as an example. The land-use planning support mechanism is used to obtain suitable development programs across the three different development modes mentioned above.

As shown in **Figure 5.7**, Kanazawa has 30 statistical areas that are divided into ten regions, with a total of 838 subregions. Population Census (2010), National Land Numerical Information (2011), and Kanazawa Urban Planning Basic Survey provided detailed statistics on land use, infrastructure, population migration data, and growth rates over time for these subregions (2009). ArcGIS has been used to calculate the distance and other variables.

Microsoft Excel VBA scripts are used to program the model specified in Section 4. The data is loaded into ArcGIS and Microsoft Excel, the model is run using VBA in Excel, and the results are exported to Excel and visualized in ArcGIS.

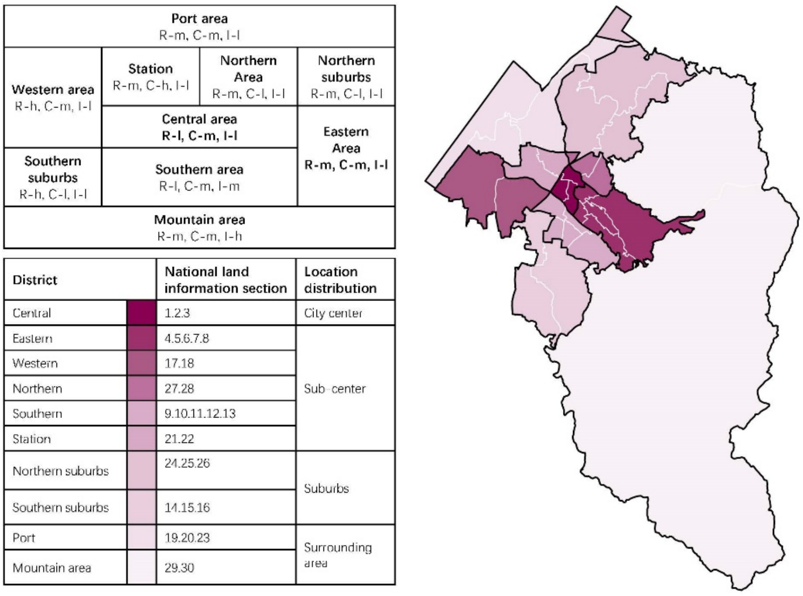


Figure 5.7 The district of the Kanazawa City

The GA parameter settings should be investigated first. We chose the initial production volume based on statistical data from previous years (2009), calculated the three different development ratios based on historical data, and chose the crossover rate and mutation rate based on experience. **Table 5.1** shows the configurations.

Table 5.1 Parameters of the support system

Development volume	Residential	5000 unit
	Commercial	200 unit
	Industrial	60 unit
Development ratio	High	Maximum value among historical data
	Medium	Average value among historical data
	Low	Minimum value among historical data
Parameters of GA	Population size	10
	Crossover ratio	0.7
	Mutation ratio	0.3

The three different development modes were then set up. According to the Kanazawa Compact City Formation Plan (2015), the key aim is to foster population growth in the central urban region, and the development mode is determined by the indicators. The population change in the central urban region (PC) can be divided into three groups based on historical data: below 74, 74-104, and above 104. Residential land mixing degrees (MD) are classified into three categories: less than 0.0976, between 0.0976 and 0.0997, and greater than 0.0997. Industrial land specialization degree (SD) is often classified into three categories: below 0.00500, 0.00500 to 0.00546, and above 0.00546.

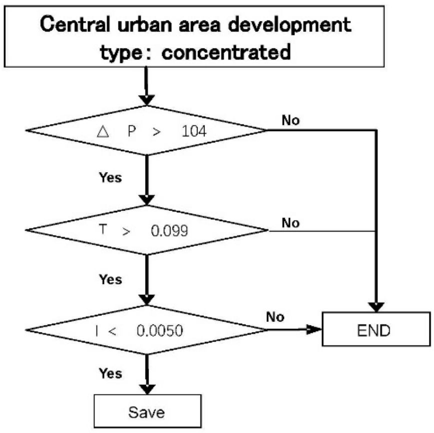


Figure 5.8 Concentrated central urban area development mode

If the annual PC is greater than 104, the central urban area's economic vitality will be enhanced, and population migration into the city will be encouraged. Simultaneously, if the MD is greater than 0.0997, commercial or industrial land will form an efficient structure that will increase the living environment's convenience. However, since the accumulation of industrial land is bad for the central city's environmental health, SD is used to reduce the environmental effects of industrial land. Concentrated Mode, which is tailored to the central urban area's intensive development strategy, can be found (**Figure 5.8**).

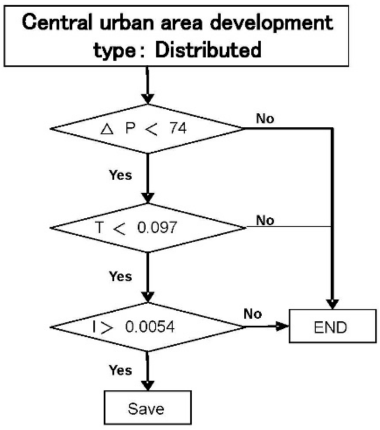


Figure 5.9 Decentralized central urban area development mode

The commercial buying power would have a weaker impact on the urbanization process if the annual PC is below 74. At the same time, if the MD is less than 0.0976, the difficulty of living in the central urban area would slow down growth. Meanwhile, if the SD is greater than 0.00546, the central city's climate would be negatively impacted. Decentralized growth in the central city would result as a result of these circumstances (**Figure 5.9**).

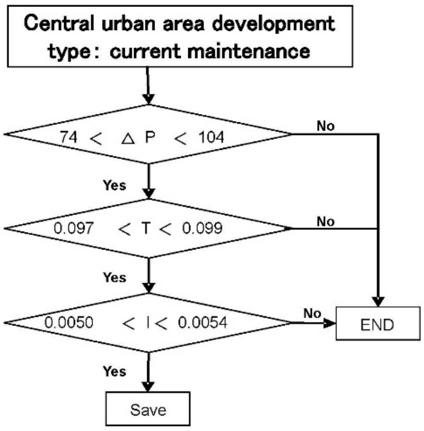


Figure 5.10 Maintenance-oriented central urban area development mode

Population recovery would have a positive effect on commercial recovery in the downtown area if the annual PC is between 74 and 104. The MD is 0.0976-0.0997, and the SD is 0.00500-0.00546 at the same time. This will help to maintain the situation and protect the environment in the central urban region, as well as establish a maintenance-oriented development mode (**Figure 5.10**).

The above three development modes are based on Kanazawa City statistics, and the land use planning support framework described in Section 错误!未找到引用源。 is used to choose an acceptable development program for each development mode that not only meets the development mode's requirements but also controls population changes in the downtown area.

5.3.2. Concentrated Mode

PC is greater than 104, MD is greater than 0.09974, SD is less than 0.0050976, and error is less than 216 in the concentrated development mode. **Table 5.2** shows that after 20,000 GA iterations, a total of 38 development programs meet the requirement.

Table 5.2 Chromosome of Concentrated Mode

	Gene	T_n	I_n	ΔP_n	F_c
C01	0 2 1 1 1 1 0 1 2 2 2 1 1 2 0 0 0 1 1 0 1 0 0 0 1 0 1 0 0 0	0.102	0.0051	110.921	72
C02	0 0 0 1 2 1 2 2 0 2 2 0 1 1 0 2 0 1 0 0 1 0 1 1 2 0 0 0 0 1	0.102	0.0049	107.718	86
C03	0 0 1 1 2 0 1 1 2 2 1 2 0 1 2 2 0 0 2 0 2 2 2 1 1 1 2 0 2 0	0.101	0.0048	118.348	101
C04	0 2 2 0 1 2 0 1 2 0 2 1 0 1 0 1 2 1 2 0 2 2 0 0 0 0 0 0 2 2	0.102	0.0049	129.336	102
C05	0 0 2 2 2 2 0 0 2 1 1 1 1 0 1 2 0 1 2 0 2 1 2 0 1 1 1 1 1 1	0.100	0.0048	120.420	102
C06	0 1 1 0 0 1 2 1 2 2 2 0 0 2 2 2 2 0 0 0 1 2 0 1 1 2 1 1 2 2	0.103	0.0050	141.152	103
C07	0 2 0 1 2 1 2 0 2 0 2 0 2 1 0 1 2 1 1 0 2 2 0 0 0 1 2 1 2 0	0.102	0.0051	123.414	106
C08	0 0 1 2 2 0 2 0 1 2 2 1 0 0 1 2 2 1 1 2 2 2 0 1 2 1 1 0 1 1	0.103	0.0047	112.758	109
C09	0 0 2 1 2 1 2 2 0 0 1 0 0 1 1 2 1 1 1 1 1 0 2 0 2 0 0 0 1 2	0.100	0.0049	127.359	110
C10	0 1 2 1 2 1 1 0 1 1 2 0 0 2 0 2 2 2 0 0 2 1 1 0 0 1 1 0 0 0	0.102	0.0048	117.651	111
C11	0 0 2 0 0 2 2 0 2 2 2 0 0 2 2 0 2 1 2 1 1 1 2 2 1 0 0 2 1 2	0.103	0.0049	157.771	113
C12	0 1 0 2 2 1 2 0 2 1 2 0 0 1 0 0 0 0 2 0 2 2 0 0 0 1 0 2 2 0	0.102	0.0050	157.947	115
C13	0 1 1 2 0 1 1 1 1 2 1 0 0 2 0 0 2 2 2 2 2 0 0 2 0 2 2 0 1 2	0.100	0.0049	167.276	117
C14	0 1 1 0 1 1 2 2 0 2 2 1 0 2 2 1 2 1 2 2 0 1 1 0 1 0 1 0 0 0	0.102	0.0051	129.713	123
C15	0 1 1 2 1 1 2 0 2 0 2 1 0 1 2 0 2 0 2 1 1 2 0 1 0 1 0 1 0 0	0.102	0.0048	125.861	123
C16	0 1 1 0 1 2 0 1 2 2 2 1 1 1 1 1 1 2 2 0 1 2 0 2 1 0 1 1 2 0	0.103	0.0050	111.008	124
C17	0 1 0 2 2 2 1 0 0 2 1 2 1 0 1 1 2 0 2 0 1 1 1 1 0 0 0 0 0 0	0.100	0.0049	118.069	131
C18	0 0 0 2 0 2 2 2 2 0 2 0 1 2 2 0 2 1 2 2 0 0 0 2 1 0 1 2 0 0	0.102	0.0050	160.638	133
C19	0 1 1 0 0 1 2 1 2 2 1 0 0 2 1 0 2 2 2 2 2 0 0 1 0 2 0 0 1 0	0.100	0.0047	149.181	137
C20	0 0 1 2 2 0 2 1 0 2 2 1 0 1 2 2 2 1 2 1 1 1 0 0 2 0 1 1 1 2	0.103	0.0050	138.639	139
C21	0 0 2 1 0 1 2 2 0 2 1 0 0 2 2 0 2 0 0 2 2 1 2 0 2 2 1 0 2 1	0.101	0.0048	112.370	140
C22	0 2 1 2 0 1 2 0 0 2 2 0 2 1 1 1 1 2 2 2 2 0 2 0 0 0 1 1 0 0	0.102	0.0050	143.610	145
C23	1 1 0 0 0 2 1 2 2 1 1 2 2 2 0 2 1 0 0 2 2 2 2 2 2 0 2 0 0 0	0.100	0.0049	112.828	147
C24	0 0 2 1 1 1 0 2 1 2 2 0 1 1 0 1 1 1 2 0 2 2 2 0 2 0 0 0 0 1	0.102	0.0045	140.628	149
C25	1 2 0 1 0 0 2 2 0 2 2 0 0 2 2 1 2 1 1 0 2 1 0 1 1 1 0 0 0 0	0.102	0.0050	118.876	153
C26	0 1 1 2 1 1 2 0 1 2 2 2 0 2 1 2 0 0 1 0 2 2 1 0 0 0 0 2 1 1	0.103	0.0048	139.448	163
C27	0 0 1 0 1 2 1 2 2 2 1 1 1 0 0 0 0 0 2 0 0 2 0 1 2 0 1 0 0 1	0.100	0.0048	109.526	169
C28	0 2 1 2 0 1 2 0 0 2 2 0 2 1 1 1 1 2 2 2 2 2 1 0 0 0 1 1 0 0	0.102	0.0048	138.176	170
C29	0 1 2 2 0 1 1 2 0 2 2 1 0 2 1 2 1 2 2 0 1 0 0 0 0 2 0 2 1 0	0.102	0.0050	159.862	170
C30	0 0 1 2 1 1 1 2 2 1 1 2 0 1 1 1 2 1 2 2 0 1 1 2 1 2 2 0 0 0	0.100	0.0050	116.987	175
C31	0 2 1 1 2 1 2 0 0 0 7 0 0 2 1 0 1 0 1 1 2 2 0 0 0 0 2 2 0 0	0.102	0.0049	117.429	177
C32	0 1 1 1 0 2 0 1 1 2 2 0 0 0 0 1 0 2 2 0 1 1 1 2 2 1 0 1 1 1	0.102	0.0049	132.617	182

C33	0 0 0 2 0 2 2 2 2 0 2 0 2 1 1 0 2 0 1 1 2 2 1 2 1 1 0 2 2 0	0.102	0.0048	140.037	183
C34	0 2 0 0 0 2 1 1 2 1 1 2 2 2 0 1 2 1 1 2 2 1 0 1 1 0 2 2 0 1	0.100	0.0048	108.997	183
C35	0 0 2 2 1 2 0 2 0 2 1 0 2 1 2 1 2 2 2 0 1 2 2 1 0 0 2 0 1 0	0.100	0.0048	115.360	194
C36	0 0 1 1 2 0 1 2 2 0 2 0 0 2 2 1 2 1 2 2 0 2 0 0 1 0 0 1 2 0	0.102	0.0050	151.424	198
C37	1 0 2 1 0 2 2 0 1 0 1 1 1 2 2 2 1 2 1 0 2 0 0 0 0 1 1 1 0 1	0.100	0.0049	124.421	200
C38	0 1 1 1 0 0 1 2 2 1 2 1 0 2 0 0 1 2 2 0 1 1 0 1 0 0 0 0 1 1	0.102	0.0048	133.525	200

It is possible to decide the common features of the chromosomes, which implies the common features of all development programs, by measuring the likelihood of genes 0, 1, 2 at the chromosomal locus. The development ratios for residential, commercial, and industrial areas in each zone are shown in **Figure 5.11**.

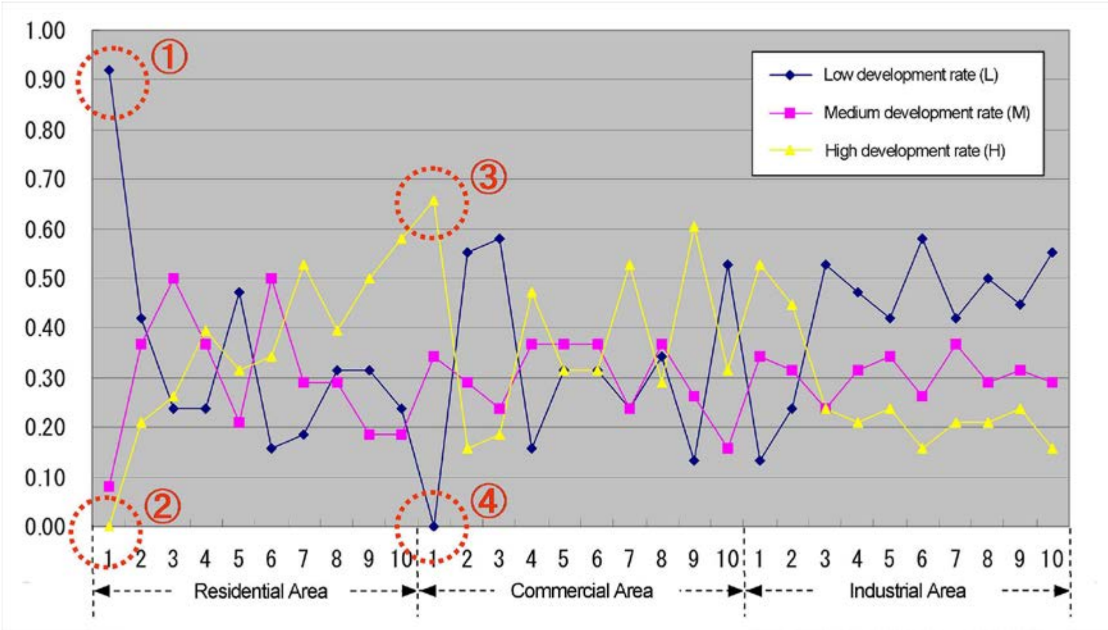


Figure 5.11 Probability of development ratio by district and land-use type of Concentrated Mode

The probability of selecting a low development rate for residential land in the central urban area is as high as 0.9 (1) in the Concentrated Mode, as shown in the figure, whereas the probability of selecting a high development rate is close to 0. (2). On the other hand, choosing a high growth rate for commercial land in the central metropolitan region has a probability of 0.66 (3), whereas choosing a low development rate has a probability of close to 0. (4). As a result, the center of this Mode is to revitalize the central city's commercial functions through large-scale commercial growth, with the aim of restoring population and increasing land use complexity.

The primary goal of residential land in such urban planning is to maintain a comfortable living atmosphere rather than rapid housing growth; the primary goal of industrial land is to set a lower development rate in the city's suburbs and surrounding areas to minimize the attractiveness of the working population and avoid population loss. Under the conditions of Concentrated Mode, this is a general characteristic of all programs.

Table 5.3 shows the effects of selecting the development ratio with the highest likelihood as the optimal development ratio for each area and land type. The site controls the land development situation; the final PC is 174, the MD is 0.102533, and the SD is 0.004347.

Table 5.3 Optimal development program of Concentrated Mode.

Residential										
Area	1	2	3	4	5	6	7	8	9	10
Gene	0	0	1	2	0	1	2	2	2	2
Dev. Ratio	2%~3%	6%~7%	8%~9%	13%~14%	16%~17%	20%~21%	12%~13%	12%~13%	6%~7%	5%~6%
Commercial										
Area	1	2	3	4	5	6	7	8	9	10
Gene	2	0	0	2	1	1	2	1	2	0
Dev. Ratio	9%~10%	6%~7%	2%~3%	13%~14%	17%~18%	33%~34%	11%~12%	3%~4%	7%~8%	3%~4%
Industrial										
Area	1	2	3	4	5	6	7	8	9	10
Gene	2	2	0	0	0	0	0	0	0	0
Dev. Ratio	7%~8%	7%~8%	4%~5%	5%~6%	33%~34%	20%~21%	8%~9%	0%~1%	4%~5%	0%~1%

The GIS framework will visualize the changes in the central urban area's demographics. **Figure 5.12** shows the population migration pattern of Kanazawa City (2010) before using this method. The blue areas represent areas where people are moving in, while the red areas represent areas where people are leaving. The population influx into the central urban area is near to zero in this case, which is why the population must be restored.

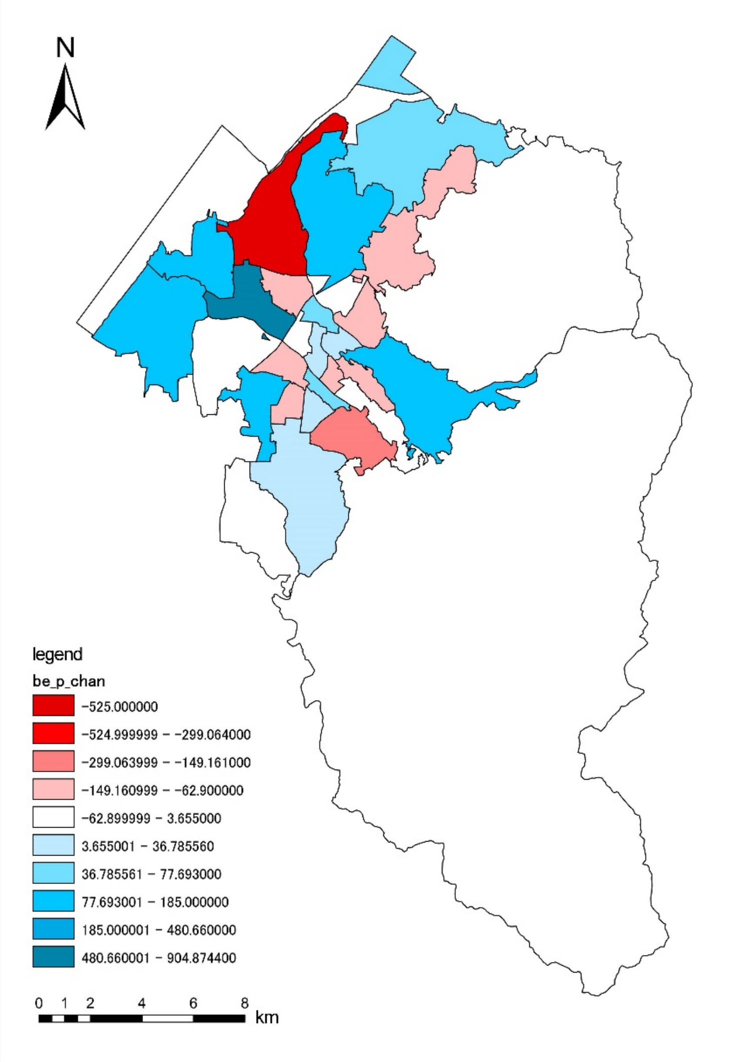


Figure 5.12 Current situation of population migration in the Kanazawa City

In Concentrated Mode, **Figure 5.13** depicts population migration. The population is greatly skewed from the suburbs further away from the city center to the center area, according to the findings. A portion of the inflowing population is obtained in the area closer to the city center, which represents the concentration of the population from the outskirts to the city center and surrounding area. This also represents a rise in the city center's economic growth rate, which has a significant effect on the center city's population recovery.

The increasingly concentrated population distribution changed the original population distribution structure, and the population accumulation in the city's central region changed the situation of suburban population loss. This occurrence prompted the city to create a more concentrated urban functional and spatial structure, completing the revitalization of the central city.

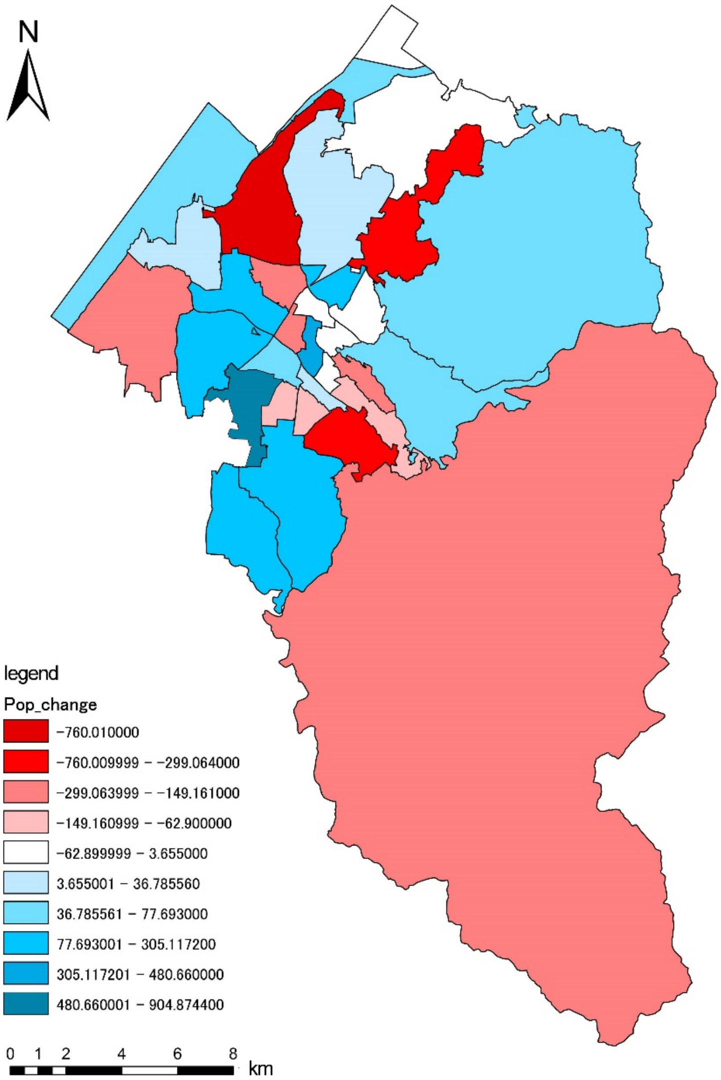


Figure 5.13 The tendency of population migration under the Concentrated Mode

5.3.3. Decentralized Mode

For the Decentralized Mode, similar findings are available. PC must be less than 73.8, MD must be less than 0.097625, and SD must be greater than 0.0054653 to qualify for Decentralized Mode. **Table 5.4** shows that after 20,000 GA iterations, a total of 52 development programs meet the requirement. **Figure 5.14** depicts the probability distribution using the same probabilistic analysis tool.

Table 5.4 Chromosome of Decentralized Mode

	Gene	T_n	I_n	ΔP_n	F_c
C01	2 0 1 2 0 1 1 1 2 0 0 1 0 0 1 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0	0.097	0.0055	44.863	45
C02	2 0 1 0 1 1 2 1 2 0 0 2 0 0 1 0 0 0 0 0 0 0 0 0 2 0 0 1 1 0	0.097	0.0055	21.631	59
C03	2 2 2 2 1 0 0 1 0 0 0 2 0 1 0 0 1 0 0 0 0 1 1 1 0 2 0 0 2 1	0.097	0.0060	52.465	64
C04	2 0 0 2 2 2 0 1 1 0 0 0 0 0 1 1 0 2 0 1 1 2 0 0 0 1 2 0 2 1	0.097	0.0055	57.151	66
C05	2 2 2 1 1 0 0 2 0 0 0 0 0 2 1 0 0 0 0 0 0 1 2 0 0 2 0 0 2 0	0.096	0.0059	70.083	67
C06	2 1 0 1 2 1 1 0 0 2 0 2 0 0 0 2 2 0 0 0 1 2 1 2 0 0 1 2 1 0	0.097	0.0055	72.054	78
C07	1 2 2 2 1 0 0 1 0 1 0 2 0 1 0 0 1 1 0 0 0 1 1 1 0 2 0 0 2 1	0.097	0.0057	39.757	80
C08	2 1 0 0 1 2 0 2 2 0 0 0 0 0 0 1 0 2 0 0 2 0 2 0 0 1 1 2 1 1	0.096	0.0055	50.279	80
C09	1 2 0 2 2 1 0 0 1 1 0 1 0 1 2 1 0 0 0 0 0 0 1 0 1 2 0 2 0 1	0.097	0.0057	54.447	81
C10	2 1 0 2 2 0 1 1 0 1 0 1 2 1 0 1 0 2 0 0 0 1 1 2 0 1 1 2 0 0	0.096	0.0057	56.106	83
C11	2 1 0 0 0 2 2 2 0 1 0 0 0 0 0 0 0 1 0 2 0 1 1 1 1 1 1 2 0 2	0.096	0.0056	60.439	85
C12	1 2 0 2 1 0 1 2 0 1 0 1 0 0 1 0 0 2 0 0 0 0 1 0 2 1 0 1 2 0	0.097	0.0057	114.562	90
C13	2 0 1 1 1 1 0 2 2 0 0 2 2 2 0 0 0 0 0 0 0 2 0 2 0 1 0 2 2 2	0.097	0.0057	68.342	95
C14	1 1 2 1 2 2 0 0 0 0 0 0 0 0 0 0 1 0 0 2 0 0 0 2 0 0 1 0 0 2	0.097	0.0055	59.551	104
C15	2 0 2 2 0 0 0 1 1 2 0 1 1 0 2 0 0 0 0 0 0 2 2 2 0 2 1 0 1 1	0.097	0.0056	34.621	105
C16	1 1 0 2 2 0 1 0 0 2 0 2 0 1 2 0 1 0 0 1 2 0 2 2 1 2 2 0 2 1	0.097	0.0055	34.981	108
C17	2 2 0 0 1 2 0 0 2 1 0 2 2 2 2 0 0 2 1 1 0 1 0 0 0 1 0 0 0 2	0.097	0.0057	48.446	110
C18	2 1 2 2 1 0 2 0 0 1 0 0 0 0 0 0 1 1 0 2 2 0 0 0 0 2 0 0 2 1	0.096	0.0055	67.912	112
C19	2 1 0 2 0 2 0 0 2 1 0 2 1 0 2 0 1 2 0 0 1 0 0 0 1 1 0 0 1 1	0.097	0.0055	22.183	112
C20	1 2 1 1 2 0 0 2 0 0 0 2 2 0 0 0 1 0 0 0 0 0 0 0 0 0 2 0 0 0	0.097	0.0055	64.724	121
C21	1 2 0 0 1 0 2 2 2 0 0 2 2 0 2 1 2 2 2 1 0 1 1 1 0 0 2 2 2 2	0.097	0.0057	55.792	123
C22	1 2 2 0 1 0 0 2 1 0 0 0 0 0 2 2 0 0 0 0 0 0 1 0 0 0 0 0 2 0	0.097	0.0056	50.609	127
C23	1 2 2 2 0 0 0 0 2 0 0 2 1 0 0 0 0 0 1 0 0 0 0 2 0 0 0 0 1 0	0.097	0.0055	54.271	127
C24	2 2 1 2 2 0 0 0 0 0 0 2 0 0 2 0 0 0 1 1 0 1 0 0 0 0 2 2 0 2	0.096	0.0060	25.488	130
C25	2 2 1 0 2 0 0 0 0 2 0 0 0 1 0 1 0 2 0 2 1 0 0 0 0 0 0 0 0 0	0.096	0.0056	54.431	130
C26	2 1 0 1 1 2 1 0 0 2 0 2 0 0 0 0 1 0 0 0 1 2 1 0 1 2 2 2 0 2	0.097	0.0055	50.582	132
C27	2 1 1 0 2 2 0 1 1 0 0 1 2 0 2 0 1 0 2 1 0 2 0 1 2 2 0 0 0 0	0.097	0.0055	60.276	135
C28	2 2 0 0 0 2 1 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0.096	0.0057	65.660	139
C29	2 1 1 0 2 0 2 0 2 0 0 2 2 1 2 1 0 1 2 0 0 0 1 0 2 0 0 1 0 0	0.097	0.0055	73.624	145
C30	2 2 2 0 1 1 0 1 0 0 0 2 0 0 0 0 1 2 0 1 2 0 0 0 0 1 0 2 2 0	0.096	0.0056	60.592	148
C31	2 0 0 0 2 0 1 2 2 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 2 0 0 0 0	0.097	0.0056	69.469	151
C32	1 2 0 1 0 1 2 0 2 0 0 2 1 0 0 1 0 0 0 0 0 0 1 0 0 0 1 0 1 0	0.097	0.0056	52.192	155
C33	1 2 0 2 2 0 0 0 2 0 0 1 0 2 0 0 0 2 1 1 0 1 2 2 1 0 0 2 0 2	0.097	0.0055	72.269	158
C34	1 2 0 1 2 2 0 1 1 0 0 1 1 0 1 0 0 1 1 1 0 1 1 1 2 1 2 0 2 1	0.097	0.0057	48.432	159
C35	2 2 0 2 1 1 0 0 0 1 0 2 0 1 1 0 0 0 0 0 1 0 2 0 1 1 0 0 1 0	0.097	0.0058	52.923	161
C36	2 0 2 1 2 1 0 1 0 2 0 2 2 1 2 0 0 1 2 0 0 1 0 1 0 0 2 1 1 0	0.097	0.0056	69.585	165
C37	2 2 1 2 0 1 0 0 2 1 0 2 0 2 0 0 0 2 0 0 0 0 0 1 2 0 0 0 0 2	0.096	0.0057	59.972	176
C38	2 2 0 0 1 1 2 0 1 2 0 0 1 0 0 0 0 0 0 2 0 0 0 0 0 0 1 2 0 0	0.096	0.0057	67.498	179
C39	2 0 0 1 2 2 1 1 0 0 0 1 0 1 2 0 0 0 0 0 0 0 0 0 0 0 0 2 0 1	0.096	0.0057	51.893	180
C40	1 1 0 2 1 2 1 0 0 1 0 2 0 0 2 2 0 1 0 1 0 1 1 1 0 0 2 0 0 2	0.097	0.0055	54.844	180
C41	2 0 2 0 1 2 0 0 2 0 0 0 0 0 0 0 0 2 0 0 0 0 1 0 0 0 0 0 0 0	0.096	0.0055	40.842	183
C42	2 0 0 2 1 0 2 1 0 2 0 2 2 1 0 1 0 2 0 0 0 2 0 0 0 0 1 0 0 2	0.097	0.0055	61.172	183
C43	2 0 0 2 2 0 1 1 1 2 0 2 1 0 1 1 1 0 0 0 0 2 1 0 1 0 2 1 1 2	0.097	0.0056	43.356	186
C44	2 0 2 2 1 0 0 2 0 2 0 2 1 0 2 1 2 0 1 0 0 0 2 2 0 0 2 2 1 2	0.097	0.0058	59.814	200
C45	2 2 0 0 2 0 0 1 1 1 0 1 1 0 0 0 1 1 0 0 1 2 1 0 0 2 0 1 1 0	0.097	0.0055	155.036	201
C46	2 0 1 0 2 2 0 1 1 0 0 1 2 0 0 1 0 1 0 2 1 2 2 2 0 0 1 1 2 0	0.097	0.0055	52.885	204
C47	2 2 0 1 2 0 2 0 0 0 0 1 2 2 0 1 0 2 0 0 1 0 1 0 0 0 2 1 0 2	0.096	0.0057	64.924	205
C48	2 0 0 1 2 0 0 0 2 2 0 2 1 1 1 0 0 0 0 0 0 1 1 1 1 0 0 1 0 0	0.097	0.0055	34.678	209
C49	2 0 2 1 0 0 0 2 2 2 0 0 0 1 2 0 2 1 0 2 0 0 2 2 1 0 1 1 2 0	0.097	0.0056	60.749	211
C50	2 1 0 0 2 1 0 1 1 1 0 0 0 0 1 1 2 1 0 2 0 0 0 1 1 2 1 1 2 0	0.096	0.0059	51.901	212

C51	1 2 0 2 2 0 0 0 1 1 0 1 1 1 2 1 0 0 0 0 0 0 1 1 2 1 2 1 1 1	0.097	0.0058	49.398	214
C52	2 2 0 1 2 0 2 0 0 0 0 1 2 2 0 1 1 2 0 0 1 0 1 1 0 0 2 1 0 2	0.097	0.0058	70.062	214

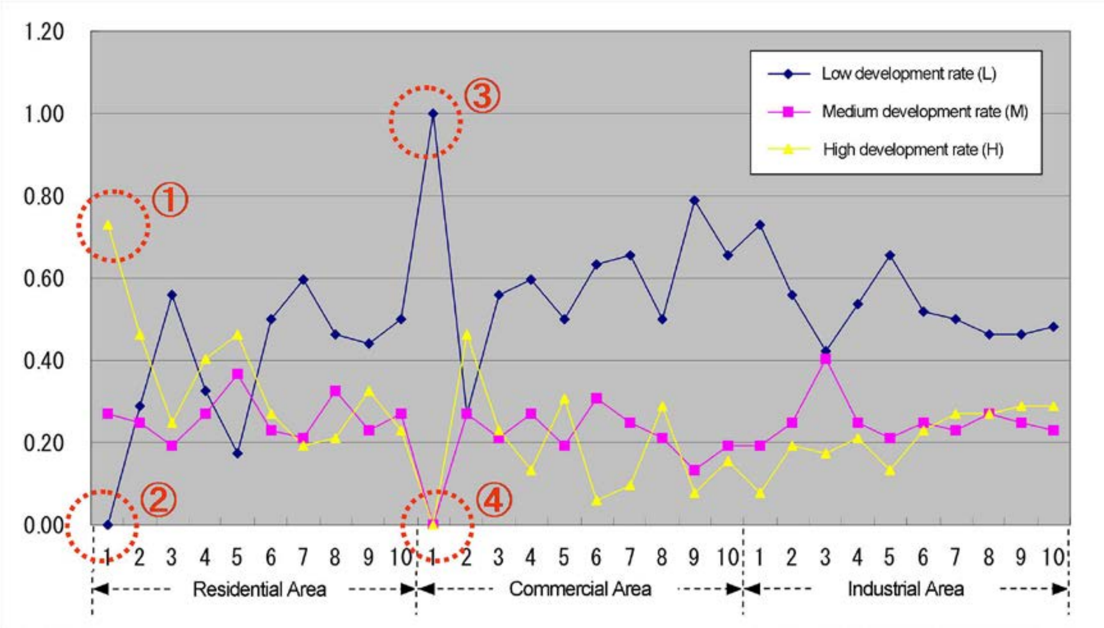


Figure 5.14 Probability of development ratio by district and land-use type of Decentralized Mode.

As shown, the likelihood of a high growth rate for residential lands in the central urban region in the Decentralized Mode is greater than 0.7 (1), whereas the probability of a low development rate is close to 0 (2). For commercial property, on the other hand, the likelihood of a low development rate is 1 (3), whereas the likelihood of a high development rate is close to 0 (4).

The central urban area's appeal has dwindled as a result of the rapid expansion of residential land and the deactivation of its commercial function. While housing construction typically results in a population inflow, the degradation of the living environment makes the optimal population concentration and comprehensive land use difficult to achieve. To draw the working population to the city center and contribute to decentralization, the industrial lands set a high growth rate in the suburbs and surrounding areas. This is a popular feature of Decentralized Mode's development program.

The growth rate with the greatest likelihood is chosen as the optimal development rate for each area and land type once more. **Table 5.5** summarizes the findings. The PC in the central metropolitan area is 23, the MD is 0.09615, and the SD is 0.00587 in this optimum growth program.

Table 5.5 Optimal development program of Decentralized Mode

Residential										
Area	1	2	3	4	5	6	7	8	9	10
Gene	0	0	1	2	0	1	2	2	2	2
Dev. Ratio	8%~9%	13%~14%	5%~6%	13%~14%	22%~23%	17%~18%	6%~7%	6%~7%	0%~1%	0%~1%
Commercial										
Area	1	2	3	4	5	6	7	8	9	10
Gene	2	0	0	2	1	1	2	1	2	0
Dev. Ratio	4%~50%	13%~14%	2%~3%	7%~8%	17%~18%	30%~31%	5%~6%	0%~1%	1%~2%	0%~1%
Industrial										
Area	1	2	3	4	5	6	7	8	9	10
Gene	2	2	0	0	0	0	0	0	0	0
Dev. Ratio	1%~2%	1%~2%	4%~5%	5%~6%	32%~33%	20%~21%	11%~12%	0%~1%	4%~5%	0%~1%

The population migration trend in Kanazawa's urban area has become apparent, as shown in **Figure 5.15**. There is a degree of dispersion in the results. The central region demonstrates a pattern of population outflow, while the surrounding urban areas have seen population inflow and outflow. The single feature focused primarily on residency in the central region cannot sustain long-term population attractiveness, and the decentralized development model would inevitably result in population transfer to the suburbs.

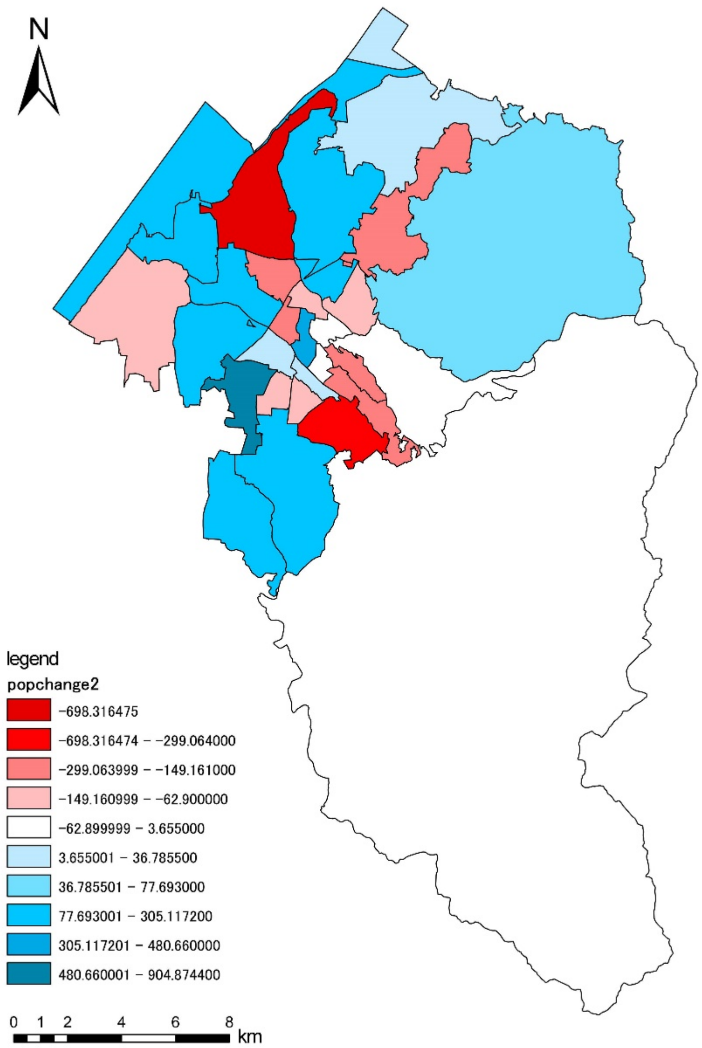


Figure 5.15 The tendency of population migration under the Decentralized Mode.

5.3.4. Maintenance-oriented Mode

The PC in the central urban region is between 73.8 and 104.04, the MD is between 0.097625 and 0.099742, and the SD is between 0.0054653 and 0.0050976 in Maintenance-oriented Mode. **Table 5.6** shows that after 20,000 GA iterations, a total of 71 development projects meet the criteria. **Figure 5.16** displays the distribution of the probabilities of growth ratios in each area and land-use functions, using the same probabilistic analysis approach as before.

Table 5.6 Chromosome of Maintenance-oriented Mode

	Gene	T_n	I_n	ΔP_n	F_c
C01	0 2 0 0 2 2 0 1 1 2 1 0 1 0 0 2 0 0 0 0 1 0 0 0 0 0 0 0 2 2	0.099	0.0052	84.660	66
C02	1 0 2 2 1 0 2 1 0 1 1 0 0 0 1 0 0 0 1 0 0 1 0 2 0 1 0 2 1 1	0.099	0.0054	86.360	74

C03	1 1 2 2 0 2 0 1 0 1 1 0 2 2 0 0 0 1 0 0 0 0 0 0 0 0 0 2 0 1	0.099	0.0054	96.410	77
C04	1 0 1 2 1 0 1 2 0 2 1 0 2 0 0 1 0 1 1 0 1 0 2 0 2 1 0 1 0 2	0.099	0.0052	91.840	79
C05	1 1 0 1 0 1 2 2 0 2 0 2 0 2 0 0 1 0 0 2 1 1 0 0 0 2 1 1 0 2	0.098	0.0051	83.360	82
C06	0 2 0 1 1 1 1 1 2 0 2 0 1 1 1 0 0 0 1 2 0 0 2 2 0 0 2 0 1 1	0.098	0.0051	95.720	85
C07	1 0 0 0 2 2 2 2 0 2 1 1 0 0 0 2 0 0 2 2 1 0 1 0 0 0 2 0 1 0 1	0.099	0.0052	89.500	88
C08	0 1 2 0 1 2 0 2 0 2 0 2 0 0 1 1 0 0 1 0 0 1 0 1 1 2 2 0 0 1 2 0	0.098	0.0051	79.350	89
C09	0 2 1 2 1 1 0 0 2 1 1 1 0 1 2 0 1 0 2 2 0 1 1 0 1 0 0 0 0 0	0.099	0.0052	97.750	91
C10	0 1 0 2 2 1 2 0 2 0 1 2 2 0 0 0 0 0 2 2 0 2 1 1 0 0 1 0 0 2	0.100	0.0052	93.570	97
C11	0 1 0 0 2 2 1 0 2 2 1 1 1 1 1 2 1 2 0 1 0 0 1 0 0 2 1 0 2 2	0.100	0.0055	81.080	102
C12	1 1 2 0 1 2 0 0 1 2 0 2 2 1 1 0 2 2 2 0 1 1 0 1 0 2 1 0 2 2	0.098	0.0053	85.580	115
C13	0 2 0 1 0 1 2 1 2 1 1 1 2 1 1 2 2 1 0 0 0 2 1 2 0 1 2 1 0 2	0.100	0.0052	96.480	115
C14	2 0 2 0 2 0 1 0 1 2 0 1 2 2 1 2 0 2 0 2 2 1 1 0 0 1 2 0 0 2	0.098	0.0052	80.770	122
C15	0 2 2 0 1 0 2 1 0 2 0 2 0 1 0 0 2 0 1 0 1 2 2 1 2 1 2 2 2 1	0.098	0.0051	79.200	126
C16	0 2 1 0 2 2 0 0 2 0 1 0 0 2 0 0 2 0 0 0 1 0 0 0 0 2 0 0 0 2	0.099	0.0051	93.310	126
C17	1 1 0 1 2 0 2 2 1 0 1 1 0 2 0 0 2 0 0 0 1 2 0 0 2 0 1 0 2 1	0.099	0.0053	87.590	127
C18	1 1 2 0 0 1 2 1 2 0 0 2 2 1 1 1 1 0 1 0 0 0 2 0 2 0 0 2 0 1	0.098	0.0053	82.200	128
C19	2 0 0 2 2 1 0 0 2 2 1 0 0 1 2 2 0 2 0 0 1 2 0 0 1 0 0 2 0 0	0.099	0.0053	86.860	132
C20	0 0 0 1 2 2 2 2 0 1 1 1 0 1 0 0 1 1 0 2 1 0 2 0 0 0 2 2 1 2	0.100	0.0052	75.220	138
C21	1 2 1 1 0 0 0 2 1 2 1 2 2 1 1 0 2 1 2 0 2 2 1 2 1 1 2 2 1 2	0.100	0.0052	81.580	140
C22	0 2 2 0 0 1 2 2 0 1 1 0 2 0 0 2 0 1 0 0 0 0 0 2 1 2 2 1 0 1	0.099	0.0052	78.630	146
C23	0 1 0 2 2 2 1 0 0 1 1 1 0 2 2 0 0 0 0 0 0 2 1 1 0 1 1 0 0 0	0.100	0.0052	77.180	148
C24	0 1 1 0 2 0 1 1 2 2 0 1 1 0 2 1 0 0 2 2 0 1 2 2 2 1 1 2 2 2	0.098	0.0053	83.830	150
C25	2 1 2 0 0 0 0 2 2 2 1 1 0 0 1 1 1 0 2 2 2 1 0 2 0 1 2 1 1 1	0.099	0.0053	101.200	152
C26	0 1 0 1 1 0 1 2 2 2 1 0 1 0 0 1 1 1 1 2 0 0 0 1 2 2 0 2 1 0	0.099	0.0052	94.620	157
C27	1 1 0 2 2 2 1 0 0 0 1 0 1 0 2 2 0 1 0 2 2 0 1 0 2 1 0 1 2 0	0.099	0.0054	83.820	162
C28	1 1 1 0 1 2 2 0 2 1 0 2 0 0 1 1 0 0 2 1 0 2 1 1 1 2 2 0 1 2	0.098	0.0054	95.150	163
C29	1 2 0 0 2 0 1 2 0 1 1 2 1 2 1 2 0 1 1 1 2 0 1 2 1 2 1 0 0 2	0.100	0.0053	84.750	167
C30	2 1 0 0 2 0 2 0 1 2 1 0 1 2 1 0 1 2 1 1 2 1 0 1 2 0 0 0 0 0	0.099	0.0052	89.540	170
C31	2 2 0 0 2 1 2 0 0 0 1 2 2 0 2 1 0 0 2 0 2 2 0 0 0 1 0 2 0 2	0.099	0.0054	76.640	174
C32	0 2 2 1 2 2 0 0 1 0 1 0 1 1 1 0 0 0 1 1 0 1 2 0 1 1 0 1 1 0	0.099	0.0053	92.530	180
C33	0 2 0 0 2 1 1 0 1 2 1 1 2 0 0 1 0 0 1 0 0 2 0 0 1 2 1 0 2 0	0.099	0.0053	79.650	188
C34	1 1 1 1 2 0 2 0 1 2 1 0 0 0 0 1 2 2 0 2 0 2 0 1 0 1 2 0 0 1	0.099	0.0054	74.320	190
C35	1 1 1 2 1 2 0 1 1 1 1 2 1 0 0 1 1 0 1 1 0 0 0 2 1 2 0 0 0 0	0.099	0.0054	85.330	197
C36	2 1 2 2 0 2 2 0 0 0 1 1 2 1 1 1 0 0 0 2 2 2 2 1 1 0 0 2 2 2	0.099	0.0054	96.860	202
C37	2 0 0 0 2 0 1 2 2 1 1 0 0 0 2 1 2 2 2 0 1 2 0 0 2 2 0 1 1 2	0.099	0.0053	92.020	204
C38	0 2 0 0 0 2 2 2 1 0 1 1 0 0 0 0 2 2 1 0 0 0 0 0 0 2 2 0 0 1	0.099	0.0053	74.050	209
C39	2 0 1 0 1 2 0 1 2 0 0 2 2 1 0 1 1 1 1 1 2 0 1 0 2 0 1 0 1 0	0.098	0.0052	84.010	211
C40	0 2 0 1 1 1 1 0 2 1 1 0 0 1 1 0 0 0 0 1 0 0 0 0 0 0 0 1 1 0	0.099	0.0053	75.770	211
C41	0 1 0 0 2 0 2 2 2 2 1 0 1 1 2 0 0 1 2 1 0 0 2 1 2 1 1 0 2 1	0.099	0.0054	91.760	213
C42	1 0 2 0 0 0 2 1 2 1 1 0 0 0 0 2 2 2 0 2 0 1 0 2 2 0 0 0 2 2	0.099	0.0053	99.100	238
C43	1 2 0 0 0 1 2 0 2 1 0 2 1 2 2 1 2 0 1 0 2 0 0 2 2 1 0 2 2 0	0.098	0.0052	104.000	264
C44	1 0 0 2 1 2 2 1 0 0 1 2 1 0 0 2 0 2 0 2 0 1 2 0 1 0 0 0 0 0	0.099	0.0053	75.140	278
C45	1 0 2 0 2 1 1 0 2 0 1 1 2 2 2 0 1 1 2 2 1 1 0 0 1 1 2 2 2 2	0.100	0.0054	102.000	281
C46	1 2 2 0 0 2 2 2 0 0 0 0 1 1 2 2 1 1 0 1 2 0 0 0 0 2 0 2 2 2	0.098	0.0052	82.230	288
C47	0 2 2 0 0 0 1 2 0 1 0 1 2 2 0 2 0 0 0 0 0 2 1 2 0 2 1 0 2 0	0.098	0.0052	100.200	291
C48	0 1 0 0 1 1 2 2 1 1 0 0 2 2 0 1 0 1 0 2 0 0 2 0 2 2 0 0 2 1	0.098	0.0053	97.630	295
C49	0 0 1 1 1 0 2 0 1 2 0 1 0 2 0 0 0 0 0 0 1 0 2 1 0 0 1 0 2 0	0.098	0.0051	93.590	307
C50	1 0 2 0 2 0 1 2 0 0 1 0 0 0 0 1 1 1 1 0 0 1 1 0 1 0 0 1 0 1	0.099	0.0053	79.270	317
C51	1 2 2 0 1 0 1 1 0 0 1 1 0 0 2 2 2 1 2 2 2 1 2 2 0 0 0 0 1 0	0.099	0.0052	97.090	321
C52	0 0 0 2 0 2 2 0 2 0 0 1 0 0 0 0 0 0 0 0 0 1 2 1 0 0 0 1 2 0	0.098	0.0052	79.180	349
C53	1 2 0 1 1 1 2 0 0 0 1 0 0 2 2 1 0 1 0 2 1 2 0 1 0 0 1 1 1 0	0.099	0.0054	84.570	350
C54	0 2 0 1 0 0 0 2 1 2 0 2 1 1 0 0 0 1 2 2 0 1 0 0 2 1 2 1 2 0	0.098	0.0053	93.350	362
C55	1 0 2 1 2 0 1 1 2 2 1 0 2 0 1 1 0 2 1 2 1 0 2 2 1 1 1 2 2 0	0.099	0.0054	77.400	364

C56	1 2 1 0 2 0 0 2 0 0 1 1 1 1 2 1 1 1 2 2 2 0 1 1 0 2 0 1 1 2	0.099	0.0055	76.230	371
C57	0 0 0 2 1 1 1 1 2 0 1 0 0 0 0 0 0 0 0 1 0 0 2 1 0 0 0 0 2 2	0.099	0.0054	78.960	372
C58	1 1 0 1 0 0 1 2 1 1 1 0 1 0 0 0 2 2 1 2 0 0 1 0 2 2 0 0 0 0	0.099	0.0054	86.820	373
C59	1 0 0 2 1 2 2 0 0 0 1 1 0 1 1 0 1 2 1 2 1 0 2 0 0 0 1 1 1 0	0.099	0.0054	101.600	385
C60	2 1 0 0 0 2 2 0 0 1 1 2 2 1 0 0 2 2 1 1 2 1 2 2 1 2 0 2 0 2	0.099	0.0054	84.230	390
C61	2 1 1 0 0 2 0 0 0 2 1 1 2 2 1 0 1 0 0 2 2 1 0 2 0 2 2 0 0 0	0.099	0.0052	89.450	407
C62	0 0 2 0 0 1 0 2 2 1 0 1 1 0 0 1 2 0 0 0 0 0 2 0 2 0 0 2 2 1	0.098	0.0052	77.740	453
C63	2 0 0 1 0 2 0 2 0 1 1 2 0 2 1 0 0 1 0 2 2 1 0 2 1 1 2 2 1 1	0.100	0.0054	78.040	453
C64	0 0 0 2 0 1 1 2 1 0 0 1 2 1 2 1 1 2 1 1 0 1 0 2 0 0 2 1 2 0	0.098	0.0052	87.650	485
C65	0 1 0 1 2 0 1 1 0 1 0 0 0 1 2 0 0 1 2 1 0 1 0 2 2 2 0 0 0 0	0.098	0.0052	95.850	543
C66	0 0 2 1 1 0 0 1 1 1 1 0 2 2 0 1 0 2 0 0 0 0 1 2 0 0 0 0 1 2	0.099	0.0053	93.210	545
C67	0 0 1 0 2 2 2 0 0 0 0 2 0 2 2 2 1 1 0 0 0 0 0 0 1 2 2 0 0 0	0.098	0.0052	89.110	547
C68	1 0 2 0 0 0 2 1 1 0 0 0 0 1 0 0 1 2 1 1 0 1 0 0 0 0 0 0 0 2	0.098	0.0052	93.640	558
C69	0 0 0 2 0 1 0 2 2 0 1 0 1 0 0 0 0 0 0 0 0 0 1 0 1 0 2 0 0 0	0.099	0.0052	77.140	568
C70	1 0 0 0 0 1 1 2 0 2 1 0 1 1 2 1 1 1 0 2 2 0 1 0 1 1 0 1 1 2	0.100	0.0051	73.950	574
C71	2 0 2 0 1 0 0 1 0 1 1 1 1 0 1 2 0 2 2 0 2 1 2 1 2 1 1 1 0 2	0.099	0.0054	102.200	622

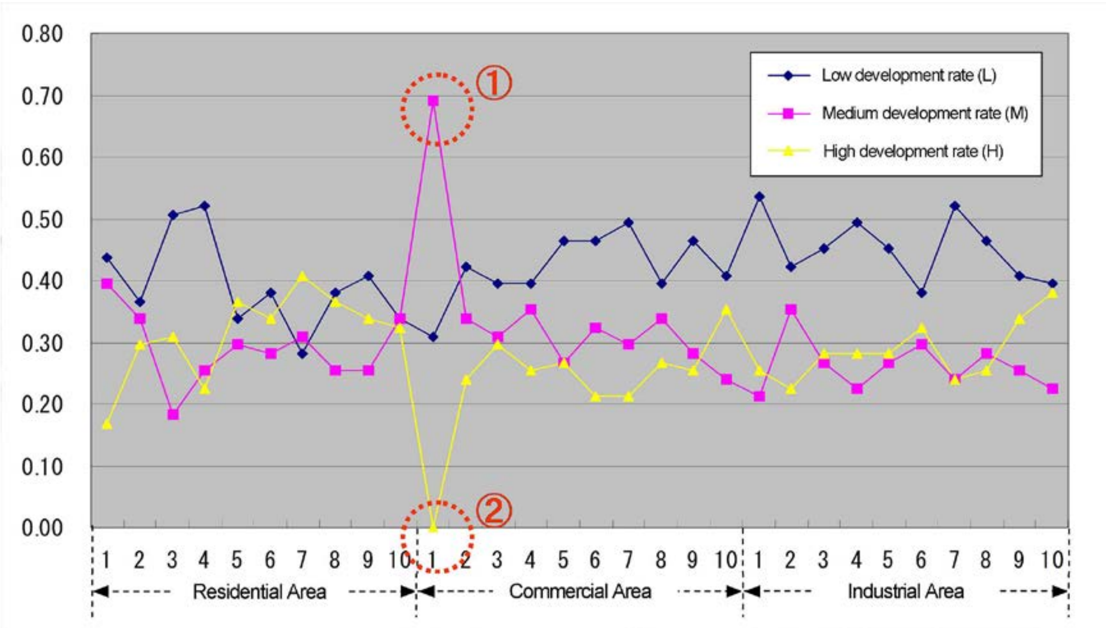


Figure 5.16 Probability of development ratio by district and land-use type of Maintenance-oriented Mode.

The probability of selecting the medium development rate for commercial land in the central urban area under the Maintenance-oriented Mode is above 0.7 (1), but the probability of selecting the high development rate is close to 0 (as shown in figure) (2). In order to preserve the status quo, commercial functions must be enabled through appropriate commercial growth. For each area and land type in the model, the growth rate with the highest likelihood is chosen as the optimal development rate. The best development software for Maintenance-oriented Mode is shown in **Table 5.7**.

Table 5.7 Optimal development program of Maintenance-oriented Mode

Residential										
Area	1	2	3	4	5	6	7	8	9	10
Gene	0	0	1	2	0	1	2	2	2	2
Dev. Ratio	2%~3%	7%~8%	5%~6%	7%~8%	22%~23%	17%~18%	9%~10%	12%~13%	0%~1%	2%~3%
Commercial										
Area	1	2	3	4	5	6	7	8	9	10
Gene	2	0	0	2	1	1	2	1	2	0
Dev. Ratio	9%~10%	6%~7%	2%~3%	7%~8%	14%~15%	30%~31%	6%~7%	0%~1%	1%~2%	0%~1%
Industrial										
Area	1	2	3	4	5	6	7	8	9	10
Gene	2	2	0	0	0	0	0	0	0	0
Dev. Ratio	1%~2%	2%~3%	4%~5%	5%~6%	33%~34%	20%~21%	8%~9%	0%~1%	4%~5%	0%~1%

The PC in the central metropolitan area is 23, the MD is 0.09615, and the SD is 0.00587 in the optimum growth program. The population migration trend in Kanazawa's downtown area has stabilized, as shown in **Figure 5.17**.

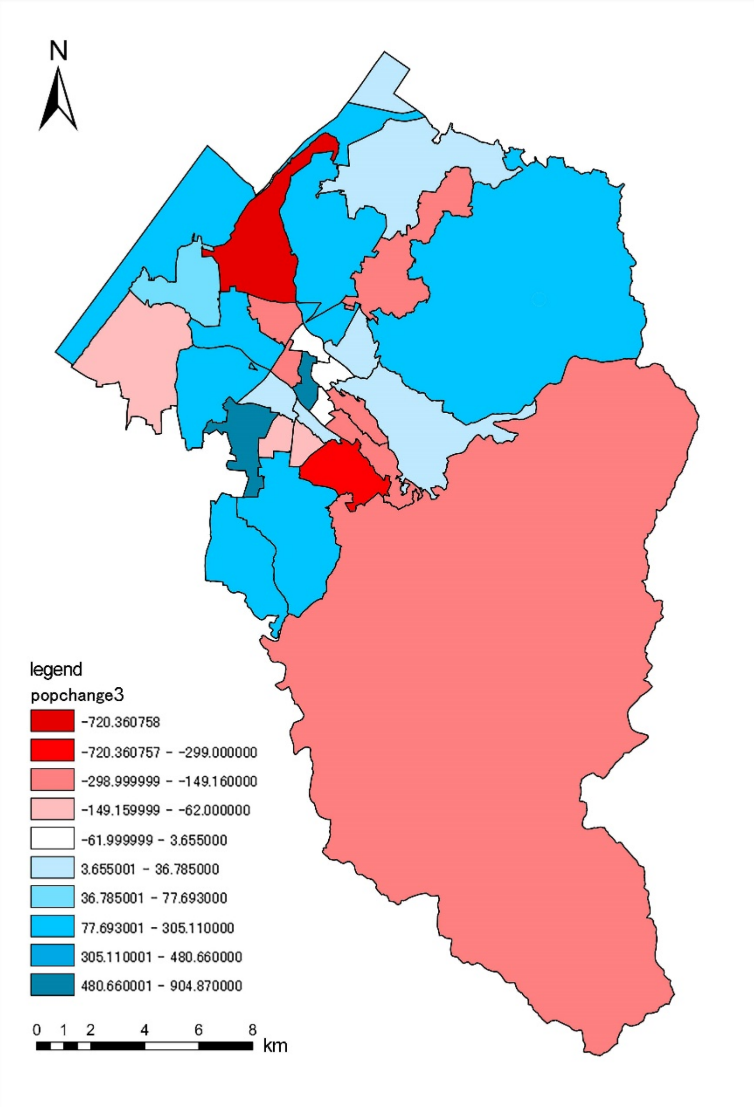


Figure 5.17 The tendency of population migration under the Maintenance-oriented Mode

5.4. Conclusions

Decentralization has resulted in a waste of established capital in metropolitan areas, causing the central urban region to deteriorate, urban land to be underutilized, and suburban land to be constantly covered by inefficient building methods (Audirac, 2005).

Population density, land use, and transportation climate are three variables that influence the compactness of urban areas when looking at the phenomenon of decentralization (Stanilov & Sýkora, 2014). This study identified and validated a land-use support system based on population density and land use structure in Kanazawa City.

One of the key points of the compact city is the selection of the development mode, and the genetic algorithm is used to solve this problem. In the GA scheme, each development program is represented by a chromosome. The optimal development program is developed by the algorithm's selection, crossover, and mutation method. The spatial interaction model is used to calculate the resulting demographic shift and land use structure based on the development program.

The findings show Kanazawa City's migration across three separate construction modes. In the focused development mode, reviving the central city's commercial functions through large-scale commercial development will help restore the population and increase the complexity of land use, which is in line with the compact city concept. In contrast, if residential construction is used to create unitary urban centers, the process of urban decentralization will be accelerated. The main factors for creating a compact city and countering urban decentralization can be seen as moderate and practical mixed urban land-use.

In summary, we have discussed the process from development mode and program to population migration and land-use structure, and we have proposed a comprehensive research approach and planning support framework, which can be used to research the environment in a variety of ways hollowing phenomenon in central urban areas. We tested the approach and framework proposed in this study in Kanazawa, discovered the best development program for various development goals, and compared the core elements for commonality, all of which are essential for compact city research and practice.

There's more work to be done. The factor of the traffic climate was not considered in the actual situation of Kanazawa, which would most likely affect the outcome of population migration. The pattern of population migration in the central urban region will be used to enrich the research content of air pollution and energy use related to population migration induced by a car driving in the future.

Meanwhile, the social attraction model, which is focused on the attractiveness of different subregions, is used in this study to forecast population migration. However, the mechanism behind it is much more complicated, and many variables such as age structure, housing preferences, and industrial structure need further investigation.

The phenomenon of urban decentralization has arisen as a result of urbanization, and it corresponds to the concept of the compact city. I hope that the findings in this paper will contribute to the advancement of urban decentralization and compact city analysis.

5.5. Notation

Notation 5.8 Variable Explanation in Formula 4

Variable	Explanation
DE_{pop}	Density of population
L_p	Land price
L	Labor population
NUM_2	Volume of 2nd industry
NUM_3	Volume of 3rd industry
D_{cen}	Distance away from center area
D_{sta}	Distance away from station area
L_u	Land use

Notation 5.9 Variable Explanation in Formula 5

Variable	Explanation
DE_{res}	Density of resident

D_{sta}	Distance away from station area
D_{cen}	Distance away from center area
F	Volume of facility
P_{com}	Increase of commercial profit
A_{com}	Area of commercial area
A_{ur}	Area of urban road
Z_{com}	Land use

Notation 5.10 Variable Explanation in Formula 6

Variable	Explanation
DE_{res}	Density of resident
D_{sta}	Distance away from station area
D_{har}	Distance away from harbor area
D_{mar}	Distance away from market area
L	Labor population
R	Water, electricity, gas Resource
G_{ind}	Industrial group
L_p	Land price
L_u	Land use
F	Volume of facility

CHAPTER 6. CONCLUSION

6.1. Conclusion

A sustainable urban form is essential for contemporary urban development, which requires an in-depth understanding of urban space production and targeted planning strategies. The primary purpose of this Ph.D. dissertation is to propose planning strategies for sustainable urban form based on the analysis of the space production process. This dissertation confirmed each element's corresponding relationship in the production process in space by analyzing space production in Japan and clarify the corresponding elements of raw materials, production process, and consumption process. On this basis, this dissertation proposes sustainable planning strategies from the perspective of these three elements.

For raw materials in space production, this dissertation summarized the planning strategies used in water-sensitive urban design in Japan and identified the water source protection, flood control, and waterfront landscape as the main aspects of sustainable urban form in Japan. Water-sensitive urban design is a set of sustainable planning strategies that can deal with water resources in the space production process.

Next, this dissertation summarized the planning strategies used in port area construction for the production process in space production. The production process should focus on the regional industrial clusters, regional cooperation, foundation integration, and the establishment of a complete industrial chain. The sustainable urban form would benefit from the sustainable regional industrial clusters.

For the consumption process in space production, land-use and population distribution are the key factors that determine how spatial products are consumed. This dissertation proposed a planning support system based on the GA algorithm for the phenomenon of urban decentralization. The appropriate development program will respond to the process of urban decentralization with the help of this system.

6.2. Future Work

For future work, there are still many specific strategies necessary to sustainable urban form, from other natural resources such as air and soil to the social elements such as symbols, ideology, and historical background. In addition, there are still many aspects worth exploring regarding space production, such as how the produced space enters the daily life and concepts of urban residents, which represents the "thrilling leap" of the exchange process of commodities. Achieving sustainable development still requires more contributions from urban planning researchers.

PUBLICATION

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