Urban New Districts' Toughness Development under The Sponge Infrastructure Project: The case of Jinan, China

Zhiqing ZHAO, School of Architecture, Harbin Institute of Technology; Heilongjiang Cold Region Urban-Rural Human Settlements Science Key Laboratory, Harbin, China.
Peilun LI, School of Architecture, Harbin Institute of Technology; Heilongjiang Cold Region Urban-Rural Human Settlements Science Key Laboratory, Harbin, China.
Lu ZHANG, School of Architecture, Harbin Institute of Technology; Heilongjiang Cold Region Urban-Rural Human Settlements Science Key Laboratory, Harbin, China.

Abstract

In recent years, worldwide extreme weather is constantly appearing. The extensive development and construction of cities had changed the original water system that caused the frequent occurrence of urban water disasters and the worsening of the water environment until the planning and construction of the Sponge cities vigorously promoted in China that the problems with urban water systems were gradually easing in 2014. In this paper, through four points of view are ecological toughness, technical toughness, social toughness and economic toughness that make a scientific top-level design of Sponge city construction. Meanwhile, it points at three key problems as the urban flood control and drainage, regulation of diffuse pollution and utilization of rainwater resources in an urban tenacity development perspective, based on the key points as the simulation technology of urban rain and flood and the LID optimization technique method to discuss the technical methods for supporting the implementation of Sponge cities. According to the Sponge city construction in the new area of pilot cities - The conceptual planning of the sponge city in the extension area of Jixi in Jinan city as the research case; put forward the planning strategies of ecological pattern construction, systematic planning and construction guidance of the sponge city in system, also explores the extended industrial development and the construction of tenacity mechanism of the Sponge city that attempts to provide a new thinking and path for the study of the sponge city planning and construction.

Keywords: Sponge City, New Urban Districts, Toughness Development

1. Background

The promotion of "new normal" accelerates the pace of urban transformation and development, which makes its development demand shift from "scale and quantity" to "efficiency and quality". The construction of the extensive development of the city has changed the original water system of the city, and the problem of water system in the city has become increasingly prominent. Since 2014, China has vigorously promoted the construction of sponge city to solve the problems related to urban water environment, water ecology and water resources. Experts, scholars and relevant administrative departments in the field of urban planning and construction have made many useful attempts and explorations in the planning and research of spongy cities.

In order to enhance the resilience of the city, several pilot projects have been set up in China to carry out the construction. Unfortunately, 19 of the 30 sponge City trials in China appeared water logging in 2016, which led to various controversies in the civil and academic circles. At the same time, it is found that the research scope of the pilot sponge city is limited by the sort out and review of various problems in the process of the planning and construction of the domestic sponge city. It often ignores the top-level design problem of sponge City, especially for the study of water system planning in larger scale regions and cities (Zhao zhiqing, Wu Zhongyang & Wang Zuowei, 2018). Under such circumstances, the construction of sponge city under the guidance of urban resilience thinking is particularly important.

However, most of the research focuses on the planning and construction of spongy cities. They are more inclined to specific municipal engineering measures, and the focus is to solve the problem of urban water logging (Wang C H, Blackmore J M, 2009). Therefore this paper puts forward the top layer design of the construction of the planning strategy of the spongy city by taking Jinan Jixi extension area as the research object, taking the problems arising in the process of the planning and construction of the sponge city as the guidance, and through the methods of urban flood defense and drainage, the control of non-point source pollution and the resource utilization of rainwater (Shao Yiwen, Xu Jiang, 2015).

2. Methodology

2.1 Range of Study

Jinan was selected as the first batch of sponge pilot cities in 2015.It selected the old city area of 39 square kilometers in the central area as the pilot area of sponge city construction (Fig.1). The scope of this plan is to select the JiXi wetland, Emei area and West Railway Station area in the western part of Jinan as the demonstration area for sponge city construction. The conceptual planning is the top-level design of sponge city. It is a commanding plan in the implementation process of the spongy city planning and construction in JiXi extension area, and provides the top level positioning and technical support for the follow-up control detailed planning, construction detailed planning, construction management, acceptance and maintenance work (Zhao zhiqing, 2016).

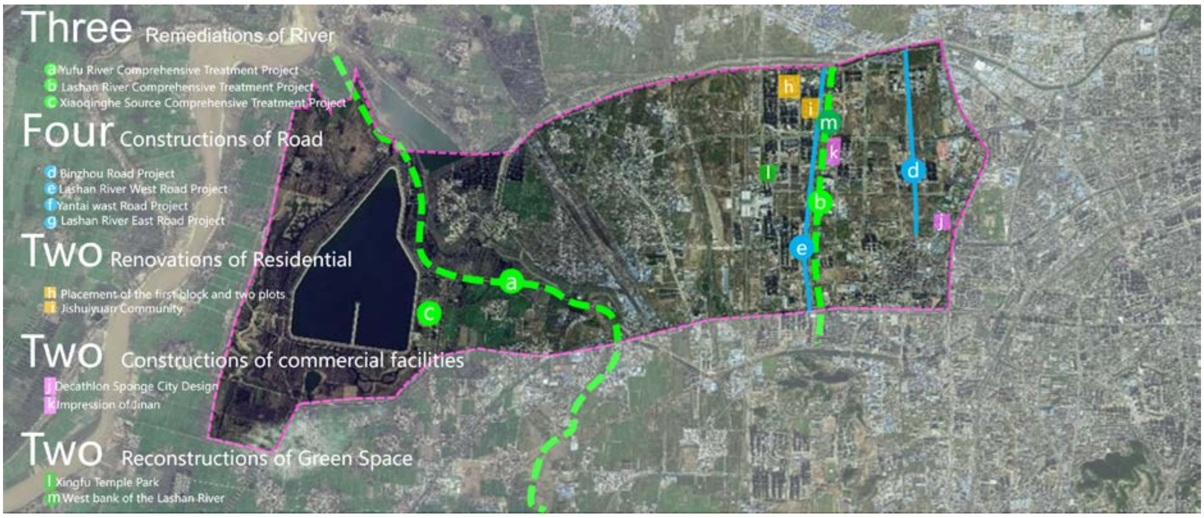

Figure 1: Current status of existing projects
Source: graphing by author

2.2 Situation Questions

(i) The utilization rate of unconventional water resources is low. The regeneration and utilization of sewage has not yet formed a complete system, and the utilization of rainwater resources has just started. There are only rainwater collection and utilization facilities in some housing estates, such as Ji Water Royal Garden District, Forest Landscape Villa district and part of the street.

(ii) There is a hidden danger of water logging in JiXi extension area. The data show that there is no water accumulation point in JiXi extension area, but its rainwater pipeline system is not perfect, the recurrence period is less than 2 years. The poor scheduling of the construction of rainwater pipe network in the west station area and the unsound pipe network in Emei area have hidden dangers of water logging.

(iii) The sewerage network system has not yet been constructed in Emei area. The effect of the direct discharge of sewage and the non-point source pollution result in poor water quality of the Mount Emei River and its downstream Small Thanh Ha. The non-point source pollution of urban water and rainwater surface runoff is more serious.

(iv) The ecological nature of a few river course shoreline is not good. The maintenance of the ecological nature of Small Thanh Ha, La Mountain River and Jade Character River is good. There is no maintenance measure for Mount Emei river bank line, so ecological shoreline restoration is needed.

(v) The risk of flood disaster is low, and the prevention and control system needs to be improved. On the south side of the Jinxi extension area, there is a flood by-pass of the La Mountain River. It introduced the flood upstream of the Small Thanh Ha into the west to the Yellow River river system and reduced the potential flood hazard. However, the rainstorm in Jinan is characterized by heavy rainfall, high intensity, obvious locality and very concentrated time history distribution. It should strengthen flood control and improve the resistance to flood disasters in the JiXi extension area (Bates S, Angeon V., Ainouche A., 2014).

2.3 Urban Toughness

Resilience thinking can solve various problems in the construction of sponge city with a new research angle, and construct a more stable urban ecological pattern from a macro perspective in order to solve the problem of poor systematic and single research scale (Adger, W. N., 2000). It establishes the overall framework of the sponge city construction system with the ability to deal with the rain and flood risk from the meso scale, and makes the construction of the sponge City collaborate highly with the special planning between the other urban subsystems, which enhance the integrity of the construction project and make it no longer blindly rely on the facilities to solve the water system problem (Bai, X., 2007). It builds the facilities of the sponge city from the micro scale, and at the same time deploys and promotes the implementation and management of the construction of the sponge city, in order to enhance the stability of the economy and control of the sponge city. The following will be discussed from four perspectives of resilience: ecology, engineering, economy and society (Fig.2).

Tenacity Thinking		Spongy City	Approach	Planning Concept
Ecological toughness	Water system toughness	Water ecology, water environment and water safety planning	Water area control and protection, water pollution control, flood control and drainage facilities planning, "Matrix -- corridor -- plaque" protection strategy	**Dominant recessive combination**——Basin perspective; surface and underground;
	Tenacity of green space system	Construction of urban green space system in sponge City	In the low-lying area of the city, sponge type green space is set up. Retention infiltration green space, Midway transmission type of green space, receiving storing type of green space.	
Technicial toughness	Technical toughness	Planning of municipal rainwater, sewage and water system	Introduce advanced pipe network system and perfect the current system	**General and special combination**——Normal rainfall and extreme climate co-ordination; flood detention, flood diversion and flood discharge co-ordination;
		Revetment improvement and rainwater utilization	Restoration and protection of ecological coastline	
	Measurement toughness	The control index of land use runoff in each block	Quantitative index control	**Micro control and global idea**——The index is refined to the plot, the unit is divided into control thinking, and the promotion area is balanced.
Sociology toughness	Management toughness	Construction management and control	Set up a sponge city management team and set up an expert think tank.	**Resource integration**——Mutual support and interconnection ensure the common operation and rapid response among departments.
	Synergistic toughness	Public participation	Coordination of governments at all levels, neighborhood organizations, community organizations and private sectors	**Cooperative inclusion**——Further develop professional subregional network to achieve the common vision of building resilience cities
Economic toughness	Potential toughness	Planning scheme of extension industry in sponge City	Sponge city culture tourism, sponge City Culture Exhibition	**Layers of progressive**——From building monomer, green space, street to functional area unit, the urban culture and industry will be improved comprehensively.

Figure 2: The Type of Toughness Development
Source: graphing by author

2.4 Data Specification

According to the DEM elevation and landset8 satellite remote sensing image data provided by the local survey service, it has carried out the analysis of the area on the slope, elevation, vegetation cover and heat island, and locked the main aggregation area of the site problem. Local rainfall data are derived from local Yearbook chronicles. In order to ensure consistency of the research foundation, these data sources chose the same year to minimize the possibility of invalid data as far as possible.

2.5 Statistical Analysis

The rainfall pattern in Chicago is composed of the maximum rainfall intensity of different duration under a certain recurrence period. The determination of rain pattern is based on the IDF relation curve at a specific recurrence period. The determination of the rainfall pattern in Chicago includes the determination of the comprehensive rainfall peak position coefficient and the determination of the rainfall graph model in Chicago (Trinh D, Chui T.,2013).

(i) The annual maximum rainfall process samples of the every duration of rainfall were segmented at intervals of 5min to calculate the rainfall peak position coefficient $r_i = t_i / T_i$ (r_i is the peak position coefficient of the rainfall, t_i is the peak value time of the rainfall , and T_i is the duration of rainfall.

(ii) First, it carries on the arithmetic average of the rain peak position coefficient of the annual maximum rainfall process samples of the every duration of rainfall, then weighted average of each diachronic peak position coefficient according to the length of each diachronic time and calculates the comprehensive rainfall peak location coefficient *r*.

(iii) It designs the rainfall recurrence period (*P*) and the duration of rainfall (*t*) based on the comprehensive rain peak position coefficient *r*, and substituting it into the rainfall pattern in Chicago derived from the rainstorm intensity formula to calculate the instantaneous rainfall intensity before and after the rain peak and the average rainfall intensity in each period. Thus, the rainfall pattern in Chicago corresponding to a certain recurrence period and the duration of rainfall is finally determined.

The rainfall pattern in Chicago makes the design of typical rainfall process based on the statistical rainstorm intensity formula. It describe the time when the peak of rainstorm occurs by introducing the rain peak position coefficient *r*, and divides the time series of rainfall duration into two parts: pre peak and post peak. The instantaneous intensity of the pre peak is $i(t_b)$, the corresponding duration is (t_b), and the instantaneous intensity of the post peak is $i(t_a)$. The corresponding duration is (t_a).The instantaneous rainfall intensity before and after the rain peak can be calculated by the following formula：

$$i(t_b) = \frac{A[\frac{(1-n)t_b}{r} + b]}{[(\frac{t_b}{r}) + b]^{n+1}}$$

$$i(t_a) = \frac{A[\frac{(1-n)t_a}{1-r} + b]}{[(\frac{t_a}{1-r}) + b]^{n+1}}$$

3. Results

3.1 Basic Data Analysis

The overall topography of the area shows the South High and North low . The altitude of the south side of the site is mostly between 30-35 meters, while the altitude of the most other areas are mostly between 20-30 meters (Fig.3). The land in JiXi extension area is relatively flat, and most of the slopes are between 0.3-5.0% (Fig.4).The proportion of the whole green space and the underlying surface of the water body can exceed 40%.The JiXi extension area has excellent natural resources and comfortable living environment (Fig.5,6).

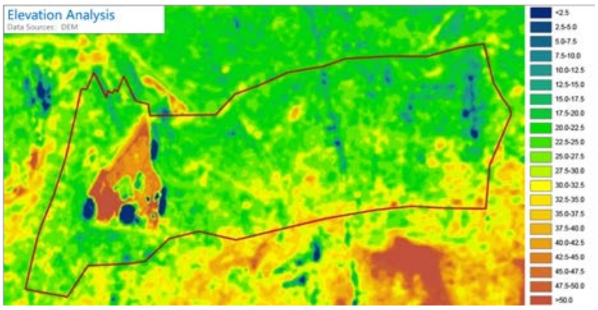

Figure 3: Elevation Analysis

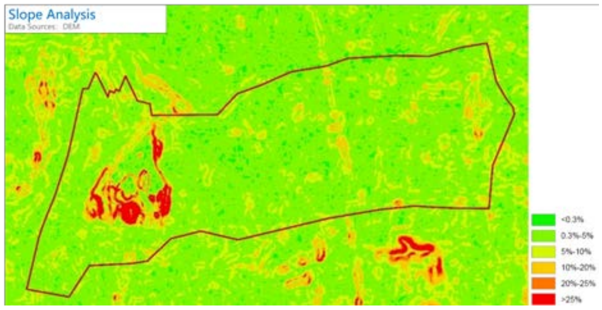

Figure 4: Slope Analysis

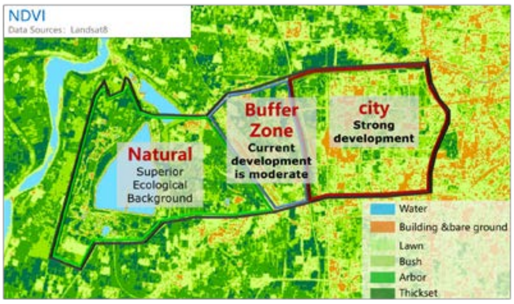

Figure 5: NDVI Analysis

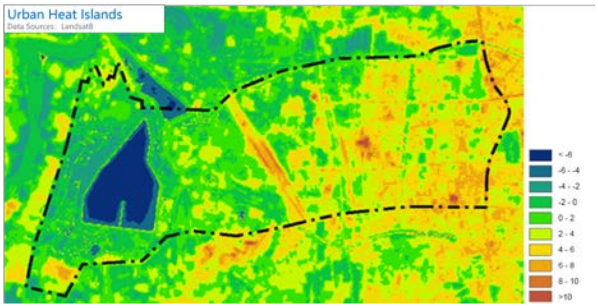

Figure 6: Urban Heat Islands Analysis

Source: graphing by author

According to the statistical data, the local rainfall has the characteristics of uneven distribution of precipitation, large variation of inter annual rainfall, seasonal variation of precipitation, and large annual average water surface evaporation. According to the rainstorm intensity formula before and after the peak, the maximum intensity of Chicago rain pattern at different recurrence periods is shown below the following picture. The maximum intensity of a 2 year rainstorm is 2.656mm/min. The maximum intensity of a 100 year rainstorm is 5.941mm/min, and the composite rain peak coefficient is 0.347 (Fig.7, 8, 9).

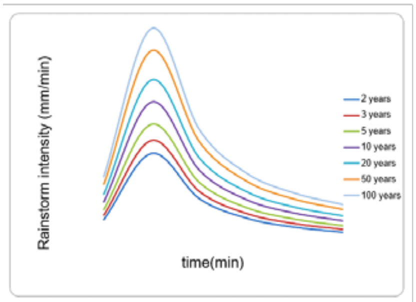

Figure 7: 30min rain pattern

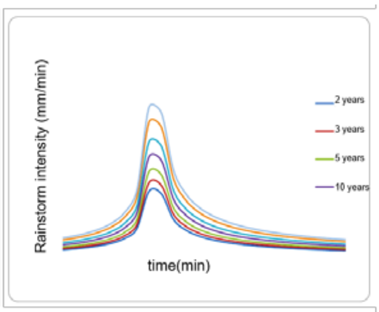

Figure 8: 120min rain pattern

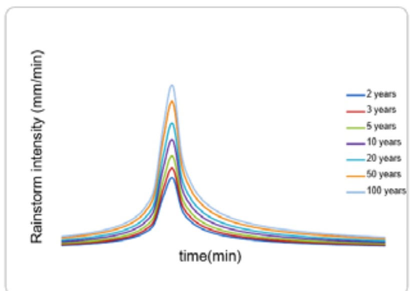

Figure 9: 180min rain pattern

Source: graphing by author

3.2 Flood Control and Drainage

The urban low-lying areas are easy to gather rainwater. Therefore, sponge type green spaces should be set up in the low-lying areas of the city to collect, store and retain rainwater. Depressions type I: water depressions. Protection requirements: coordination of general regulations and regulatory rules must be preserved. Depressions type II: waterless depressions. Protection requirements: according to the actual situation, the depressions should be used as green land, lake or other land, or construct the LID facilities (Fig.10).

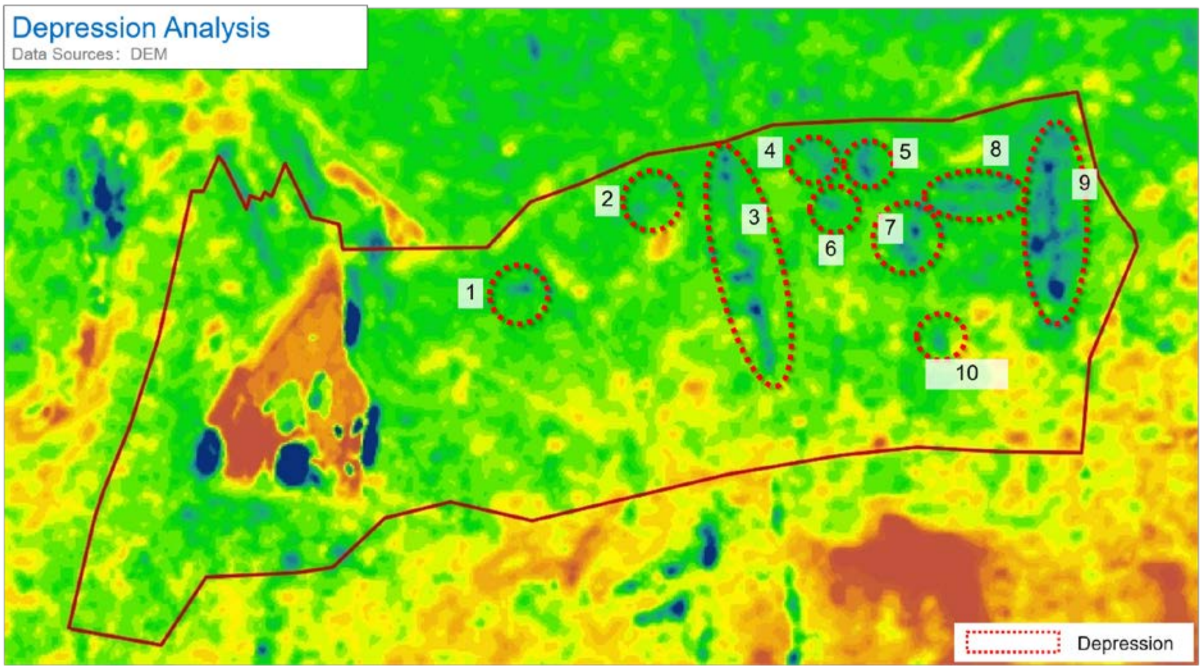

Figure 10: Depression Analysis
Source: graphing by author

3.3 Pollution Control

(i) Increase the ecological purification facilities. Setting up ecological purification facilities in streets and communities, including vegetation buffer zones, grass planting trenches and rainwater gardens, so as to beautify the environment and reduce runoff source pollution.

(ii) Perfect drainage pipe network. The current situation of rainwater network construction is not perfect. There are lots of shanty towns in Mount Emei area, and the density of rainwater and sewer pipe network is low. Part of the road which was not constructed in the West Railway Station area resulted in incomplete pipe network. The pipeline network should be constructed in stages according to the actual situation, so as to reduce non-point source pollution.

(iii) Put up the initial rain discard flow devices. In the rainwater pipeline, the initial rain discard flow device is added, and the initial rainwater is treated and discharged to the river to reduce the pollution of the rain water after washing the pollutants to the river system.

(iv) Sewage interception. Improve the sewage pipe network system, shut off the sewage straight discharge port, discharge all the sewage into the sewage treatment plant, and prevent the sewage from being directly discharged into the river water system (Fig.11).

Figure 11: Classification of Pollution Control
Source: graphing by author

3.4 Runoff Unit

In order to connect the implementation scheme of the spongy city in the JiXi extension area, and to provide support for the implementation of the follow-up construction projects (Fig.12). Facilitating the further deepening of the runoff control indexes in the construction land of the control units, the control units can carry out independent runoff monitoring (Table.1).

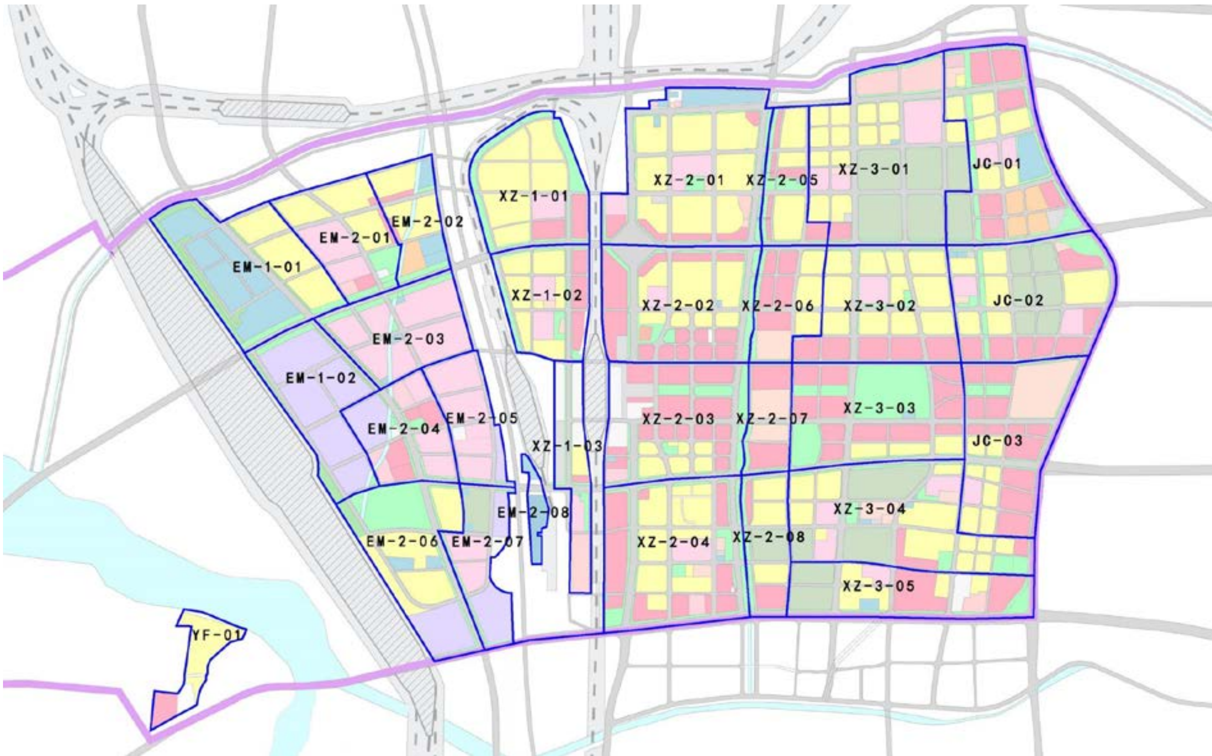

Figure 12: Control Unit of Runoff Rate
Source: graphing by author

Unit	Area(hm²)	Annual runoff control rate (%)	Rainfall design (mm)
XZ-1-01	94.53	78%	31.2
XZ-1-02	67.00	75%	27.7
XZ-1-03	41.72	64%	19.0
XZ-2-01	161.71	60%	16.7
XZ-2-02	127.90	62%	17.7
XZ-2-03	118.70	60%	16.7
XZ-2-04	148.00	68%	21.7
XZ-2-05	46.32	72%	25.0
XZ-2-06	51.41	64%	19.0
XZ-2-07	34.55	67%	21.0
XZ-2-08	45.15	69%	22.5
XZ-3-01	177.85	68%	21.7
XZ-3-02	117.54	72%	25.0
XZ-3-03	127.95	76%	28.9
XZ-3-04	149.46	67%	21.0
XZ-3-05	88.14	71%	24.0
JC-01	137.57	72%	25.0
JC-02	134.08	71%	24.0
JC-03	117.03	72%	25.0
EM-1-01	118.04	77%	30.0
EM-1-02	86.71	73%	25.9
EM-2-01	71.00	78%	31.2
EM-2-02	43.04	77%	30.0
EM-2-03	75.5111	76%	28.9
EM-2-04	61.5281	75%	27.7
EM-2-05	49.0934	74%	26.8
EM-2-06	101.7757	79%	32.3
EM-2-07	51.7206	73%	25.9
EM-2-08	9.8845	71%	24.0
YF-01	22.93	65%	19.6

Table 1: Runoff Control Indicators of Construction Land
Source: graphing by author

4. Methodology

4.1 Framework of the Resilience Structure

In order to avoid a series of problems, such as poor systematic scheme, single research scale, and fragmentation of construction projects, this plan divides the construction of the spongy city planning system into three levels, which are the ecological pattern planning of the sponge city, the system planning of the sponge city and the planning of the construction of the sponge city (Alexander D E, 2013). In these three levels, it joins the guidance of resilience thinking, and solves the problems in the process of the planning and construction of the traditional sponge city, and makes the construction system of the sponge city more flexible (Fig.13).

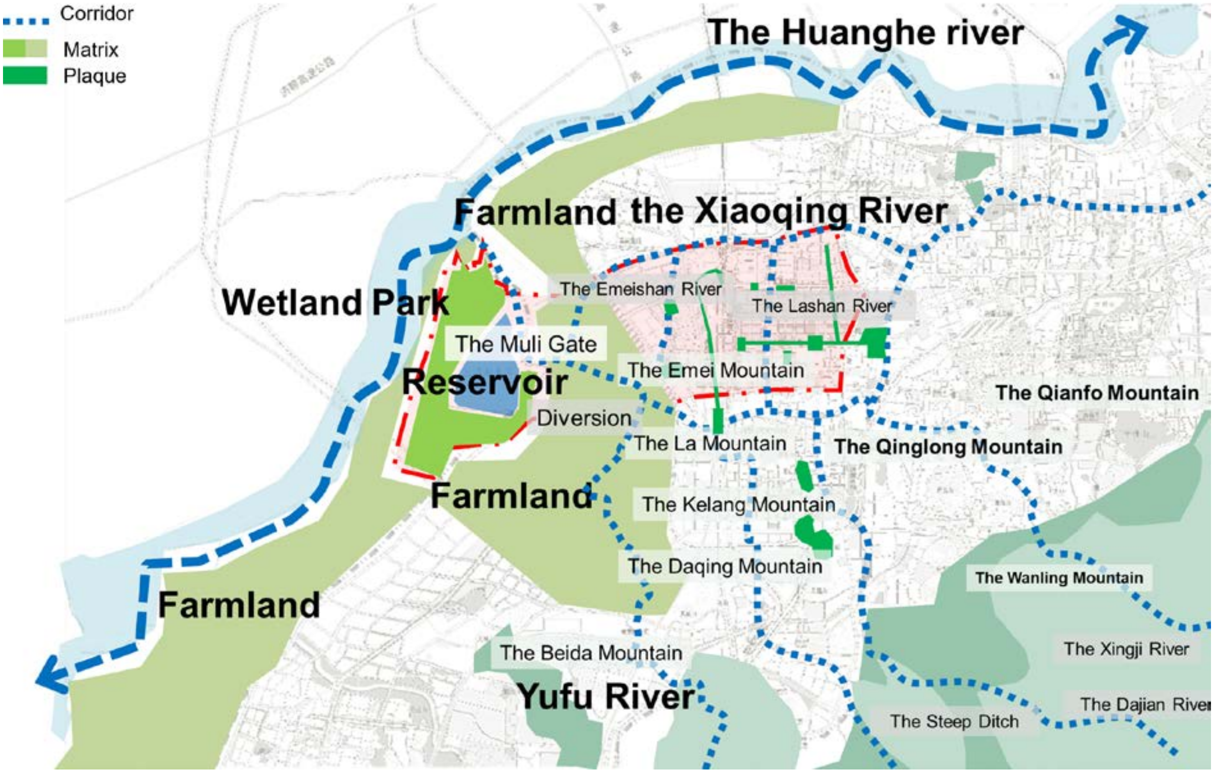

Figure 13: Framework of the Resilience Structure
Source: graphing by author

4.2 Maintenance of Derivative Industry

The development of sponge city extension industry can bring some economic benefits to sponge city construction, and promote diversified industrial development in the promotion area. This plan has utilized the natural resources in the JiXi extension area and the landscape design of the sponge city construction project. At the same time, it combines the six major groups of owners' main group business (including ecotourism, cultural industry, health industry, etc.), and puts forward to develop the two major industries of the cultural tourism and cultural exhibition in spongy city in JiXi (Jabareen Y, 2013).

4.3 Dynamic Supervision and Control

The planning and control system of sponge city construction in JiXi extension area includes three aspects (Huang Xiaojun, Huang Xin, 2015): organization guarantee, technology control and management implementation. The main control phase includes the whole cycle from planning to implementation of the construction .It guarantees that in any stage of the construction of the sponge City, there will be a clear department responsible, reliable technology to provide security, corresponding regulations, and can quickly deal with and solve the problem, so as to ensure the stability of the construction system of the sponge city (Fig.14).

Figure 14: Dynamic Supervision and Control
Source: graphing by author

5. Methodology

On the basis of four aspects of urban resilience, through integration analysis of resilience, flood control, pollution source control and runoff unit control, we can conclude: a. the rigidity of sponge facilities is the foundation of urban toughness. b. the implementation of the whole process of resilience is important to the project. c. dynamic supervision and control is the guarantee of urban resilience. In the current practice of sponge City, the new tenacity mechanism and renovation methods are constantly optimized. At the same time, the development of urban and ecological environment system involves many complicated factors, and other types of data should be expanded. The decision making method mentioned in this paper still needs supplementary and practical feedback, which is also needed for further work in the future.

References:

Zhao Zhiqing, Wu Zhongyang, Wang Zuowei (2018). “Research on Sponge City Planning Strategy Guided by Resilience Thinking”, *Beijing Planning Review*, 2, 34-39.

Wang C H, Blackmore J M (2009). “Resilience Concepts for Water Resource Systems”, *Journal of Water Resources Planning and Management*, 135(6): 528-536.

Shao Yiwen, Xu Jiang (2015). “Understanding Urban Resilience: A Conceptual Analysis Based on Integrated International Literature Review”, *Urban Planning International*, 30(02): 48-54.

Zhao Zhiqing (2016). “Research on the establishment of urban vulnerability assessment system based on climate change”, *Proceedings of China Urban Planning Annual Conference*, 15, 467-482.

Bates S, Angeon V., Ainouche A. (2014). “The pentagon of vulnerability and resilience: A methodological proposal in development economics by using graph theory”, *Economic Modelling*, 42: 445-453.

Adger, W. N. (2000). Social and ecological resilience, Are they related? *Progress in Human Geography*, 24(3), 347–364.

Bai, X. (2007). Integrating global environmental concerns into urban management: The scale and readiness arguments. *Journal of Industrial Ecology*, 11, 15–29.

Trinh D, Chui T. (2013). “Assessing the hydrologic restoration of an urbanized area via integrated distributed hydrological model”, Hydrology and Earth System Science Discussions, 10(04): 4099-4132

Alexander D E (2013). “Resilience and Disaster Risk Reduction: An Etymological Journey”, *Natural Hazards and Earth System Science*, 13(11): 2707-2716.

Jabareen Y (2013). “Planning the Resilient City: Concepts and Strategies for Coping with Climate Change and Environmental Risk”, *Cities*, 31: 220-229.

Huang Xiaojun, Huang Xin (2015). "Resilient City And Its Planning Framework", *City Planning Review*, 39(02): 50-56.