

The Matrix Coupling Integrated Planning Experiment of Coastal Sponge City Under the Framework of Pressure-State-Impact-Respond (PSIR) Taking Xiamen as an Example

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ABSTRACT

The construction of sponge city has become an important way to coordinate the balance between human development and natural ecological environment. Therefore, the research on the coupling planning of the coastal sponge city in the framework of Pressure-State-Impact-Respond (PSIR) was put forward. On the basis of detailed analysis of the characteristics of sponge city and PSIR framework, a whole set of coastal sponge city matrix coupled planning index system was put forward. With the information technology used as the main technical means to monitor, the researchers analyze and evaluate the system. Finally, the system was illustrated and analyzed with Xiamen city, Fujian province as an example.

Keywords: sponge city, PSIR, overall planning, index system

I. INTRODUCTION

With the progress and development of human science and technology, the society has made great achievements (Xia J et al. 2017) [1]. However, with the continuous progress of human society, the natural ecological environment has also undergone dramatic changes. The main reason for this change is the great damage to the natural ecological environment during the development of human society. This kind of destruction has not only the excessive use and development of natural resources, but also the unbalance of natural ecological environment, and the emission of social life and production waste in the process of development, resulting in the destruction of natural ecological environment (Shao W et al. 2016) [2]. With the aggravation of the imbalance and destruction of natural ecological environment, the sustainable development of human society has been greatly affected.

As an important sign to measure the level of social development, the relationship between the city and the natural ecological environment is complementary (Li H et al. 2017) [3]. In current era, the natural ecological environment has been greatly damaged, and urban water

resources have become increasingly tense, but in contrast to this situation, the frequent floods in cities are now affecting the normal development of cities (Wang Y et al. 2017) [4]. According to the comprehensive analysis, climate change caused by greenhouse gas emissions and excessive urban development are the main causes of the current contradiction. Therefore, how to solve this problem has become the main problem facing the sustainable development of human society (Zhang W et al. 2017) [5]. In view of this, the research on the matrix coupled planning of the coastal sponge city under the framework of PSIR is proposed, and it is hoped that it can provide some reference for the development of the city in the future.

II. PRESENT SITUATION AND RESEARCH REVIEW OF THE DEVELOPMENT OF SPONGE CITY

Sponge city is a kind of urban planning and construction concept which arose on the basis of rain and flood management measures at the end of last century (Jiang Y et al. 2018) [6]. The rapid development of human society also promotes the urban expansion and construction of high intensity, and then it will cause great damage to natural hydrologic cycle, water storage and drainage system and habitat (Zevenbergen C et al. 2017) [7]. Therefore, the western countries led by the United States have put forward various rain flood management concepts or practices. The original purpose of the best management measures for rain and flood is to control non-point source pollution through

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engineering or non-engineering measures (Zhang J et al. 2017) [8]. In the course of subsequent development, these measures have been extended from the initial simple engineering or non-engineering measures into systematic measures to complete the systematic control of urban runoff and pollution (Jiang Y et al. 2017) [9].

With the development of researches on rain-flood management measures, people began to use "sponge city" to describe the relationship between hydrology and ecology and cities (Tao C et al. 2017) [10]. After entering the new century, the research on "sponge city" has begun to unfold gradually, for example, the morning edition has launched a discussion on sponge city in the United States. China has also become a social concern because of environmental problems, and has begun to do some research on sponge cities, for example, scholar Zhang Shuhan made a detailed exposition of the relevant technical measures for sponge city (Danjie Wu et al. 2016)[11]. The Chinese government has promulgated a series of relevant laws and regulations to promote the application and research of the concept of sponge city (Xiang Gao et al. 2017) [12]. Therefore, from the domestic and international development, sponge city is becoming the main direction of urban development.

III. BUILDING PLANNING INDEX SYSTEM WITH PSIR FRAMEWORK METHOD AND ITS OVERALL PLANNING APPLICATION

A. Construction of index system of matrix coupling integrated planning for coastal sponge cities based on PSIR framework

As the main direction of human future urban development, the idea and purpose of the sponge city is to

coordinate the relationship between the urban development and the natural hydrological ecology, so as to ensure the sustainable development of the human society. In this paper, the integrated planning of coastal sponge cities is studied in the framework of PSIR. The main purpose is to combine the concept of sponge city with PSIR framework, so as to ensure the harmonious development of urban development and natural ecological environment. The PSIR framework was perfected on the basis of the PR framework in the late ten century, and eventually formed the PSIR/DPSIR framework, as shown in "Fig. 1", the whole framework consists of five basic elements: driving force, pressure state, impact response and so on. When the destruction of the natural ecological environment has an impact on human beings, human beings will respond positively to this impact, for example, enacting various laws and regulations to limit and regulate the impact of human society on natural ecological environment, so as to achieve the purpose of protecting the natural ecological environment. However, for the planning and construction of the sponge city, the main purpose is to coordinate the balance between the natural hydrology system and the city through the best management measures of rain and flood, the fundamental reason is still a positive way of responding to the destruction of natural hydrology caused by the over development of the city itself.

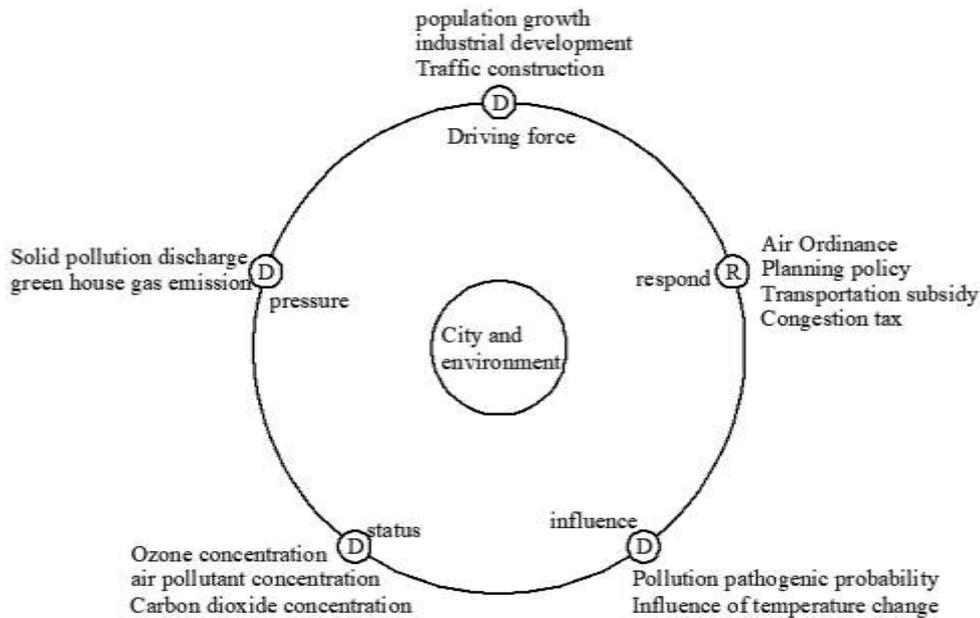


Fig. 1. The basic structure of PSIR Framework.

With the gradual popularization of PSIR framework, human society has put forward various sustainable development indicator systems to measure and develop the harmonious relationship between human society and natural ecological environment. So for the PSIR framework of the coastal sponge city matrix coupling integrated planning and construction, it is also possible to construct the planning, construction and evaluation index system of coastal sponge cities based on the construction of these index systems. From the present point of view, the evaluation index system based on PSIR framework mainly includes two indicators

system of sustainable development, main factors and capital accounting, this article selects the sustainable development index system of the theme elements as reference for planning, construction and evaluation index system of coastal sponge city, the reason is that the latter is biased in terms of computation and maturity is not high, so computation is extremely complicated. In addition, the main purpose of spongy city planning is to coordinate the balance between the city and the natural hydrological environment, so the index system of sustainable development of the theme elements is constructed.

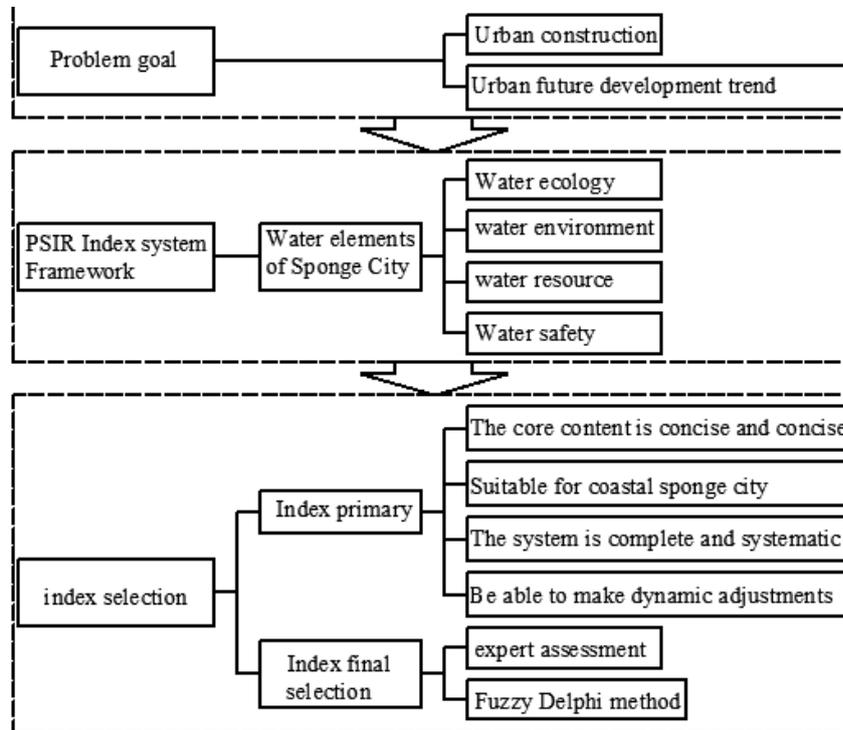


Fig. 2. The idea of constructing the Coupling Integrated Planning Index system of Coastal Sponge City Matrix based on PSIR Framework.

Then the whole idea of construction can be carried out in accordance with "Fig. 2", taking the framework of PSIR index system as the core, the rest is built in an auxiliary way. First of all, the element of sponge city is to balance the natural hydrological environment; therefore, the core of the framework is the four elements of the index system, which are the ecology, environment, safety and resources of the water elements. The subdivision of these four key elements is decided by the current situation of the construction of the sponge city and the latest development trend. Based on these two potential conditions, the index system under the PSIR framework needs to be constructed, and then the indicators with low degree of influence or no influence should be selected, and exclude those indicators that are relatively low or no impact. The selection of indicators is generally conducted according to the core streamlining, system integrity, dynamic adjustment and the characteristics of sponge city construction, then through expert evaluation and fuzzy Delphi Fa to make the final choice. When the index system of coastal sponge city is completed, it is

possible to carry out the planning of the sponge city by matrix coupling planning.

B. Matrix coupling integrated planning of coastal sponge cities under PSIR framework

According to the above idea of constructing sponge city index system, the index system of coastal sponge city is planned and constructed from the medium level around water element. Then, the content of the index system is matrix coupled with the PSIR framework, so as to get the index system of coastal sponge city matrix coupling overall planning under the PSIR framework. "Fig. 3" is a schematic diagram of the key application of the city index system under the PSIR framework. The whole index system is based on four elements: water ecology, water security, water resources and water environment. First of all, urban development causes damage to the natural hydrological environment and forms water ecological problems. The emergence of environmental problems will have a direct

impact on the formation of water resources, and thus respond to the use of water resources of mankind. After the problem of water resources, it is inevitable that human beings will be worried about water security, and then put forward relevant measures and feedback to change this situation, and then improve the water ecological environment. The construction of the index system is based on the driving force of water ecology rather than the traditional driving force of economic development. That is, the matrix coupling planning of coastal sponge city is based

on the full understanding of the PSIR framework, and cannot be coupled by traditional logic. In the construction of coastal sponge city, the factors influencing water environment include the destruction in the process of urban development hypothesis and the technical measures after the deterioration of water environment. So the above analysis can be known. The relationship between the matrix coupling and the overall planning of the coastal sponge city can be called "PSIR frame × water elements".

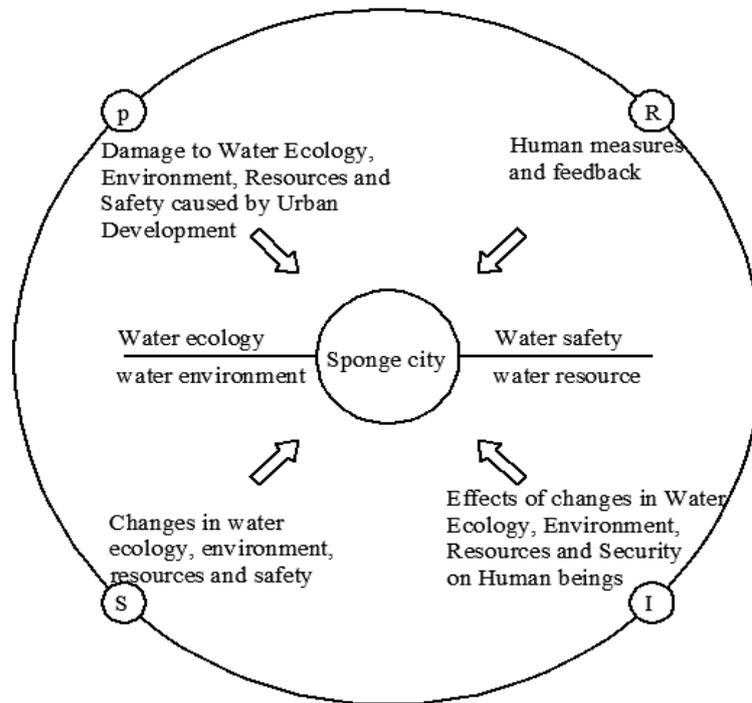


Fig. 3. Application of PSIR Framework in Matrix Coupling Planning of Coastal Sponge City.

It can be known from the above analysis that the matrix coupling planning of coastal sponge city under PSIR framework is a matrix coupling relationship of "PSIR framework x water element". Therefore, the coastal sponge city indicator system with water ecology, water environment, water resources and water security as the four main elements is shown in "Table I", the four target layers are subdivided according to the "P" — pressure, the "S" — state, the "I" — effect and the R — response PSIR framework. The first is the pressure of water ecology, the pressure can be expressed by the ratio of ecological area change, the growth rate of urban construction area and the ratio of hardened area, and the water ecology can be used for the length of the ecological coastline, For example, the coastline, the rate of total runoff control; the influence of the formation is the number of urban waterlogging days, and the corresponding cities are described by the subsidence green space, the roof greening, the area of the urban park biological detention facilities, the area of the coastal wetland and so on; the second is the water environment, the pressure index of water environment

is measured by two indexes of industrial sewage and per capita domestic sewage, the state index is represented by the SS ratio of the suspended matter, the impact index is the evaluation index of the number of water pollution pathogenic persons, the response index is expressed by the control rate of marine pollution and runoff pollution; the third is the pressure index of water resources, which can be measured by the leakage rate of water supply network and the two indexes of water consumption, in which the water consumption is based on the water consumption of GDP per 10000 Yuan, the change of water resources storage is the state index of water resources, the impact indicators are measured by water availability per person, the response indicators are measured by sewage reuse and rainwater utilization and seawater desalination. However, the pressure index of water safety mainly comes from the pollution of water resources, shortage and the destruction of ecological zones. It coincides with the first three species and is no longer listed separately. The state index of water safety is expressed by water quality rate; the impact index is measured by the rate of disease and

the number of waterlogging days. The number of waterlogging cannot only affect the safety of human beings, but also reflect the ecological condition of urban water. The response index is measured by four indexes, such as the scale of the urban rain and flood

storage pool, the rate of permeable paving, the proportion of water resources protection funds and the design recurrence period of the rainwater irrigation canal.

TABLE I. COUPLED PLANNING OF COASTAL SPONGE CITIES BASED ON PSIR FRAMEWORK

	Pressure	Status	Influence	Respond
Water ecology	Ecological area change (percentage)	Ecological shoreline length	Urban waterlogging days	Sunken green space (percentage)
	Increase in completed area (percentage)			Roof greening (percentage)
	Hardened area (percentage)	Total annual runoff control rate (percentage)		Proportion of biological detention facilities in urban parks
				Proportion of Rain Water wet pond wetland in city
water environment	Industrial sewage discharge Per capita domestic sewage discharge	SS ratio of suspended solids	Number of cases of water pollution	Runoff and marine pollution control
Water resource	Leakage rate of water supply network	Changes in water resources storage (percentage))	Available per capita water consumption	Reuse of sewage (percentage)
	Water consumption (per 10,000 GDPs)			Rainwater resources utilization(percentage)
Water safety	From other pressure items	Water quality compliance rate	Pathogenic rate of drinking water	Seawater desalination volume
				Storage tank scale
			Annual waterlogging days	Ratio of Water Environment Protection funds to Government Fiscal Expenditure
				Urban surface permeable pavement ratio
	Design recurrence period of rainwater pipe network			

After the completion of the coastal sponge city matrix coupled overall planning index system under the framework of PSIR, the coastal sponge city can be planned as a whole according to the three stages of urban planning preparation, implementation and evaluation, the index system provides basis for target, planning requirements and detailed planning in the preparation stage. However, in the process of implementation, the location, objectives and plans of the plan are put into urban construction. At the stage of planning evaluation, it is mainly based on the basis of comparison. In the evaluation stage, the comparison of the index system needs to be completed by dynamic testing, that is to say, the implementation of coastal sponge city index system needs to establish a complete set of real-time information detection system to complete the detection of each index data.

IV. RESULT ANALYSIS AND DISCUSSION

A. Case analysis of Xiamen, Fujian province

In order to illustrate the integrated planning of coastal sponge City matrix coupling under the PSIR framework, here, Xiamen City of Fujian province is selected as an example for analysis. As shown in Figure 4.is located on the coast of the East China Sea, has a coastal line that zigzags to 234 kilometers, Located in the Jiulong River entrance to the sea, Xiamen city comprise Xiamen Island, Penghu Islands and the

coastal part of north Jiulong River, it is a very beautiful coastal city. The city has been planning the coastal sponge city since 2015 and it is expected to take 15 years to complete the construction of the whole sponge city. In the planning of the city, the sponge city of Xiamen city was planned and constructed from the four aspects of water ecology, water environment, water resources and water security. According to the geographical environment characteristics of the city, the whole sponge city is divided into six main regions, such as "mountains, rivers, forests fields and lakes", this is the regional ecological protection and repair area, the village and town rainwater pollution control area, the industrial zone sponge construction area, the urban incremental sponge construction control area, the urban organic renewal spongy construction control area and the comprehensive management area of the rural river, through the analysis of the construction of the whole city and the trend of the future development, the protection and development of the natural ecological and hydrological environment in the whole urban area are coordinated and controlled.

B. Application results analysis: detailed management, functional zoning, restoration of ecology

On the basis of the overall planning, Xiamen has further refined the sponge city construction in the city through the integrated planning method of the coastal sponge city matrix coupling under the PSIR framework,

the natural hydrological environment of the whole area is divided into seven corridors, five districts and two centers. Which are coastal ecological corridors, Jiaojiang water corridor, Yongning River water corridor and four green corridors, the division of corridors is aimed at controlling urban runoff and water pollution; the five regions are spongy area of coastal wetland, ecological sponge area of farmland, spongy area of farmland in the north of Jiangbei, sponge area protected by water source wetland and spongy area of western mountain. The purpose of the division of the five areas is to provide the drainage, storage and infiltration of rainwater through the construction of green roofs, sinking green spaces, storage tanks, storage facilities, biological retention pools, and collection and recycling facilities, so as to achieve the recycling of water resources, and gradually restore the original natural hydrological ecosystem.

C. Related control methods of sponge city

In addition, through the formulation of relevant laws and regulations to limit emissions from poultry farming, industrial and domestic pollution, effective control of water pollution will be carried out. The core of the water source in the western spongy area of the mountain and the city green heart, which is the main part of the long pool, coordinate the natural ecological water and the balance of the urban living water, so that the city and the natural ecological environment can reach a harmonious coexistence.

In order to control and detect the situation of the construction of the sponge city, a complete set of information monitoring and control system is established to monitor the water corridor, area and engineering facilities of the city. Monitoring and alerting the real time state of the sponge city through information equipment, such as surveillance cameras, sensors, unmanned aerial vehicles, and personal mobile phones of urban residents throughout the city, at the same time, the equipment is used to complete the collection of relevant data, and the progress of each index is analyzed according to the collected data, and according to the results of the analysis to adjust the various indicators, therefore, the sponge city and the natural ecological environment are in a dynamic balance.

V. CONCLUSION

In the continuous development of human society today, there is an irreconcilable contradiction between the fierce urbanization process and the natural ecological environment, how to balance the natural ecological environment and the sustainable development of human society has become a common problem facing the global society. Under this background, this text presents a study on the integrated

planning of coastal sponge city matrix coupling under the PSIR framework. According to the construction characteristics of the coastal sponge city, based on the full analysis of the PSIR framework, the four major water factors such as water ecology, water environment, water resources and water safety in sponge city are coupled, a set of index system for integrated planning of marine sponge city's matrix coupling is put forward. And taking the Xiamen city of Fujian Province as an example, this paper analyzes the comprehensive planning index system of the coastal sponge City matrix coupling, the effect of the overall planning application and the relevant countermeasures and suggestions, but regrets that the length is limited. We have not designed the overall planning system in detail, which need to be further studied in the future, contribute to scientific urban overall planning scientifically, management in an orderly, natural and flexible way.

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