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Towards government mechanisms of sponge city construction in China: insights from developed countries

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Abstract

The sponge city concept is a new strategy for China designed to solve its urban water problems. The tasks involved in sponge city construction (SCC) have brought new challenges regarding the urban construction process for local Chinese governments. However, there is still no comprehensive and systematic study of the government mechanisms for guiding the construction of sponge cities. This paper aims to develop an evaluation index system of government mechanisms at the whole-of-nation scale. This system covers five elements of government mechanisms. This evaluation index system covers the specific content of the government mechanism anticipated before the process of SCC. Since work systems, functions, and capacities differ with each given local government, the work mechanism of local governments can be adapted to local conditions according to the research results of this paper. By doing so it is possible to make full use of the constraint and management function of each indicator, so that all departments can constantly optimize the allocation of resources and clarify responsibilities, so as to effectively promote the construction of a sponge city.

Keywords: China; Evaluation index system; Government working mechanism; Policy; Sponge city construction; Urban water management

Introduction

The management of water resources has undergone at least four major paradigm shifts (Van der Voorn & Quist, 2018). At the beginning of the 20th century, the dominant paradigm was single purpose

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water resources management. By the 1930s, water resources management become multi-purpose. By the 1970s, water resources management became more environmental. Since the 1990s, the management of water resources has been undergoing a transition to adaptive forms of management like sponge city-based management. At the 18th National Congress of the Communist Party of China in November 2012, a major decision was made for the 'promotion of ecological civilization.' In December of the following year, at the Central Working Conference on Urbanization (CWCU, 2013), party leader Xi Jinping pointed out that 'priority should be given to using more natural forces to drain water and build 'sponge cities' with natural accumulation, infiltration, and purification.' Consequently, a new path of sustainable urban development – based on an ecological civilization and focusing on sponge city construction (SCC) – was formed in China from the top down (CPC News, 2014). In October 2014, the Ministry of Housing and Urban-Rural Development (MOHURD) issued a related document with a guiding ideology, design philosophy, and control objective for SCC. With this, the sponge city concept became well known across China (Wang *et al*., 2018).

Sponge cities are municipalities having an urban water system with a comprehensive management mode (Yang & Lin, 2015; Zhang *et al*., 2016; Wang *et al*., 2017). From the hydrological perspective, the evolution of rainwater in the urban environment includes canopy interception, soil infiltration, depression storage, surface and water evaporation, slope runoff and confluence processes, drainage network collection and discharge, river network collection and regulation, and coupling processes such as water quality and ecological dynamics. The urban water problem is the result of the action of each link in urban hydrology and its associated process. As a result, the formation of sponge cities is based on urban hydrology and the physical laws associated with such processes. A sponge city is designed to absorb, clean, and use rainfall in an ecologically friendly way to decrease quantities of urban water runoff while improving their quality. Further, these cities fully consider the effects of vegetation, soil, rivers, and the water system on urban rainwater runoff.

Creating a sponge city requires controlling urban flooding, utilizing water resources, protecting the water environment, and restoring water ecology. It enables cities to mitigate or reduce the frequency and severity of urban floods, improve water quality, utilize rainwater resources, and redress the ecological degradation of urban water (Zhang *et al*., 2016; Wang *et al*., 2018). As systematic projects, SCC should ensure the efficient consideration and comprehensive treatment of urban waterlogging, water resources, the water environment, and water ecology. Therefore, mechanisms for multi-sectoral coordination and unified governance must first be established. The establishment of these mechanisms brings new challenges to local governments' mechanisms of urban construction. However, at present, the study of sponge city is limited to the construction concept, planning mode, and technical measures. It lacks in-depth analysis of the role of government in SCC.

The study is organized as follows. In the section below, we analyze the experiences of other countries' water management systems, followed by an examination of the Chinese government's current efforts and challenges in constructing sponge cities. Then an evaluation index system of government mechanisms is developed and described. In doing so we show that the SCC process at each stage needs to focus on the problem at hand. Local governments can give full play to the constraint management function through the mechanism described here; constructing an evaluation index system can induce constantly each department to optimize the allocation of resources and clarify the responsibilities related to SCC, so as to promote the progress of SCC effectively. In the final section, a discussion follows in which we establish a framework for the government mechanism evaluation, followed by suggestions for further research.

Developed countries' urban water management systems

Systems' overview

Researchers world-wide have explored urban water management models for decades. Over ten years ago, integrated urban water management (IUWM) was suggested as an alternative to traditional urban water management (Mitchell, 2006). IUWM differs from traditional management concepts in terms of design and construction, in that IUWM emphasizes comprehensiveness and systematization. The IUWM concept can be applied in a variety of ways, and consequently, many different approaches are being developed based on the problems each country encounters (Pearson *et al.*, 2010). Countries such as the United States, the United Kingdom, Japan, and Australia have increasingly recognized IUWM as a new urban water management strategy (Saraswat *et al.*, 2016). These countries have considered their own characteristics to propose urban water management systems which could be adapted to their natural environment and societal needs. Numerous countries have introduced this concept and formulated relevant policies to solve urban water problems.

For example, the United Kingdom has established sustainable drainage systems (SuDS) that consider water quality and quantity as well as public recreation measures (e.g., the rain garden is used to collect, absorb, and purify the rain water from roofs or surfaces, while at the same time being ornamental), with the objective to slow the flow rate, decrease the flow itself, purify the quality of the rainwater entering the pipe network, and preserve the natural environment's water demands (Defra, 2015; Ellis & Lian, 2016).

Australia has implemented water-sensitive urban design (WSUD) to solve the problem of urban water shortages caused by the vast differences in its national climate. From an urban master planning perspective, this design considers problems related to the hydrological cycle and water conservation measures before implementing regional planning and construction (Lloyd *et al.*, 2002; Sharma *et al.*, 2016; Ahammed, 2017).

The United States also implemented Low-Impact Development (LID) to systematically manage and control rainwater at the source. LID measures aim to restore the hydrological cycle in the underlying surfaces of urban areas, or restore it to its natural state before the area's development (Broder, 2005; Ahiablame *et al.*, 2012; Fletcher *et al.*, 2015).

Germany possesses mature technology and has implemented reasonable measures for rainwater control management using three primary rainwater recycling approaches: a residential rainwater recycling system, a rainwater collection and utilization system for buildings, and a rainwater decontamination and purification filtration system (Herrmann & Schmida, 2000; Shen & Köck, 2012).

China has proposed its own IUWM strategy according to its national conditions to solve the water issues in its urbanization process. Thus, China initiated its Sponge City Strategy by imitating, absorbing, and adapting the best practices from the previously mentioned strategies and programs, then incorporating special Chinese characteristics (Wang *et al.*, 2018). Regarding its systems engineering, the SCC should consider traffic in a city, in addition to its landscape and municipal and ecological functions, the industrial development in urban planning overall, and the spatial layout (Zhang *et al.*, 2016). Thus, a sound construction management mechanism is critical to support various departments' functions.

Managerial experiences in Germany and the United Kingdom

As developed countries began to study the recycling and utilization of water resources, they gained relatively rich experience in ensuring the comprehensive utilization of rainwater. These countries have used legislative supervision, policy guidance, management systems, and audit supervision to strengthen rainwater utilization.

Germany

By the 1970s, Germany had a relatively complete urban water utilization system. Its current rainwater management system has become standardized to reflect general laws and regulations, technical regulations, and economic incentive policies (Schuetze, 2013).

Regarding laws and regulations, Germany first introduced a rainwater discharge fee system. To achieve the goal of zero growth for runoff into the pipe network, German cities formulated their own standards for collecting rainwater fees according to the provisions established by ecological and water laws as well as regulations for local administrative fee management (Liao *et al*., 2016). In residential and commercial areas with rainwater collection measures, a penalty or reward would be handed out based on the practical effects of these measures. The management system involves level management with extensive social participation.

The German government's water agency is the Ministry of Environmental Protection, which is responsible for supervising water supply, water quality and quantity, drainage, and sewage treatment. In terms of central and local use of water resources, there are four levels of management: the national, federal-state, and local water authorities, as well as various water supply associations. According to the government's mandate, the water department shall handle overall water management, maintain the ecological balance in water areas, ensure that the water quality requirements of residents and economic development are met, and guarantee the long-term water supply. Additionally, this department will adopt market means to operate and accept various forms of public supervision (Shen & Köck, 2012).

The United Kingdom

Three main departments are responsible for rainwater management in the United Kingdom (Cambridge City Council, 2015): the Drainage Engineering Division, responsible for the discharge of sewage and rainwater in the community (residential, commercial, or industrial), sewage treatment duties, and the collection of sewage charges; the Highway Administration Bureau, which is not only responsible for rainwater drainage from local trunk roads, but also holds the rights and obligation to build, apply, and maintain discharge facilities; and private landowners, who are responsible for rainwater management in the area (The Construction Industry Research and Information Association – CIRIA, 2001). Based on the country's long-term maintenance and responsibility for its sustainable emissions system, all departments must negotiate and reach a maintenance management agreement to clarify responsibility for the sustainable emission project's maintenance after its delivery.

Further, the government has established the laws and regulations required to better implement SuDS, from its planning and construction to its maintenance and management. Table 1 presents some of these policies.

Through exploration and practice, developed countries have gained extensive construction and management experience in urban flood control. More importantly, some developed countries have established laws and regulations related to urban water management that direct social behaviors, reduce water pollution, and protect the environment.

Table 1. SuDS laws and regulations (Susdrain, 2007).

	Regulatory framework
Planning stage	**England:** Technical Guidance to the National Planning Policy Framework (2012)
	Scotland: Planning and Flood (2004)
	Scottish Planning Policy (2010)
	Wales: Planning Policy Wales, 4th Edition (2011)
	Development and Flood Risk (2004)
	Northern Ireland: Planning and Flood Risk (2004)
Construction and management stage	**England and Wales:** Flood Risk Regulation (2009)
	Flood and Water Management Act (2010)
	Scotland: Drainage Project Art (2002)
	Building Act (2003)
Supervision and administration	**England and Wales:** Environment Act (1995)
	The Groundwater Regulations (1998)
	Water Resources Act (1991)
	Scotland: Flood Risk Management Act (2009)
	Water Environment and Water Services Act (2003)
	Northern Ireland: The Water and Sewerage Services Act (2016)

Policy guidance and incentives are also crucial. For example, Germany encourages all sectors of its society to actively participate in urban water management by offering subsidy policies such as rainwater subsidies, tax exemptions, and incentive funds. Additionally, a practical organization and management system can guarantee efficient promotion of the urban water management system. The aforementioned countries use their governmental water departments to manage their entire water systems. Further, implementing a hierarchical system with clear functions at all levels is conducive to the unified management, dispatch, and supervision of water resources.

Countries should learn from each other and conduct both localized and regional studies in accordance with national conditions. Although the management systems of different countries have different names and district focuses or stages of development, the development trends of urban water management share the same goal: the promotion and continuous improvement of water resources.

Government mechanisms of SCC in China

Policy development

In December 2013, the Central Urbanization Working Conference proposed to 'build a sponge city with natural accumulation, natural penetration, and natural purification.' Subsequently, the Chinese government has introduced a series of policies to support and promote the construction of a sponge city in terms of its construction concept, financial support, pilot selection, technical guidance, and performance assessment.

The MOHURD (2014) issued technical guidelines for LID in sponge city rainwater systems' construction in a trial implementation. The aim was to guide the planning, design, construction, management, and maintenance of LID technologies for sponge cities. The following July, MOHURD identified 18 evaluation indexes for six aspects of such development, including water ecology and the water environment, and identified responsible departments, evaluation procedures, and methods to form a sponge city assessment and evaluation system (MOHURD, 2015). By October 2015, the General Office of the State Council (GOSC) had further defined the sponge city's goals and requirements, construction methods, and policy direction, and specified methods to expedite these goals based on SCC status (GOSC, 2015). In March 2016, MOHURD proposed detailed requirements based on the special sponge city development plan's concept, principles, organization, and content.

Between January 2015 and April 2016, a total of 30 pilot sponge cities were identified in China. These pilot cities would receive financial support from the Ministry of Finance (MF) for three consecutive years, and their demonstrative and driving roles were to propel the construction of sponge cities across the entire country. In 2016, relevant, successive notices were issued by the MF, MOHURD, MWR, and CDB to ensure financial support for SCC. Table 2 presents the documents' details.

Government function positioning

Figure 1 illustrates the SCC framework. In constructing a sponge city, the government is not only the organizer and builder, but also the supervisor and service provider. As the body responsible for approving and executing various plans, the government guides the formation of initial ideas and selects their direction.

First, the government develops a set of planning periods and implementation programs according to the SCC's goals. Specifically, all governmental departments will formulate special plans according to their own functional attributes to guide SCC in various professional fields. The government also guides the SCC's development in being aware of its responsibilities and forms a positive atmosphere in society through publicity and education to enhance the public's awareness of SCC.

As a public policymaker and supervisor, the government promotes the construction and transformation of sponge facilities through policy guidance, laws, and regulations. It creates various planning policies, including those that pertain to land, finance, taxation, the introduction of talent, the promotion of technology, and resource allocation. Additionally, as a provider of public goods and social services, urban infrastructure is typically an important part of the government's financial investment. Raising capital and controlling investments are important guarantees in a sponge city's construction, as the SCC is in an exploration stage. Experience still needs to be developed in many areas. Further, the government's supervisory and management functions in the SCC process are particularly important.

Table 2. SCC-related polices.

	Document	Department
Technical guidance	Technical guidelines for sponge city LID in its rainwater system construction, as a trial implementation – October 2014	MOHURD
	Performance evaluation and examination methods for the sponge city, as a trial implementation – July 2015	MOHURD
	Guidance and opinions on promoting SCC – October 2015	GOSC
	Conditional provisions to prepare special plans for the sponge city – March 2016	MOHURD
Pilot program	Organizations' declaration of 2015 pilot sponge city – January 2015	MF, MOHURD, MWR
Financial support	Notice to promote financial support for the sponge city – January 2016	MF, CDB
	Notice to conduct 2016 central financial support for pilot SCC – March 2016	MF, MOHURD, MWR

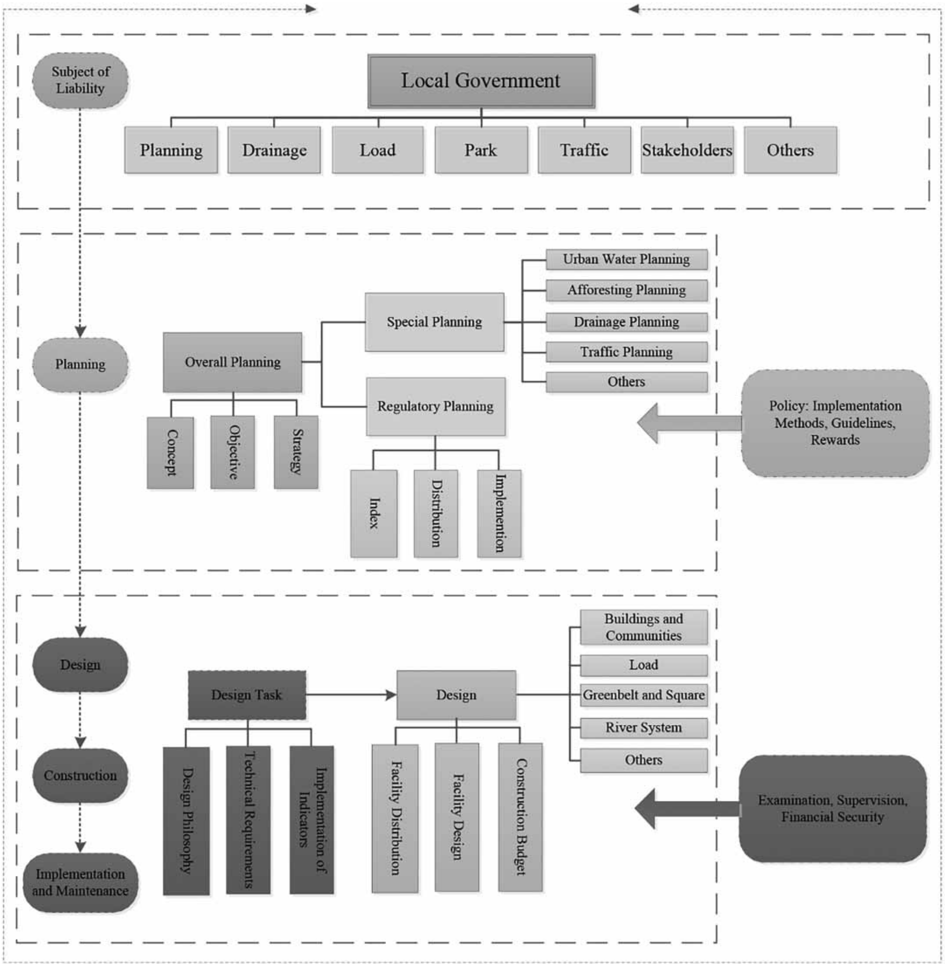

Fig. 1. Schematic diagram of the SCC framework.

Governance frameworks

The SCC is a long process. Governance arrangements are the key to the sustainable and healthy development of SCC. Hegger *et al*. (2014) proposed Flood Risk Governance Arrangements (FRGAs) which can be defined as institutions resulting from an interplay between actors and actor coalitions involved in all policy domains relevant for flood risk management. In this paper, we adopt the definition of FRGAs by Hegger *et al*. (2014) to develop the governance frameworks of SCC as in Buijs *et al*. (2018), and improve the framework according to the characteristics of China. The improved framework is described in the following four parts:

- Multi-level governance. As for flood risk governance, which is organized locally, regionally, or nationally, sponge cities are also built on multi-levels. The central level in China only sets general standards and technical guidelines through policy legislation. The local level governments have

main responsibility for all water issues in SCC and thus develop management institutions according to their own government functions, management modes, and capacity.
- Multi-sector governance. As systematic projects, SCC should ensure the efficient consideration and comprehensive treatment of urban flooding, water resources, water environments, and water ecologies. Therefore, governance for multi-sectoral coordination and unified governance must first be established.
- Multi-actor governance. Modern public affairs management is not only dominated by state agencies, but also by stakeholders. The government must appropriately guide the civil society participation in SCC, which is conducive to scientific decision-making and effective policy implementation.
- Whole-process governance. The whole process of SCC includes decision-making, planning and design, construction implementation, and operation and maintenance, which all need clear governance norms and specific knowledge within existing domains (Figure 1).

Challenges for the SCC

China is a vast country, covering an area of 9.6 million square kilometers. The country has diverse topography, complex hydrological characteristics, and numerous urban types (e.g., coastal city, riverside city, plain river network city, mountain city). Due to the diversity of the natural geographical and the socio-economic conditions in these cities, the current situation and causes of problems with water are also different; thus, different cities face different water problems. SCC will occur in many forms, depending on the specific requirements of the diverse municipalities in China's different basins. Therefore, SCC, from a national implementation perspective, will face many difficulties and challenges. It involves the transformation of ideas, the establishment of new theories and technical systems, the setting of standards, new methods in planning design, innovation in management modes, cross-disciplinary collaboration, a guarantee system of policy and implementation, and scientific and reasonable monitoring and evaluation, among other tasks (Che *et al*., 2015). The main challenging problems for SCC are as follows:

- Some local governments lack a correct understanding of the concept of sponge city and start construction without the proper planning and design (Xia *et al*., 2017). On the one hand, the function and applicable scope of LID measures are exaggerated and blindly pursued for the use of green rainwater infrastructure to solve urban water problems, regardless of the actual urban pipe network conditions, green land rate, and other restrictions. On the other hand, the construction scope is limited to LID. The urban water system planning and urban pipeline network improvement are ignored. Green infrastructure is overemphasized and ignores the combination of grey infrastructure (Che *et al*., 2015; Cui *et al*., 2016).
- At its core, SCC addresses the urban water problem but SCC projects lack: (a) planning and construction teams with a background in hydrology, (b) a fundamental monitoring system, and (c) a mechanism for the construction and management of sponge city projects. Thus, there is a lack of interdisciplinary advanced science and technology support for the urban integrated water system associated with sponge city. Further, there is neither a necessary post-evaluation management system nor a system construction for SCC (Zhang *et al*., 2010; Xia *et al*., 2017).
- In the process of promoting the construction of a sponge city, although there has been an eagerness for the projects, the actual appropriate effects have yet to emerge. In the sponge city pilot areas, generally, it appears difficult to not only include the older urban areas but also to accommodate some new urban

areas and areas yet to be built. The construction of 15 km^2 of pilot areas will be completed within three years, including the planning, design, construction, and operation evaluation. There are all kinds of choices of grey and green infrastructure and reasonable combinations that need evaluation. Rivers, lakes, and river basins may be involved in the comprehensive improvement as well. On top of these factors, there are enormous pressures and challenges to complete the implementation of the overall planning for a scientific, orderly, and comprehensive project design and construction as soon as possible (Che *et al*., 2015).

Based on the above analysis of the existing SCC problems, we find that the most important factor is the correct grasp and mastery of the sponge city concept. From the perspective of systematizing these sponge cities, an institutional guarantee should be established that strengthens management governance to ensure and perfect the construction of a top-level system. A relatively complete mechanism must be created in terms of policies and laws, government administration, economics, technology, and civil society participation. These measures will all complement and be integrated with each other, and should play multi-level synergistic roles.

Developing an evaluation index system of government mechanisms

At present, many cities have implemented the SCC concept. Due to the differences among each local government's functional departments, management modes, and capacities, SCC has no unified organization management mode. However, local governments can give full play to the constraint management function through the mechanism, so constructing an evaluation index system can make each department constantly optimize the allocation of resources and clarify their responsibilities related to SCC, so as to promote the progress of SCC effectively.

Principles

A scientific and reasonable evaluation index system must not only reflect the construction level of the sponge city, but also provide an effective technical guarantee for its scientific and standardized construction. To establish the evaluation index system of the government working mechanism of SCC, the following principles should be followed:

1. Systematic principle (Bear & Shamir, 1989). The evaluation index system should start with a systematic approach that ensures that all aspects involved in the SCC are covered, and the index should be able to scientifically and reasonably describe the quantitative relations and internal laws of social phenomena.
2. Scientific principle. The evaluation index system should be able to describe the meaning and possibility of realizing a sponge city construction. The construction level of sponge cities in different resource conditions, stages, and regions should be reflected objectively and scientifically based on the actual situation of a specific region and a specific stage. The evaluation index has a clear significance, a standard calculation method, and a standard statistical calculation method.
3. Guiding principle (Gao *et al*., 2007; Song *et al*., 2009). The index system should be able to guide and support decision-makers. It also needs to reflect environmental, economic, resource, and social

pressure. Moreover, it can guide the orderly development of SCC and provide the basis for government departments to formulate the relevant policies.

Structure

In accordance with the construction content of the sponge city, the government working mechanism should include: (a) organizational structures, (b) system norms, (c) technical systems, (d) investments, and (e) civil society participation. Organizational structures are fundamental and act as the 'head' of the sponge city construction that leads overall planning and coordination. System norms have normative and mandatory administrative means. Technical systems are tools to implement SCC projects more economically and efficiently through the rational use of scientific and technological methods. Financial investments are important guarantees to promote the sustainable development of the SCC. Civil society participation generates the power, through publicity and education, to improve the awareness of the public, so as to make SCC a universal development, and to function in the role of democratic supervision. Therefore, this paper takes the five items above as evaluation criteria. It consists of several levels of indicators and corresponding sub-indicators.

Selection of evaluation indicators

A hierarchical structure of evaluation indicators was set up, as shown in Figure 2. The rationale for the selection of these indicators is discussed below.

Organizational structures

SCC is a systematic project for the management of the construction of multi-sector, cross-profession, and multi-type projects. Therefore, a new functional department – Sponge Office was created. The office plans the SCC with consideration of the whole city area and establishes a linkage mechanism that links the governance center with departmental coordination and responsibility implementation. Each member unit has a District Government Management Committee, an Urban Planning Bureau, an Urban Development and Reform Commission, and an Urban Finance Bureau, among others. The Sponge Office is responsible for coordinating sponge construction tasks across all departments and each member department is responsible for cooperative implementation. For instance, the Urban Development and Reform Commission defines the SCC requirements in the approval process of the project; the Land and Resources Department specifies the SCC requirements in the land supply process; and the Construction Department examines the related requirements for engineering measures of the SCC project in the construction permit and completion acceptance process. The organizational structure and functions of a Sponge Office are shown in Figure 3. The Sponge Office is responsible for interpreting the needs of SCC, and for formulating the construction plan. It also clarifies its overall responsibility and coordinates the work of the departments.

It is worth noting that Figure 3 is just an example. Due to the differences in the composition, management mode, and capabilities of city government functional departments, the Sponge Office may not be the necessary or optimal management institution or model for SCC. Cities can give full play to the management role of the regime, enabling each department to continuously optimize resource allocation and

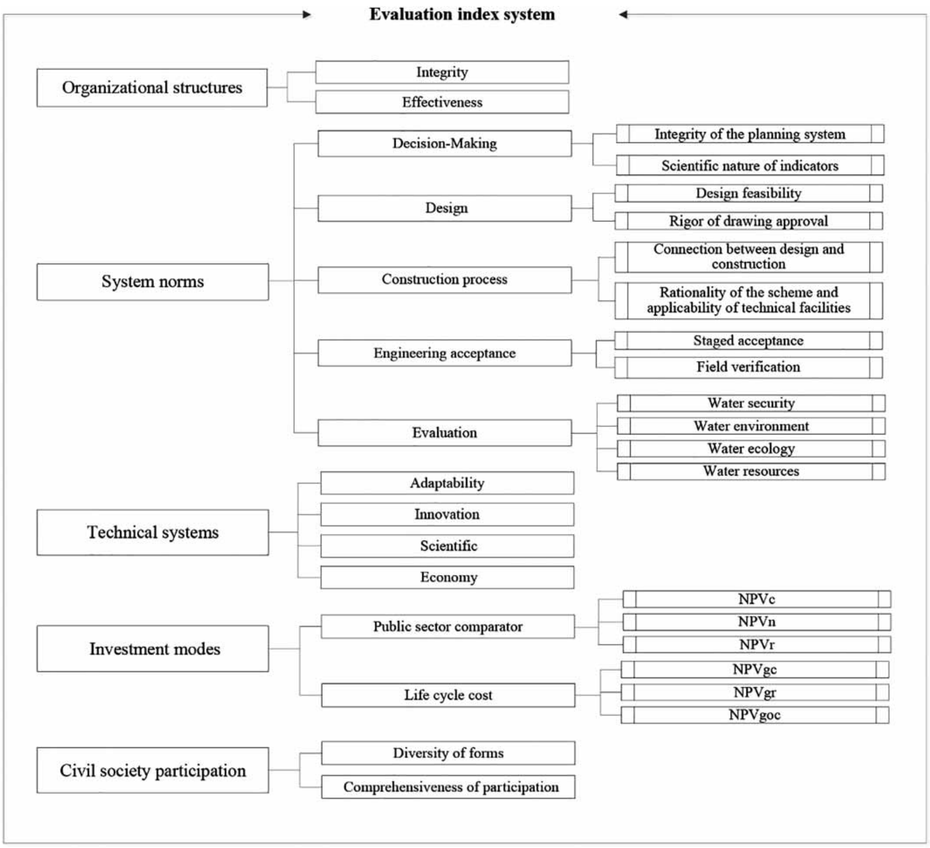

Fig. 2. An evaluation index system of government mechanisms.

strengthen the content of duties related to the SCC to achieve efficient coordination (Wang *et al*., 2017). The organizational structure is responsible for coordinating sponge construction tasks across all departments. Thus, the integrity of the organizational structure is an important indicator. For the steady promotion of SCC, the effectiveness of the linkage and coordination among different levels and functions is a vital indicator (Figure 2).

System norms

The process of SCC includes decision-making, design, construction, engineering acceptance, and evaluation.

1. Decision-making. The rationality of decision is mainly determined by planning system integrity and the scientific nature of the indicators (Figure 2). The special plans of the sponge city should be integrated into various special plans and thus form a perfect planning system (shown as Figure 1). Additionally, scientific sponge indicators should be the foundation of the implementation plan.
2. Design stage. The feasibility of the design scheme is very important. Designers should pay attention to site survey and resident visits to accurately grasp the actual site problems and sponge construction needs.

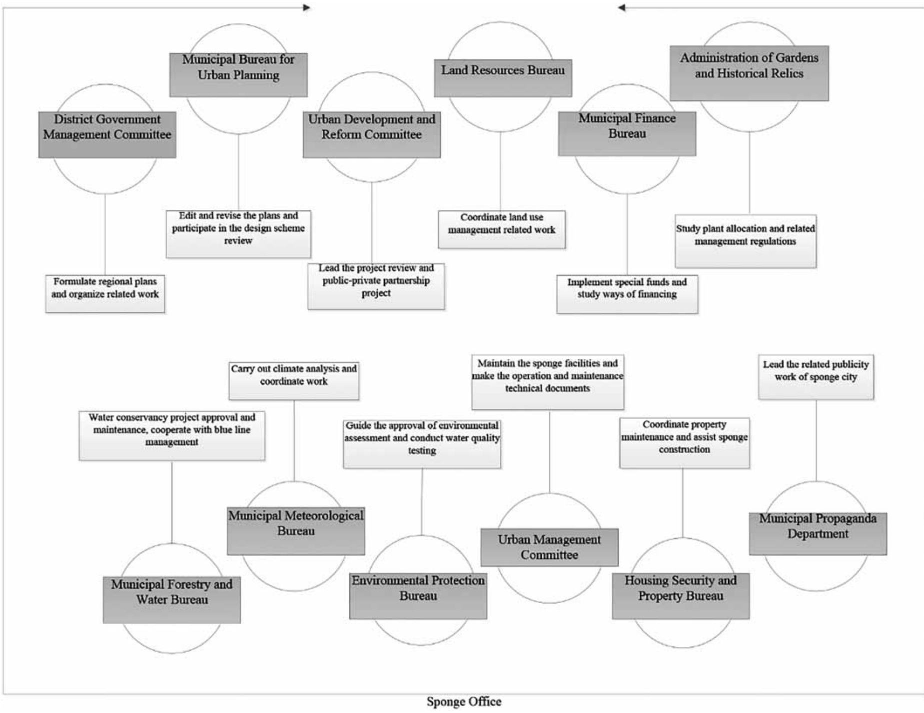

Fig. 3. Organizational structure of Sponge Office.

Also, the link of drawing review should be strictly controlled. The result of the drawing review depends on the sponge construction drawing guidelines, review specifications, and expert opinions.

3. Construction stage. On the basis of ensuring the construction standardization of sponge facilities, the following contents should be mainly grasped: designers should participate in the whole process to avoid a disconnection between the design party and the construction party; and according to the site construction conditions, judge the rationality of the scheme and the applicability of technical facilities in a timely manner.
4. Acceptance stage. Sponge facilities need to cooperate with each other regarding ground and underground projects to give full play to the construction effect; however, the completion time of ground and underground differs. As such, staged acceptance is an important index to ensure the correct connection between the ground and underground segments of the sponge facility. In addition, field validation can verify that the sponge facility is functioning as intended.
5. Evaluation. The basic evaluation index system is determined by four aspects, namely, water security, water environment, water ecology, and water resources. Performance indicators are shown in Table 3. The ability to control waterlogging is determined by the maximum water accumulation time and depth.

Technical systems

Parameters relevant to the SCC technology system include adaptability, innovation, scientific, and economy. The technical adaptability of any system must be researched before urban planning and

Table 3. Assessment system of a sponge facility's operational effect.

Evaluation index	Performance indicators
Water security	Drainage network rate (%); Waterlogging control capability
Water environment	Volume capture ratio of annual rainfall (%)
Water ecology	Water quality compliance rate (%)
Water resources	Rainwater utilization (%)

design. This priority level provides an important basis for the rational selection of the technology to be implemented. Technological innovation refers to the research and development of technical products suitable for different regional characteristics or the ability to solve different problems. The scientific indicators of a technology can avoid blindly adopting new technologies and products. They are necessary to ensure that there is a problem-solving and goal-oriented, flexible application of the technology, and a reasonable connection of control facilities, to achieve overall regional compliance. Economy of technical systems is also an important index in the technical system. The economy of technology means that the technical scheme adopted by the project can obtain the best economic benefit under a certain consumption level. The size of economic benefit is one of the important bases to choose the correct technical scheme. Therefore, it is necessary to comprehensively evaluate the economic benefits of the whole life cycle from planning, design, construction, and later operation and maintenance.

Investments

Investments in SCC primarily come from central special allocation subsidies, local fiscal expenditures, bank loans, and the introduction of private capital through PPPs (public–private partnerships). The guidance of the GOSC on the promotion of SCC issued in 2015 (no. 75 [2015] of the state council) clearly required that cooperation between the government and social capital (PPP) should be actively promoted in the operation of sponge city projects.

This study employs the 'value for money' (VfM) principle to determine whether a given sponge city project is suitable for the use of the PPP mode (Cheung *et al.*, 2009; Sang & Zhang, 2017). This was done by conducting a VfM evaluation under PPP for a sponge city project to analyze the public sector comparator (PSC) value of the sponge city project and the life cycle cost (LCC) value of the PPP mode. PSC refers to the cost estimates made by the public sector based on past experience for project products or services at the same level as the PPP model. By comparing LCC and PSC of sponge city project under the PPP mode, VfM is calculated. If the result is positive, the PPP mode is more in line with the principle of VfM than the traditional financing mode for public projects (Morallos & Amekudzi, 2008; Liu *et al.*, 2018; Nguyen *et al.*, 2019).

The PSC and LCC indicators are shown in Table 4.

Table 4. Indicators of VfM.

Indicator	Sub-indicator
PSC	NPVc; NPVn; NPVr
LCC	NPVgc; NPVgr; NPVgoc

NPVc refers to the net present value of construction, investment, operation, and maintenance of the reference project; NPVn is the net present value of competition neutrality fee; NPVr is the net present value of all risks of sponge city projects; NPVgc is the net present value of construction, investment, operation, and maintenance of the sponge city PPP project invested by the government; NPVgr is the net present value of the risk cost borne by the government in the construction of sponge city under PPP mode; NPVgoc is the net present value of supporting measures taken by the government to promote the implantation of the project.

Civil society participation

Civil society participation is an important part of managing modern public affairs. Consequently, the government must appropriately guide the public in participating in social affairs, which is conducive to scientific decision-making and effective policy implementation. The forms of civil society participation must be diverse. The main forms of participation include hearings, symposiums and consultations, online solicitation of opinions, and community-level interviews. Different forms can be targeted for different social groups. The comprehensiveness of participation refers to dividing the public into project teams, professionals, stakeholders, other relevant groups and organizations, and the general public according to different concerns and interest points. A variety of public education and awareness raising methods are adopted to provide important support for the smooth development of SCC.

Discussion and conclusion

At present, the promotion and application of SCC rely mainly on governmental guidance and promotion. In the process of SCC, problems to be solved include how to build sponge cities, how to guide and coordinate social parties to participate in their construction, and how the government should lead and provide support in this process. Therefore, government mechanisms hold an important role in the SCC process.

By combining foreign water resources management system experience with China's current water policies, technology and management systems, the evaluation indicators and corresponding sub-indicators of SCC are specified in a hierarchical structure of several levels as follows: organization structures, system norms, technical systems, investment modes, civil society participation. The selection of each indicator is well explained and then combined with the government mechanism. Although this evaluation index system covers every detail of SCC and can guide all departments to clarify the tasks in the construction process, it is not perfect.

There are at least two issues that the system could deal with but have not been fully explored in this paper:

1. Division of evaluation stages. In order to evaluate the construction degree of the sponge city in different periods accurately, the construction of the sponge city can be divided into the starting stage, primary stage, medium stage, good stage, and excellent stage. There are different standards in different stages. The systematic management approaches like adaptive management combined with normative planning approaches like backcasting which were reported by Van der Voorn *et al.* (2012, 2017) can be used to develop and implement long-term adaptation strategies and policies for the construction of the sponge city.

2. Determination of evaluation criteria. As the SCC is a dynamic process of long-term development and change, new problems will be encountered constantly over the construction process. Thus, in the evaluation of the government mechanism, the most critical problem is to scientifically and reasonably determine the evaluation standard. SCC requires constant monitoring and learning from the results of previous management actions to improve management policies and practices (Pahl-Wostl *et al.*, 2007). Therefore, the evaluation criteria of the SCC can be improved by establishing the learning process and the conditions required for learning processes to take place.

The focus of future work is to solve the above two problems and improve the evaluation index system.

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