**Modern Environmental Science and Engineering (ISSN 2333-2581)**
**June 2018, Volume 4, No. 6, pp. 516-521**
**Doi: 10.15341/mese(2333-2581)/06.04.2018/004**
**Academic Star Publishing Company, 2018**
**www.academicstar.us**

# Evaluation System of Sponge City Construction in Taiwan Metropolitan System under the Impact of Climate Change

Su Qingmu, and Chang Hsueh-Sheng
*National Chengkung University, Department of Urban Planning, Taiwan*

**Abstract:** Climate change to the city to bring more uncertain disasters, construction of sponge city has become a viable alternative to this change. Taiwan's urban system is also more and more attention to the construction of sponge city. This article combs the construction of sponge city oriented through the historical context and related literature. And the organization of water ecosystem, social economic system, system and mechanism system for three, through the combination of the Delphi method, fuzzy analytic hierarchy process and principal component analysis of indicators assigned to make it more systematic and scientific. The construction of the evaluation system is conducive to reveal the potential of urban future development and adjustment.

**Key words:** sponge city, climate change, evaluation index, evaluation method, evaluation system

## 1. Background and Origin

Due to human activities, the global climate anomalies are becoming more frequent, and have become part of our daily news of floods, typhoons, and drought. According to the IPCC's fifth assessment reported [1], the global warming this year will rise 4.8°C, drought and climate events will become normal if the development of its current form. Taiwan as the world's 18 major water-scarce areas [2], in recent years is to face the increasingly serious challenges of climate change, heavy rain and drought frequent increase. And because of the seasonal rainfall in Taiwan, nearly 70% of the rainfall is mainly concentrated in the wet period (5-10 months), the southern region even higher, so the spatial and temporal distribution of rainfall is seriously uneven. According to the data of the Taiwan Water Resources Department, 74% of the total rainfall is through the river runoff, and most of them flow to the ocean. Therefore, the average amount of water that can be distributed per person per year in the Taiwan area is only one-seventh of the world's average rainfall. Considering that nearly 80% of the population in Taiwan is living in urban areas, let the water stay in the city, become a top priority, so that the city as sponge with drought, flood control, emission reduction and other benefits. In response to climate change, the city has also taken a number of engineering and non-engineering means, and sponge city construction is more and more attention, but also achieved some results. However, there is no corresponding evaluation system. In order to deal with the impact of climate change and the corresponding performance evaluation, we need to construct the evaluation system of sponge city and practice the effect of sponge city on urban slowdown and adjustment under extreme weather.

## 2. Review of Literature

There is no international agreement on how to build a sponge city, and from the historical context, the sponge city and the international rainwater

**Corresponding author:** Su Qingmu, Ph.D.; research areas/interests: urban space. E-mail: 865921044@qq.com.

management methods have a high degree of fit. According to the natural resources, human environment, urban scale and hydrogeological characteristics of the various cities and regions, according to local conditions to develop the corresponding construction goals, more typical of the United States New Orleans urban water network design, low impact development [3, 4], Sustainable Urban Drainage Systems in the United Kingdom [5], Water Sensitive Urban Design in the Australia [6], Technical guide for sponge city construction in the China Mainland [7], Sponge livable city in the Taipei City [8]. These ideas each have their own development priorities and differences. So the focus of the assessment is also focused (Table 1).

**Table 1 Related to the theory of sponge city.**

| country/region | method | Development | The mainly oriented |
|---|---|---|---|
| United States | New Orleans urban water network design | Through the point, line, surface space planning to establish interrelated water environment system<br>Create an open urban water environment, enhance the quality of urban environment | Water ecology<br>Water environment<br>Water use |
| United States | low impact development | Rainwater on the ground, scattered, small-scale source processing<br>Sustainable ecology, landscaping, improve urban microclimate | Water use<br>Water ecology |
| United Kingdom | Sustainable Urban Drainage Systems | Rainwater, industrial wastewater and domestic waste separation, to maintain good public health, reduce environmental pollution and reduce the use of natural resources (such as water, energy, materials). | Water safety<br>Water use |
| Australia | Water Sensitive Urban Design | Vertical series planning system, horizontal integration of urban water management<br>Integrated water cycle management, water-sensitive urban design, water-sensitive urban development three levels of comprehensive development of water | Water resources<br>Water use<br>Water safety<br>Water environment<br>Water system |
| China Mainland | Technical guide for sponge city construction | Listed six categories of eight categories of indicators. Construction of the city with the time to absorb water, storage of water, infiltration of water, purified water, when needed to store the water “release” and to use . | Water use<br>Water ecology<br>Water environment<br>Water safety<br>Water system |
| Taiwan | Sponge livable city | From the tough water adjustment, sustainable water use, friendly water environment for the three, to improve the urban water cycle, to enhance the flood tolerance, diversified active water use, stable water supply and efficient water, ecological diversity of water, rich charm of water recreation six principles For the goal | Water use<br>Water resources<br>Water environment<br>Water ecology |

In the relevant literature of Taiwan, in order to cope with climate change, from the perspective of sustainable development of land, the coastal, wetland, animal and plant resources, ecological networks, water conservation and utilization develop appropriate strategies and adjustments [9-11].

And from the sustainable safety of water, the need to deal with the impact of water and environmental impact: water supply shocks, water demand shocks, water quality impact, etc. [12], which requires water sustainable management and utilization and sustainable management of water resources [13]. The sustainable operation and utilization of water is to strengthen the construction of living infrastructure to achieve water supply and demand balance and effectiveness and enhance the resilience of urban and rural areas [14-15]; and the sustainable management of water resources requires comprehensive river basin management [16-19] (including total runoff management, permeable area, lagging storage space, water recycling), agricultural land use and conservation, biological habitat environment protection and Low-carbon energy strategy. The relevant literature also emphasizes the need to strengthen the system and mechanism of the building [14], from the supervision and early warning mechanism, the growth management mechanism [17], review the relevant planning, the stakeholders of the system construction. Through the comparative analysis of

domestic and foreign related sponge city research, in the construction of sponge city evaluation system can be from the following three aspects: First, the water ecosystem, including water development, water security, water environment; Second, the socio-economic system, including water management, water use, water efficiency; Third, the system and mechanism system, including institutional level, mechanism level.

## 3. Principles of Index Construction

**Systematic and targeted.** Indicators need to meet the sponge city meaning, need to reflect the sponge city construction of the elements and the problems faced. Evaluation system to water ecosystems and socio-economic system as the focus, not only to consider the water storage, drainage, flood control and drought the whole process, but also consider the issue of carbon reduction and economic benefits.

**Operability and independence.** The selection of indicators should be guided by the future construction of sponge city. Therefore, the choice of indicators should consider the feasibility of data collection, for those difficult to collect information indicators, should make the appropriate adjustments and abandon, and to maintain the relative independence of the indicators. It can repeat or eliminate duplicate indicators for indicators with strong relevance.

**Straightening and quantification.** For the development of water resources, conservation, management and utilization can take quantitative principles, with data to support the theory, more objectivity. The corresponding system and mechanism leve used a straightening way to supplement to Make the sponge city evaluation index system more credibility, as it is difficult to use data to quantify.

## 4. The Establishment of Evaluation Indicators

The establishment of assessment indicators, mainly to take the frequency of statistical methods, that is, through the statistics with the sponge city concept related literature, including the indicators of eco-city, smart city, tough city, low-carbon city, close city, sustainable city and other related sponge city, and then according to the water ecosystem, socio-economic system, system and mechanism system to refine the indicators of statistics. In this paper, a total of 22 articles were selected on the selection of indicators, and the general index system was calculated according to the principles selected by the indicators and the concept of the sponge city. The experts' suggestions were made to further adjust the indicators and confirm the final index system. In this paper, the evaluation index of sponge city is divided into three evaluation facets, eight evaluation projects and 30 evaluation indexes (Table 2).

## 5. Evaluation of Assessment Methods

In the past, the valuation of sponge city-related concepts was divided into two categories: the first category, mainly Delphi method, analytic hierarchy process and so on, and this process is susceptible to human interference, With the experts of the knowledge, experience, preferences have a great impact, belonging to the subjective assignment method; The second category, mainly principal component analysis, extension analysis and so on is through a large number of statistical data to determine the weight of the information through the results more convincing, but the subjective analysis of the researchers cannot be considered, belonging to the objective assignment method. Table 3 provides a scientific basis for the assessment of sponge cities by analyzing and comparing case studies.

Most of the previous assessment methods focus on the way the expert questionnaire scoring, re-outcome and light process. The evaluation of input-output efficiency and process dynamics is inadequate. Based on the existing evaluation experience, it is necessary to use the method of Delphi method, fuzzy analytic hierarchy process and principal component analysis method to determine the weight of each index in the evaluation system of sponge city in Taiwan. The first

**Table 2 Composition of sponge city assessment indicators.**

| Evaluate facets | evaluation items | Evaluation of indicators | Correlation | Description |
|---|---|---|---|---|
| the water ecosystem | Water development (Stable water supply) | Groundwater level | + | The higher the water level, the more water available |
| | | Annual runoff total vacancy rate | + | Vacancy rate is also low, water use is also high |
| | | Per capita water consumption | + | The higher the water consumption per capita, the more unfavorable to water development |
| | | Annual precipitation | + | The more annual precipitation, the more water available |
| | Water safety (Flood water control, tough soil) | Flooding potential | - | You can see flooded areas and flooded grades |
| | | Frequency of climate disasters (floods, droughts) | - | The higher the frequency, the more insecure the water |
| | | Environmental population load | + | The higher the load, the more water |
| | | Urban drainage pipe density | + | The higher the density, the easier it is to drain |
| | | Water quality | + | The better the quality, the more safe the water |
| | | Reservoir flood control capability | + | The higher the scheduling capacity, the more water |
| | Water Environment (Optimize water quality, create water environment) | Metropolitan green coverage | + | The higher the green coverage, the better the water environment |
| | | Wetland area | + | The bigger the area, the better the water environment |
| | | Urban surface area ratio | + | The bigger the area, the better the water environment |
| | | Species diversity | + | The higher the species diversity, the better the water environment |
| the socio-economic system | Water management (Deployment capacity at the time of the disaster) | Per capita GDP | + | The higher the GDP per capita, the more able to manage |
| | | Technical staff ratio | + | The more professional, the stronger the ability to adjust |
| | | Flood control command system coverage | + | The higher the coverage, the stronger the ability to adjust |
| | | Disaster prevention manpower | + | The more people with disaster prevention, the stronger the ability to adjust |
| | Water use (Comprehensive utilization, ease the contradiction between supply and demand) | Wastewater Recycling Efficiency | + | The higher the utilization rate, the more conducive to water development |
| | | Rainwater resource utilization | + | The higher the utilization rate, the more conducive to water development |
| | | Local surface water development utilization | + | The higher the utilization rate, the more conducive to water development |
| | Water efficiency (Input-output benefits) | Environmental Governance Investment | + | The more the investment, the better the governance effect |
| | | Economic output benefit | + | The more the output, the higher the return |
| | | Release oxygen | + | The more the release, the better the effect of emission reduction |
| System and mechanism system | Level of institutional level (Regulatory norms, easy to implement) | Growth management | + | Dynamic management, established goals easier to achieve |
| | | Urban flood control and other technical specifications | + | Regulatory norms, easy to implement |
| | | Planning Enforcement Rate | + | The higher the implementation rate, the more favorable the environment |
| | Level of mechanism (Perform optimization, improve efficiency) | Public awareness | + | The higher the public awareness, the more conducive to the realization of environmental protection |
| | | Investment and financing mechanism construction | + | You can revitalize the financing channels |
| | | Performance appraisal | + | Perform optimization and improve efficiency |

**Table 3 Analysis and comparison of related cases of evaluation methods.**

| Case | Introduction of method | Subjective assessment or objective assessment | Dynamic assessment or static assessment | Input-output Indicators and efficiency indicators | method |
|---|---|---|---|---|---|
| The Preliminary Study of Constructing the Indicators of City Climate Risk Governance [20] | Climate risk control indicators, after the expert questionnaire to develop APH questionnaire, and then by the experts and scholars to determine the importance of the final determination of the weight and weight of the indicators. | The process is determined by man. Subjective assessment | Mainly in the status quo to assess the disaster, vulnerability and accommodation capacity, are static assessment. | No indicators of structural benefits | Delphi method, analytic hierarchy process |
| The Development and Analysis on Natural Disaster Statistics Index System in Taiwan [21] | Through the fuzzy Delphi method to integrate the opinions of experts and scholars, select the index system, and then use the fuzzy hierarchy analysis method to calculate the weight and order of the evaluation index; Finally, through the index system to analyze the counties and cities in Taiwan | Human factors, the experts will be integrated into the fuzzy number of views, there is a certain degree of objectivity, but to subjective assessment based. | Mainly on the vulnerability of the disaster, the degree of loss, management statistics. Belong to static assessment | No indicators of structural benefits | Fuzzy Delphi method, fuzzy hierarchy analysis method |
| A Study on the Evaluation Framework of Eco-city — A Case Study in Taichung City [22] | The two-stage expert questionnaire survey was conducted with the fuzzy mathematics theory and the Delphi method and the hierarchical analysis method. Finally, the evaluation system was obtained and the evaluation effect | | Statistical analysis of the social, economic and environmental aspects of eco-cities is a static assessment | The environmental protection investment, per capita afforestation area and the effect of emission reduction. | Fuzzy Delphi method, fuzzy hierarchy analysis method |
| Research on Evaluation System of Growth Model and Countermeasures [23] | The weights of each index are determined by fuzzy analytic hierarchy process and principal component analysis, and the comprehensive evaluation model is constructed by linear weighted sum function method. Finally, an example is verified. | Application of two pairs of comparison method to determine the weight, and mathematical function transformation to solve the problem of information between indicators of duplication. Both the subject and the subject are evaluated | Change the stage of economic development is divided into the stage of change, change the stage of exploration, change the acceleration phase, change the smooth stage; and economic, science and technology, resources, people's livelihood and other indicators to measure, belonging to the assessment of static and dynamic. | No indicators of structural benefits | Fuzzy analytic hierarchy process, principal component analysis |

application of Delphi method and fuzzy analytic hierarchy process can objectively reflect the experience and evaluation of sponge city construction by experts and people, and apply the related fuzzy function to solve the problem of grading of grading process and avoid the subjectivity of scoring. Second, the application of principal component analysis, the use of mathematical transformation of the way to build a comprehensive index, you can directly reflect the indicators of the contribution of comprehensive indicators, making the assignment more objective and scientific. The evaluation process should take into account the evaluation of different periods, which can reflect the potential of the different stages of the city,

can reveal the possibility of urban future development and adjustment. The adjustment of indicators on the input and output efficiency to scientific quantitative makes as a government adjustment and performance assessment.

## 6. Conclusion

Based on the current situation of Taiwan's cities, the city's basic shape in Taiwan, sponge city construction is mainly based on small sponge construction [24], mainly concerned with the integrated management of water, and the integration of the theory of low impact development, sponge city construction also In the stage of development, the evaluation system of sponge city has not yet been formed. In this paper, the evaluation system of Taiwan sponge city is preliminarily established through the comparative study of relevant classical cases and research methods. From the water ecosystem, socio-economic system, system and mechanism system for three, application of Delphi method, fuzzy analytic hierarchy process and principal component analysis method to study the indicators, for the construction of Taiwan sponge city to provide a reference evaluation tool. Of course, in the practical operation, should be based on the characteristics of the city and the development of the situation, the corresponding adjustments.

## References

[1] Contribution of Working Group III, *Climate Change 2014: Mitigation of Climate Change, The Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 2014.

[2] National Climate Change Policy Program, Economic Development Committee of the Executive Yuan, 2012.

[3] Waggonner and Ball, Greater new Orleans urban water plan, *Urban Design*, 2013.

[4] Thurston County Water Resources, *Low Impact Development Barriers Analysis*, Washington: Thurston County, 2011.

[5] D. Butler and J. Parkinson, Towards sustainable urban drainage, Department of Civil Engineering. Imperial College of Science, Technology and Medicine.

[6] J. Floyd, B. L. Iaquinto anf R. Ison et al., Managing complexity in Australian urban water governance: Transitioning Sydney to a water sensitive city, *Futures* 61 (2014) 1-12.

[7] Housing urban and rural construction, Performance evaluation and assessment of sponge city construction (Trial), Housing urban and rural construction, China Mainland, 2015.

[8] P. Zhensheng et al., Permanent Taipei sponge city, *Civil Water Conservancy* 43 (2016) (5).

[9] Land plan method, Presidential palace, Taiwan, 2015.

[10] Coastal Management Act, Presidential palace, Taiwan, 2015.

[11] Wetland Conservation Act, presidential palace, Taiwan, 2015.

[12] X. Zhixiong et al., *Taiwan Science Report on Climate Change*, National Science Council of the Executive Yuan, 2011.

[13] National Climate Change Policy Program, Economic Development Committee of the Executive Yuan, 2012.

[14] National Climate Change Policy Program (draft), Economic Development Committee of the Executive Yuan, 2016.

[15] Forward construction plan — water environment construction, Economic Department of the Executive Yuan, 2017.

[16] Land and land development strategy plan (approved), National Development Board, 2010.

[17] National Regional Plan. Interior Administration Department, Taiwan, 2013.

[18] National Program for Action on Climate Change (draft), Environmental Protection Department of the Executive Yuan, 2016.

[19] Integrated river basin management plan (103-108 years) (approved), Ministry of Economic Affairs, Taiwan, 2014.

[20] K. M. Hsu, The preliminary study of constructing the indicators of city climate risk governance, *Journal of Humanities and Social Sciences* 52 (2014) (4) 203-258.

[21] W. Jieying and J. Yijin, The development and analysis on natural disaster statistics index system in Taiwan, *Journal of Geography* (2008) (51) 65-84.

[22] Y. C. Huang, A study in a study on the evaluation framework of eco-city — A case study in Taichung City, Donghai University, 2009.

[23] Z. L. Na, *Research on Evaluation System of Growth Model and Countermeasures*, University of Jinan, 2013.

[24] L. Xuanyu, Talking about sponge city, *ZTE Project* (2017) (135) 80-86.