A Review of LID (Sponge City) Development in China

Yutong Guan[1] and Xiaonan Tang[2*]

[1,2] Department of Civil Engineering, Xi'an Jiaotong-Liverpool University
* Corresponding: Xiao.Tang@xjtlu.edu.cn

Abstract

Under rapid urbanization, urban flooding has become a big concern in many Chinese cities over recent years. In response to this issue, a plan of sponge city construction was introduced in China in 2013 and implemented in 30 pilot cities by 2019. However, urban waterlogging still exists in more than 60% of the pilot cities after sponge city practices construction. This indicates that there are still challenges in the sponge city implementation in China. This paper outlines the current research state of sponge city in China, including the application of LID (Low Impact Development) techniques, optimization and performance, and some LID challenges in China. In addition, this review pays much attention to the research and implementation of LID in China. This review also provides some suggestions for future works to guide LID development in China.

Keywords: Urban flooding, Spongy city, LID, Sustainable environment Stormwater treatments

1. Introduction:

Urban areas are threatened by urban flooding caused by progressive urbanization, climate change, population growth, and land-use change. Urban flooding is mainly presented in two ways: street flooding and CSO (Combined Sewer Overflow), which leads to deteriorated water quality and property loss (Stovin et al., 2013; Xu et al., 2019). In response to the degraded water quality and urban flooding issues, worldwide attention has been paid to develop a more sustainable, eco-effective, and cost-effective management practice to control urban surface runoff. Low Impact Development (LID) was proposed to mitigate the effects of rapid urbanization in America. It was first introduced in Maryland and was soon distributed to a national audience (Eckart et al., 2017). Similar design philosophies include Low Impact Urban Design and Development (LIUDD) in New Zealand, Water Sensitive Urban Design (WSUD) in Australia, Best Management Practices (BMPs) in the United States and Canada, Sustainable Urban Drainage System (SUDS) in the UK and Sponge City Design (SCD) in China. The LID aims to maintain the natural hydrology (surface runoff, infiltration, evapotranspiration) to pre-development level (USEPA, 2000), while LIUDD has a similar intent but focuses on ecosystem health rather than hydrology characteristics (Fletcher et al., 2015). Australia proposed the concept of WSUD in the 1990s, encompassing aesthetical and recreational needs as well as stormwater management. Likewise, the concept of SUDS was initially set out in the UK in the 1990s. The key philosophy of SUDS is to replicate natural, pre-development conditions at a site to manage surface water runoff, which is comparable to the principle of LID.

In contrast, although Sponge City Design in China is incorporated within SUDS, LID and WSUD approaches, the construction or even the concept was not put forward until 2013, nearly 20 years later than that in developed countries. The idea of Sponge City was introduced at Central Urbanization Working Conference in 2013 (Xia et al., 2017). Thereby, this paper may refer to any one of these design philosophies as LID.

Despite the late start of LID in China, many studies have investigated LID application and performance in China. However, as a developing country, the established design, implementation and evaluation method used in developed countries may not be suitable in China. For example, by the end of 2015, the population in China has reached 1.4 billion, with more than a half crowded in cities, which means a higher urban population density in China than in western countries, leading to rapid urbanization and land-use change (Chan et al., 2018; Xia et al., 2017). In other words, compared with developed countries, China is less likely to have enough room to compensate for the increased runoff volume caused by development. Moreover, it is hard to realize the pre-development hydrology characteristic aim in China. Therefore, more attention should be paid to stormwater management than source control (MHURD, 2014).

Although several studies have provided an overview of LID research, little view has been given on the current situation in China. Eckart et al. (2017) summarized the LID alternatives techniques, from design, optimization, modelling, monitoring to performance throughout the world. (Fletcher et al., 2015) gave a brief description of LID about the history, terminology, application, limitation and recommendations for future works. (Houle et al., 2013) compared the maintenance cost, labour demands and system performance by testing 26 treatment strategies over a 6-year study in New Hampshire, America. (Lloyd et al., 2002) examined the design, construction, monitoring and performance of LID practices by conducting a case study in Melbourne, Australia. However, there is still a lack of LID research overview on China to guide policymakers and contractors. (Shao et al., 2013) stated that half the population and 70% of the property in China suffer from flood risk. According to 'China Flood and Drought Disaster Bulletin-2017' (MWRPRC, 2017), from 2000 to 2016, the direct economic loss of China due to floods accounted for 0.54% of GDP in that year on average and more than 12,000 people directly suffered from flooding every year. Moreover, urban waterlogging caused by stormwater has become the most severe reason (Xia et al., 2017). Therefore, an eco-friendly, cost-effective solution to address the urban flooding issues is essential.

In this paper, the current research state of LID in China is given through reviewing several aspects of LID, including design, implementation, construction, monitoring and performance. Furthermore, recommendations for future work in these perspectives are suggested in this study.

2. LID Alternatives

The basic principles of LID in China are appropriate design, environmental friendly, safety central, local adjustment, coordinate construction (MHURD, 2014). Jiang et al. (2018) explained the aim of sponge city in China to reserve the sponge-like natural capacity of a city and restore and manage stormwater. Most researchers categorized rainwater management techniques into two categories: infiltration-based techniques and retention-based techniques (Eckart et al., 2017; Fletcher et al., 2013). However, according to 'Draw and Construction Guidance of Sponge-like rainwater control and utilization in residential areas,' CIBSDR divided LID practices into three aspects: infiltration-based techniques, harvesting and reuse techniques, and regulating emission systems (CIBSDR, 2017). In this section, the concept, design and construction of each LID alternative will briefly be introduced.

2.1 Infiltration-based Techniques

Infiltration-based LID alternatives can be described as devoted to baseflow by recharging from the surface flow and subsurface flow (Fletcher et al., 2013). According to the guidance published by (China Institute of Building Standard Design and Research (CIBSDR), 2017), infiltration-based LIDs include permeable pavements, green roofs, swale systems (concave herbaceous field), bioretention systems, permeation tubes and infiltration inspection wells. Extra attention should be paid herein. Unlike studies abroad, infiltration-based LIDs in China consist of both infiltration and retention techniques as long as it has the function of infiltration or storage volume of stormwater.

Permeable pavements

Permeable pavements include permeable bricks, permeable concrete, and sand-based permeable bricks. In various situations, permeable bricks could be used at parking lot, squares, residential areas, pavements, and pedestrian streets. Permeable concrete is suitable for light load roads in residential areas and parks. In contrast, sand-based permeable bricks could be applied to not only the parking lot, square, residential areas, parks, and pedestrian streets but also in other infiltration-based techniques such as tree pool.

USEPA-US Environmental Protection Agency (2000) stated permeable pavements are helpful in reducing surface runoff and stormwater treatments.

Green roofs

Green roofs are described as partially or fully vegetated rooftops, which can counterbalance the removed vegetation due to building construction (Ahiablame et al., 2012). Green roofs are beneficial for stormwater runoff detention, extreme climate mitigation, and air and water quality improvement (Ahiablame et al., 2012; USEPA, 2000; Xu et al., 2019). (Toronto and Region Conservation, 2010) categorized green roofs as two types: intensive and extensive. Intensive green roofs could support rooted vegetation and pedestrian, while extensive green roofs could only support an herbaceous vegetative cover due to its thin growing medium layer.

Swale systems

Swale systems (referred to as the concave herbaceous field in China) are shallow open channels with mild side slops, filled with erosion and flood-resistant vegetation (Ahiablame et al., 2012; Eckart et al., 2017; USEPA, 2000). Based on the announcement published by (MHURD, 2014)), the selection of plants should be more inclined to salt-tolerant, flood-resistant, pollutant resistant plants. Swale systems have the advantages of low construction and maintenance cost, moderate community acceptance, and good water quality improvement (Corson, 2006). CIBSDR categorized swale systems into three types: the infiltration type, the overflow type, and the type of infiltration combined with overflow.

Bioretention systems

Bioretention systems are facilities constructed in lowland and designed to store and treat stormwater runoff through the vegetation-soil- microorganism ecosystem (MHURD, 2014; USEPA, 2000). Rain gardens are beneficial for pollution removal and groundwater recharge. Moreover, it can provide wildlife habitat and aesthetic, the recreational zone for residents (Ahiablame et al., 2012; Corson, 2006; Eckart et al., 2017).

Infiltration trenches

MHURD described infiltration trenches as channels with vegetation cover, which can be used to collect, convey and discharge rainwater. Furthermore, they can be combined with other LID practices and conventional urban drainage systems (MHURD, 2014). Infiltration trenches have good performance in pollutant removal and low maintenance cost (Barkdoll et al., 2016; Corson, 2006).

Infiltration wells

Infiltration wells are defined as wells with permeable walls and bottom beds that can allow stormwater to infiltrate naturally (MHURD, 2014). Infiltration wells are beneficial for preserving and improving groundwater quality and quantity and reducing the flooding and erosion rate caused by surface water runoff (Keep Our Earth Now, 2012). MHURD suggests that infiltration wells are used in the green areas around buildings, roads and parking lots.

2.2 Harvesting and reuse techniques

Harvesting and reuse techniques aim to restore rainwater and reuse it to urban water greenland, wash automobiles or simply supply landscape water bodies (MHURD, 2014). Fletcher et al. (2013) stated harvesting and reuse techniques could play an important role in future urban hydrology management. Noteworthily, the initial split-flow device, harvesting device, restore device and disinfect system could be integrated into one device called a rainwater module.

3. LID Optimization

LID practices contain the complicated design of hydro-environmental and socio-economical considerations, which require extensive efforts in testing or modeling various characteristics (Baek et al., 2015; Zhang and Chui, 2018). Therefore, considering the extensive adoption of LID practices, LID optimization is necessary to achieve a better performance in a limited budget (Eckart et al., 2017).

Basically, the optimization tools are categorized into two types: hydrological-based models and genetic algorithms (Liu et al., 2019). The hydrological-based models mainly include the stormwater management model (SWMM), soil and water assessment tool (SWAT), the stormwater drainage system design and analysis program (DRAINS), and the hydrological simulation model (SLAMM) (Liu et al., 2019). These models can simulate the hydrological characteristics of a whole storm event and analyze its impact on the watershed. The genetic algorithms mainly include the non-dominated sorting genetic algorithm II (NSGA-II), the multi-objective particle swarm optimization, and the multi-objective, socio-economic, boundary-emanating, nearest distance algorithm (MOSEBEND) (Liu et al., 2019; Eckart et al., 2017). These algorithms usually contain multiple objectives to deal with various and complex parameters in LID design (such as configuration, location, technique selection) (Eckart et al., 2017).

Among all the hydrological-based models, SWMM is the most popular one because SWMM has a specific LID model to simulate the hydrology and hydraulics characteristics and their sensitivity response to various LID design parameters (Liu et al., 2019). The most popular genetic algorithm is NSGA-II, which is created for multi-objective optimization and can be applied in many fields (Deb et al., 2002).

In recent years, the combined optimization method of both models and algorithms is becoming more and more popular in applying LIDs (Eckart et al., 2017). Bekele and Nicklow (2007) integrated SWAT with NSGA-II to optimize the LID design. SWAT is a model to predict the movement of sediments, pesticides and other chemical yields based on hydrological cycle simulating, which requires complex input parameters including climate, hydrologic response, topography, vegetation, soil properties, etc. (Neitsch et al., 2011; Bekele and Nicklow, 2007). NSGA-II can be adopted to help simplify the process of parameter calibration of the SWAT model. Bekele and Nicklow (2007) pointed out that the use of NSGA-II in calibrating SWAT can lead to better model performance and simulation results. Li et al. (2019) employed SWMM and AHP to evaluate the performance of different LID scenarios to design a cost-effective, better functional LID practice in China. AHP was adopted to assess the individual benefits of LID scenarios (including environmental, economic and social impact). Li et al. (2019) stated this optimal method could be applied to both design optimization before construction or performance emulation during operation. Other combination uses of models and algorithms include SWMM-GA (Sebti et al., 2016), SWMM-LCCA (Mei et al., 2018), SWMM-PSO (Duan et al., 2016).

However, SWMM has its limitations. One of the limitations is that SWMM cannot be integrated with AutoCAD directly (Chen et al., 2016). Considering AutoCAD is the primary design software used by Chinese architectural designers and the high demand for LID construction in China, an effective optimization method that is friendly to designers is necessary. In addition, none of the optimization methods mentioned above have taken resident thoughts into consideration, which may lead to a serious problem in China. As the retrofit of old residential areas is an important control of source pollution in sponge city implementation, the designers must consider the future functions and convenience of the LID practices to the local residents. For example, Yu (2018) emphasized the willingness of residents to increase the number of parking lots in a LID retrofit of the old residential area. This should be taken seriously in the design process of LID; otherwise, the residents may do vandalism to satisfy their parking needs or other requirements.

4. LID Performance

4.1 Hydrology Performance

In recent years, there has been extensive research on LID practices (Barkdoll et al., 2016; Ahiablame et al., 2012). Scholars have long debated the effectiveness of LID techniques (Qin et al., 2013; Ahiablame et al., 2012). Many discussions have been made in different LID practices in foreign countries (Houle et al., 2013; Ahiablame et al., 2012; Gulliver et al., 2009; Gregory, 2014; Corson, 2006). USEPA (2000) suggested evaluating LID effectiveness through hydrological and pollutant removal measures, while TS&CVC (2011) recommended that LID performance is assessed by water balance benefit, water quality improvement, and erosion control benefit. However, there is little investigation on LID performance in China. This section introduces several prevalent methods to evaluate LID effectiveness and describes LID performance in the objectives of hydrological function, pollutant removal capabilities, and erosion control benefit. Furthermore, suggestions for future research and development have been proposed.

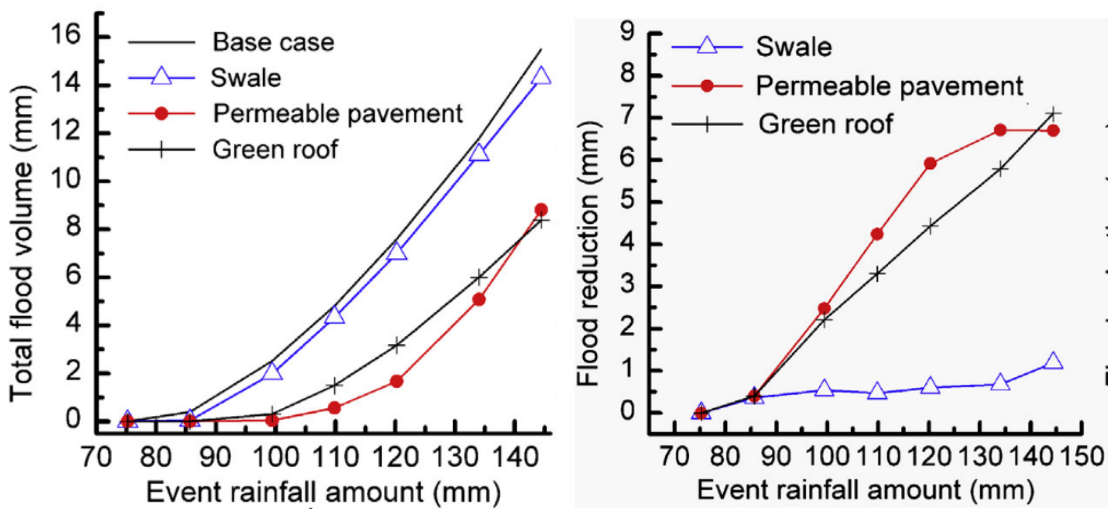
Infiltration capacity is commonly evaluated by field monitoring and mass balance method (Gulliver et al., 2009). However, field monitoring typically requires a long duration, extensive effort, and high expense. To this effect, Gulliver et al. (2009) proposed a ‘four-level assessment’ for LID practices, which involved visual inspection, infiltration capacity testing, synthetic runoff testing and monitoring. The first three levels can provide information such as infiltration rate estimation and maintenance need with less cost and effort. The visual inspection (level 1) is recommended conducted annually to observe the further requirements for LID maintenance.

The hydraulic function of LIDs has been studied broadly, including laboratory experiments and on-site tests (Qin et al., 2013). In China, however, only a few construction projects have qualified the LID performance through the field monitoring method. Jia et al. (2015a) conducted a series of field monitoring of a LID-BMP treatment train system in Foshan, a city in southern China, based on 19 storm events. This LID-BMP system consisted of three grassed swales, a buffer strip, a bioretention cell, two infiltration pits and a constructed wetland (Jia et al., 2015a). To estimate the efficiency of the LID-BMP system, the ‘sum of loads (SOL) method’ and ‘efficiency ratio (ER) method’ is adopted in this study. The monitoring results showed the bioretention cell possessed the best runoff control capacity with a reduction of 62.2% in volume and 66.0% in peak flow. The grassed swales reduced 36.2% of runoff volume and 44.3% in peak flow. All the percentages above were calculated on average over the 19 storm events. Jia et al. (2015a) also pointed out that the runoff flushing could seriously affect the bioretention cell performance, which would result in media material loss. The bioretention cell showed good efficiency in removing COD, Cu, NH3-N, TN and Zn (Table 1).

She et al. (2015) observed the LID performance under two extreme storm events (i.e. 25-year and 50-year storm events) using the visual inspection method. While the other campus area was flooded for more than 3 hours, the designed drainage area of the LID system did not show any possibility of waterlogging. The results showed that well-designed LID facilities (including green roofs, planters, an infiltration trench and a detention pond) have the capacity of dealing with extreme storm events.

Roehr and Kong (2010) conducted a case study in Shanghai, China, to monitor the runoff reduction effect of green roofs. They emphasized the need to consider climate conditions in the process of green roof design. For instance, Shanghai has high annual precipitation around 1348mm (LI and WU, 2018), which can almost satisfy the irrigation requirement of high water use plants. Thereby, in this case, high water use plants are encouraged in the designing process, as it performs much better in runoff volume reduction than low water use plants.

Most of the LID performance is simulated using the SWMM in China (Huang et al., 2014; Li et al., 2019; Qin et al., 2013; Liao et al., 2015; Mei et al., 2018). Qin et al. (2013) tested the sensitivity of three LID designs (the swale scenario, the permeable pavement scenario, the green roof scenario) using SWMM. The results showed that the storage depth of the surface layer mainly affects the flood volume reduction of the swale system. The permeable pavement design is significantly influenced by the height and void ratio of the storage layer; surprisingly, the green roof is slightly affected by the design parameters. A possible reason might be that the underdrain system is the dominant factor in flood volume reduction rather than other design parameters in the green roof scenario. The total flood volume and flood reduction trends are shown in Figure 1. It is evident that permeable pavements and green roofs have better performance in runoff reduction than swale systems.



(a) (b)

Fig 1. Hydrology performance of base case, swale, permeable pavement and green proof: (a) total flood volume and (b) flood volume reduction

Huang et al. (2014) employed SWMM to simulate the performance of five LID alternatives (i.e. a bio-retention cell, a grass swale, an infiltration trench, a porous pavement and a cistern system). They found that porous pavements have the most remarkable effectiveness in runoff reduction with a reduction rate of 35.58%, while the reduction rate of infiltration trenches is 30.80%.

Mei et al. (2018) compared the effectiveness of different LID designs under various storm event scenarios. The results showed that permeable pavements and green roofs outperformed vegetated swales or bioretention cells in all the four hydrology function characteristics: flow rate, the reduction rate of peak flow, outflow volume, and flood volume. Mei et al. (2018) also noted that the integrated use of LIDs in a treatment train could increase their effectiveness significantly. This conclusion was also confirmed by (Brown et al., 2012) and (Jia et al., 2015b).

4.2 Water Quality Treatment Performance

Woods-Ballard et al. (2015) pointed out that LIDs played an important role in preventing surface runoff pollution. Benefits delivered by LIDs are generally categorized into four aspects: sediment, nutrients, metals, and bacteria (Eckart et al., 2017; Woods-Ballard et al., 2015). Zhang et al. (2009) demonstrated the expected pollutant removal efficiency based on a USEPA report in 1984, as listed in Table 1.

Table 1.Water treatment performance of various LID practices

BMP type	typical pollutant removal/%				
	suspended solids	nitrogen	phosphorus	pathogens	metals
dry detention basins	30–65	15–45	15–45	< 30	15–45
retention basins	50–80	30–65	30–65	< 30	50–80
constructed wetlands	50–80	< 30	15–45	< 30	50–80
infiltration basins	50–80	50–80	50–80	65–100	50–80
infiltration trenches/dry wells	50–80	50–80	15–45	65–10	50–80
porous pavement	65–100	65–100	30–65	65–100	65–100
grassed swales	30–65	15–45	15–45	< 30	15–45
vegetated filter strips	50–80	50–80	50–80	< 30	30–65
surface sand filters	50–80	< 30	50–80	< 30	50–80
other media filters	65–100	15–45	< 30	< 30	50–80

Zhang et al. (2009) tested the LIDs efficiencies in a reservoir watershed in Shenzhen, China (shown in Table 2). Zhang et al. (2009) emphasized that treatment trains could significantly outperform over one single LID technique. The removal efficiencies of planter box/biobox would decrease rapidly with increased rainfall volume while pond and wetland would decrease gently.

Table 2. Water quality treatment performance of various LID practices

source	LID	TSS (%)	BOD_5 (%)	TP (%)	NH3-N (%)	SS (%)	COD (%)	TN (%)	NO3-N (%)	Zn (%)	Cu (%)	Cd (%)
Zhang et al. (2009)	pond/wetland	70~90	20~50	30~70	30~70	/	/	/	/	/	/	/
	swale	50~90	30~55	25~70	-10~35	/	/	/	/	/	/	/
	planter box/biobox	70~90	20~50	30~70	30~70	/	/	/	/	/	/	/
Jiang et al. (2017)	rain garden	/	/	56.99	59.73	51.79	39.80	56.84	49.84	/	/	/
	swale	/	/	69.80	74.27	82.19	75.11	69.02	73.56	/	/	/
Jia et al. (2015)	bioretention	-10.75	/	-21.26	51.10	/	17.93	48.61	/	100.00	69.45	/
	bioretention+swale	34.85	/	95.26	73.48	/	18.52	74.00	/	/	/	/
Huang et al. (2015)	grass swale	81.55	/	68.90	58.10	/	64.35	56.05	36.85	74.55	/	77.80
Fu and Li (2017)	grass swlae	85.50	/	79.60	70.70	/	76.50	/	28.80	/	/	/
	permeable pavements	83.30	/	74.30	56.20	/	48.30	/	14.30	/	/	/
	bioretention	85.10	/	84.50	79.40	/	80.40	/	28.20	/	/	/

Jiang et al. (2017a) monitored the field performance of swale and rain garden systems from 2014 to 2017 in Xi'an, China. They found that swales performed better in the second year. A possible reason was the loose soil and the good supplement of vegetation. Jia et al. (2015a) obtained the same conclusion that the pollutant treatment effectiveness of bioretention systems would increase in the second year. They monitored the nutrients and metals removal efficiencies in southern China. The results are given in Table 2. Jia et al.

(2015a) stated that more attention should be paid to the selection of the media material of LIDs because the use of flower soil (a common media material in China) can result in high phosphorus content in the outflow. Huang et al. (2015) found that the residual leaves after trimming could be another source of high phosphorous content in outflow, particularly when there is a long-duration storm event. He assessed the performance of grass swales in controlling roadway runoff pollutants. Their results are shown in Table 2.

Basically, considering the pollutant load treatment efficiencies, the performance of LID practices is arranged as bioretentions (rain gardens) > swales > green roofs > permeable pavements (Droguett, 2011; Fu and Li, 2017).

5. LID Challenges in China

This section reviews the challenges faced by China through three aspects: knowledge gap, investment financing, monitoring and maintenance, and government policy.

The knowledge gap of LID implementation in China mainly includes lacking integral and systematic view and basic research (Xia et al., 2017). Chen and Zhen (2018) identified that the Sponge City Implementation is conducted by various government departments (such as urban plan, water conservancy, municipal, etc. (Xia et al., 2017)), leading to the chaos of management. Therefore, a more specific and integrated management department needs to be founded. Jiang et al. (2018) stated that a system thinking of gray and green infrastructures integration management should be supported by the government, while Xia et al. (2017) pointed out that a natural ecosystem should be considered in the system thinking. The lack of basic research mainly refers to the optimization of design and planning. Considering a large number of LID constructions in China and the great use of trans-disciplinary approaches in successful urban water management projects, the trends imply that the indispensable of a more effective, multidisciplinary design and planning method clearly (Li et al., 2018; Xia et al., 2017; Jiang et al., 2018). Biswas and Hartley (2017) mentioned special attention should be paid to a more open-minded, scaled up designing method such as design the LID in a watershed scale rather than at a particular site.

The second concern is investment financing. The potential cost of a LID practice is approximately USD 15-22 million for each square kilometer (Jiang et al., 2017b; Dai et al., 2017), but the government investments (including both central and local) could only account for 33% of the whole budget (Dai et al., 2017). Moreover, the subsidy supported by the central government is only present for three years, with no clear plans about the investment sources in the future. Recently, the central government is encouraging the private sectors to take a financial role in sponge city constructions. However, this PPP (public-private partnership) market is still emerging, which remains a lot of policy and intervention uncertainties. Dai et al. (2017) pointed out that the participant of PPP could be limited by three factors: the conflict policy, the distrust of governments, and the risk of long-term commitments. Thus, the government is indispensable in the current stage of sponge city construction.

The limited monitoring data of LID performance is concerned by several researchers (Sun et al., 2014; Xu et al., 2019; Li et al., 2018; Chen and Zhen, 2018). The monitoring data is helpful to evaluate and improve the LID design, operation and maintenance (Jiang et al., 2017a; Gulliver et al., 2009). Moreover, considering the investment gap, the cost and benefit data could assist in drawing the attention of private sectors in financing (Jiang et al., 2017b). The monitoring could be conducted through two aspects: the online, real-time monitoring for data collecting and the early warning system for potential risk of overflow or leaking. However, the monitoring and maintenance issues have been largely ignored in China (Dai et al., 2017). Although more than thirty cities have been selected as pilot cities, only a few of them have monitoring plans after construction. So far, only one city of them, Xiamen, has a real-time monitoring system on a minute level (Chen and Zhen, 2018). In general, almost all the unprofitable public projects lack operation and maintenance after completion (Dai et al., 2017).

Challenges in government policy are related to the aspects mentioned above. Government policies could regulate the need for a more effective, combined inter-department corporation. Considering the investment gap, the government should bring up policies such as tax credits, deductions, or performance-based exemptions to incentivize private sectors (Biswas and Hartley, 2017). Given the lack of monitoring data, a possible solution could start from the pilot cities. As the monitoring data could be helpful to guide future work in sponge city, this should be regulated on a national scale. Take the expensive monitoring cost into account, this action should be supported by government policy or finance. In addition, government policy could also help solve weak implementation by plugging regulatory loopholes (Biswas and Hartley, 2017) and gather public participation by proposing their interests in decision making (Dai et al., 2017).

6. Conclusions

Sponge city implementation plays an important role in sustainable environment construction in China. This paper gives a brief description of the current research state of sponge city in China. The different techniques and performance of LID practices are assessed. LID performs well in flood volume reduction and water quality improvement. Suggestions for future sponge city design are given: more attention should be paid to local residents' needs, and a more friendly policy should be proposed.

Since no public database of the life-cycle process is available in China, this literature overview does not cover the life-cost cycle assessment in China, which would be helpful if it is integrated with the optimization process. In the future, this should take into account for the guidance of future sponge city construction in China.

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