Cities 93 (2019) 13–30

Contents lists available at ScienceDirect

Cities

journal homepage: www.elsevier.com/locate/cities

Implementation of the "sponge city" development plan in China: An evaluation of public willingness to pay for the life-cycle maintenance of its facilities

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ARTICLE INFO

Keywords:
Sponge city
Willingness to pay
Contingent valuation method
Life-cycle maintenance
Logistic regression
Tobit model

ABSTRACT

Urban stream syndrome, including urban waterlogging, flood risk, water shortage, water pollution and ecological restoration, are major challenges that cause potential risks to human beings. Recently, the sponge city construction (SCC) initiative in China has received extensive attention because it aims to systematically solve all of these urban water-related issues for a city. To date, little research has focused on the life-cycle operations, maintenance requirements and low public awareness of sponge city facilities (SCFs; e.g., rain gardens, green roofs, grass swales, and pavement greenbelts), which are challenges facing the development and sustainability of the SCC initiative. The aim of this study is to explore (i) the willingness to pay (WTP) for the life-cycle maintenance of SCFs and its determinants and (ii) the public's perceptions and attitudes towards the SCC initiative. We conducted a questionnaire-based survey combined with contingent valuation in three pilot sponge cities and then applied a two-phase logistic model and Tobit model to estimate the WTP of the respondents and the factors influencing the WTP. The results show that 76% of the respondents agreed to pay for life-cycle maintenance of SCFs, and the median amount of WTP was 16.57 CNY (2.53 USD) per month. Important factors influencing WTP include respondents' perceptions of the efficacy of the SCFs, concerns regarding the waterlogging risk and support for the SCF construction plans. The findings of this research extend our knowledge of the public's perceptions of and attitudes towards the SCC initiative and suggest that public contributions could serve as a crucial and feasible funding source for the life-cycle maintenance of SCFs.

1. Introduction

Urban waterlog disasters have been widely studied in many countries, as they can cause severe negative impacts on urban water safety, the economy and human life (Arnbjerg-Nielsen, Leonardsen, & Madsen, 2015; Jiang, Zevenbergen, & Ma, 2018; Kim et al., 2017; Lin et al., 2018; Smith, Smith, Baeck, & Miller, 2015). With the acceleration of urbanization and the increase in the number of extreme stormwater events, urban waterlog issues are becoming more frequent in global cities with poor water management conditions. Many countries in the world have developed urban resilience design approaches to enhance cities' capacities to control urban flooding risks, such as best management practice (BMP), low impact development (LID) in the US and Canada, water sensitive urban design (WSUD) in Australia, and sustainable drainage systems (SuDS) in the UK, among others. Resilience-boosting urban stormwater management strategies are mainstream development approaches of city design receiving significant attention globally.

In recent years, many cities in China have been seriously affected by urban waterlog issues, which have resulted in substantial economic losses and many fatalities (Hu, Han, & Meng, 2015). Sponge city (SC) is a new strategy of urban stormwater management (USM) in China, which refers to the city's good resilience in adapting to environmental changes and dealing with environmental disasters caused by rainwater. The connotation of an SC is to build a city that can absorb, store and purify rainwater as a sponge does and then naturally filter the rainwater through the soil, allow it to reach urban aquifers, and release it for reuse when needed. Before the concept of SC was put forward, some USM philosophies identified as innovative (i.e., LID, BMP, WSUD, SuDs, etc.) had already emerged and were implemented in some developed countries aiming to maintain the hydrology of urban catchments closer to predevelopment conditions (Eckart, Mcphee, & Bolisetti, 2017). The principles of SC are similar to those of stormwater management philosophies but also have differences (Eckart et al., 2017) (Table 1). For instance, the SCC particularly focuses on the rainwater capture process (i.e., a specified proportion of the annual runoff should be

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https://doi.org/10.1016/j.cities.2019.04.007
Received 22 May 2018; Received in revised form 30 March 2019; Accepted 21 April 2019
Available online 01 May 2019

Table 1
Comparison of the main content and characteristics between SCC and other USM strategies worldwide (Ashley et al., 2015; Wang, Ding, & Wang, 2018; Zhang & Chui, 2018).

USM strategies	Connotation	Scope	Main contents	Main characteristic	Facilities
Green infrastructure (GI)	A network providing the "ingredients" for solving urban and climatic challenges by building with nature	In and around towns and cities	Stormwater management, climate adaptation, reduced heat stress, greater biodiversity and food production, better air quality, sustainable energy production, clean water and healthy soils, improved quality of life through recreation and providing shade and shelter	Represent a network of green spaces and corridors with objectives beyond stormwater management, such as maximizing ecosystem services, watershed restoration, and biodiversity conservation; more-or-less synonymous with LID in the stormwater management literature	Urban forests, constructed wetlands, green roofs and green walls, green alleys, green school yards, and low-impact development facilities
Low-impact development (LID)	An ecologically based planning and engineering design approach to managing stormwater runoff and stormwater treatment technologies	Normally related to macroscopic planning and development for an entire urban region	Implement engineered small-scale hydrologic controls to replicate the predevelopment hydrologic regime of watersheds through infiltrating, filtering, storing, evaporating and detaining runoff close to its source	LID represents practices which are often implemented on site to control stormwater at the source and recover natural hydrologic processes and predevelopment conditions	Bioretention cells, green roofs, infiltration trenches, permeable pavement, rain gardens, rain barrels, and vegetative swales
Best management practice (BMP)	A type of water pollution control practice	Mostly indicates individual engineering practices (both urban and rural)	Auxiliary pollution controls in the fields of industrial wastewater control and municipal sewage control, and may refer to a principal control or treatment technique in stormwater management and wetland management	Include both nonstructural activities and structural practices that can reduce pollution from stormwater discharge, not necessarily on-site practices	Stormwater ponds, stormwater wetlands, infiltration practices, filtering practices, and open-channel practices
Sensitive urban drainage system design (SuDS)	Describe urban drainage systems that deal with surface water as alternatives to traditional piped drainage	Urban area	Sustainable management of surface water, groundwater and flood risk, maintaining the urban water cycle, protect the natural cycle, comprehensive consideration of water quality and environmental comfort	SuDS will become business as usual and necessitate innovative collaboration and engagement with local communities	Seep ponds, underground ditches, rainwater retention ponds, and constructed wetlands
Water-sensitive urban design (WSUD)	Philosophical approach to urban planning and design that aims to minimize the hydrological impacts of urban development on the surrounding environment	Both urban and rural area	Protection of natural water systems, integration of stormwater treatment into the landscape, reduction of runoff and peak flows, improvement of water quality draining from urban area	Shown how surface water contributes to "livability," incorporating multiple-use corridors that maximize the visual and recreational amenity	Rainwater collection boxes, watery landscapes, and green roofs
Sponge city (SC)	A systematical framework with approaches to improve urban water syndrome	Old downtown and new urban area	Protection and use of the original ecosystem, ecological restoration, low-impact development, upgrading terminal water treatment technology	Combination of both natural water system functions and artificial infrastructures as facilities	Low-impact development facilities, terminal treatment engineering projects, and natural elements, such as original water bodies or urban forests

Note: Abbreviations can be found in Table A1.

retained in the urban area, according to the technical guidance).

One main characteristic of SC is to combine green facilities with gray facilities and to involve natural elements (such as natural wetlands, ponds and river network systems) to treat rainwater, which differ from urban resilience-boosting strategies in other countries. The natural infiltration process of rainwater is blocked by impervious surfaces in urban areas, which causes high peak runoff and waterlog under heavy rain conditions. To mitigate the runoff volume and to recharge the ground water, the SC applies features such as permeable pavement, infiltration trenches or rain gardens to restore the natural infiltration process blocked by impervious surfaces. To facilitate storage and multiple reuse of the rainwater, artificial storage modules, rain barrels and underground storage tanks are implemented together with the natural water system to recycle the rainwater. To purify the runoff water, green and gray facilities, including biological retention facilities, rainwater gardens and vegetative swale, etc., as well as decentralized end-pipe treatment technologies, such as cyclone separators, are developed. The SCC initiative has received a great deal of attention worldwide, as it aims to systematically solve urban water-related issues, including urban waterlog, flood risk, water shortage, water pollution and ecological restoration.

In 2015, approximately 330 Chinese cities were considered to be water scarce or severely water scarce according to United Nations measures, while another 330 cities failed to meet national standards for flood prevention (Harris, 2015). The Chinese government announced the SC initiative in late 2013, and a technical guideline was followed in 2014 to guide the construction projects (MOHUD, 2015). A development framework for the SC is shown in Fig. 1. The implementation of SC plans could have a wide range of benefits within city boundaries; however, there are still several challenges and risks that remain in the process of SCC like other USM practices worldwide (Eckart et al., 2017; Jia, Wang, Zhen, Clar, & Yu, 2017; Jia, Yu, & Qin, 2017; Jiang et al., 2018; Liu et al., 2017; Ren, Wang, Wang, Huang, & Wang, 2017). Although the performance and implementation of some USM adaptations, such as LID and BMP practices, have been widely studied (Palla & Gnecco, 2015; Williams, Rayner, & Raynor, 2010), uncertainties regarding their net life-cycle maintenance and cost-effectiveness remain unresolved (Zhan & Chui, 2016). In addition, understanding the potential concerns and attitudes of the public is key to achieving better acceptability of USM practices.

Many studies have paid attention to the evaluation of environmental goods for USM practices and to explore opinions and attitudes from the public (Ashley et al., 2015; Bastien, Arthur, & Mcloughlin, 2012; Eckart et al., 2017; Mell, Henneberry, Hehl-Lange, & Keskin, 2013; Polyakov, Iftekhar, Zhang, & Fogarty, 2015; Sirina, Hua, & Gobert, 2017; Zhang & Chui, 2018). The evaluation of USM (Ashley et al., 2015; Bastien et al., 2012; Eckart et al., 2017; Mell et al., 2013; Polyakov et al., 2015; Sirina et al., 2017; Zhang & Chui, 2018) is still in its early stages in terms of that in developed countries (Superuser, 2007), where the willingness to pay for USM plans, projects and infrastructure has, for instance, been elicited in the UK (Mell et al., 2013), US and Australia (Bowman, Tyndall, Thompson, Kliebenstein, & Colletti, 2012; Walsh, 2016), and in France within the context of the Water Framework Directive (Sirina et al., 2017). A recent research survey conducted in Norwegian shows that households who feel exposed and live near areas that experience urban flooding would have higher WTP for municipal charges to avoid insecurity than those who live further away, but the respondents were only asked about their preferences for hypothetical scenarios rather than subjective exposure experiences (Torgersen & Navrud, 2018).

Although the WTP for public preferences on USM plans, policies, design and creation of facilities has been investigated in some studies, it has seldom been done with explicitly mention of the maintenance and management of the facilities. Lindsey (1992) first conducted an experiment on contingent valuation for eliciting people's WTP for a stormwater management plan in Baltimore, US (Lindsey, 1992). Lindsey and Knaap (1999) investigated public WTP for urban greenway projects in Indianapolis and found that people value greenways, but the WTP amount was strongly limited by the private ownership of the facility (Lindsey & Knaap, 1999). Clark et al. (2002) valued public WTP for a flood and ecological risk control policy in an urban watershed, which combined hydrologic models of flood control and biotic models of ecologic risk with economic models of WTP and psychological models to evaluate two alternative policy objectives. Although the methodology was interesting, the findings had no relationship with USM facilities (Clark et al., 2002). A recent study examined consumer value for conservation and low-impact design features in one housing market by using different valuation techniques to estimate residents' WTP, but it investigated LID features rather than the life-cycle maintenance of the facilities (LCMF) (Bowman et al., 2012).

In Australia, Mankad et al. (2015) qualitatively explored psychological and policy-related factors underpinning community acceptance of treated urban stormwater for domestic use, as well as community views regarding managed aquifer recharge for stormwater treatment and delivery. The study found nine key social indicators of community acceptance, which highlighted important factors with respect to the acceptance of stormwater reuse in an urban community (Mankad, Walton, & Alexander, 2015). While stormwater reuse is part of the USM practice's function, some interesting factors, such as the fair distribution of treated stormwater, trust and supportive of the technology, could have the same importance in regard to long-term maintenance of the USM facility. Some USM studies have demonstrated that the risk perception of the public has an important impact on their WTP to lower environment risks (Jorgensen & Syme, 2000; Leonard, Mankad, & Alexander, 2015; Veronesi, Chawla, Maurer, & Lienert, 2014). The risk perception was mainly focused on human health, i.e., the quality of recycling stormwater for potable and nonpotable uses. A contingent valuation (CV) of stormwater pollution study conducted in four Australian cities noted the respondents' attitudes towards paying, thereby explaining variability in WTP, and was a larger predictor than the price bid (Jorgensen & Syme, 2000). Dong et al. (2017) suggested that research in the future needs to find the correlation between environmental attitudes and intentions to learn about and install environmentally friendly practices and actual practice adoption (Dong, Guo, & Zeng, 2017). Wang, Sun, and Song (2017) examined public perceptions on sponge city construction and estimated the public's willingness to support sponge cities through domestic water fee surcharge or buying government-issued credit securities, which could offer insights to design a more properly PPP model promoted by the government to overcome financial insufficiencies (Wang et al., 2017).

Four studies were found that specifically addressed the study of CV with USM practice facilities. Three of them focused on the entertainment, amenity and leisure value that facilities can provide (Bastien et al., 2012; Polyakov et al., 2015; Sirina et al., 2017). Bastien et al. (2012) estimated the potential value to residents of living in close proximity to a SuDS pond in the UK, Polyakov et al. (2015) investigated the possibility that rain gardens provide amenity benefits that are capitalized into house prices in Australia, and Sirina et al. (2017) conducted a survey to determine the factors influencing the probability of urban park users' WTP to enjoy an urban park in France. Mell et al. (2013) applied a contingent valuation survey preferences for urban green infrastructure investments WTP, while the respondents' choices were based on development scenarios of pictures rather than real experiences (Mell et al., 2013).

The LCMF is crucial to the sustainability and long-term economic feasibility of the USM practice (Eckart et al., 2017). In the early stages of USM practices in developing countries, there has been controversy over the difficulty of the life-cycle maintenance and management of the facilities. (Chan et al., 2018). It is difficult to evaluate the cost-effectiveness and environmental service value of USM practices, which makes it challenging to estimate its life-cycle costs and benefits. In conclusion, studies that directly combine life-cycle maintenance on USM facilities with public perceptions and attitudes towards enhancing

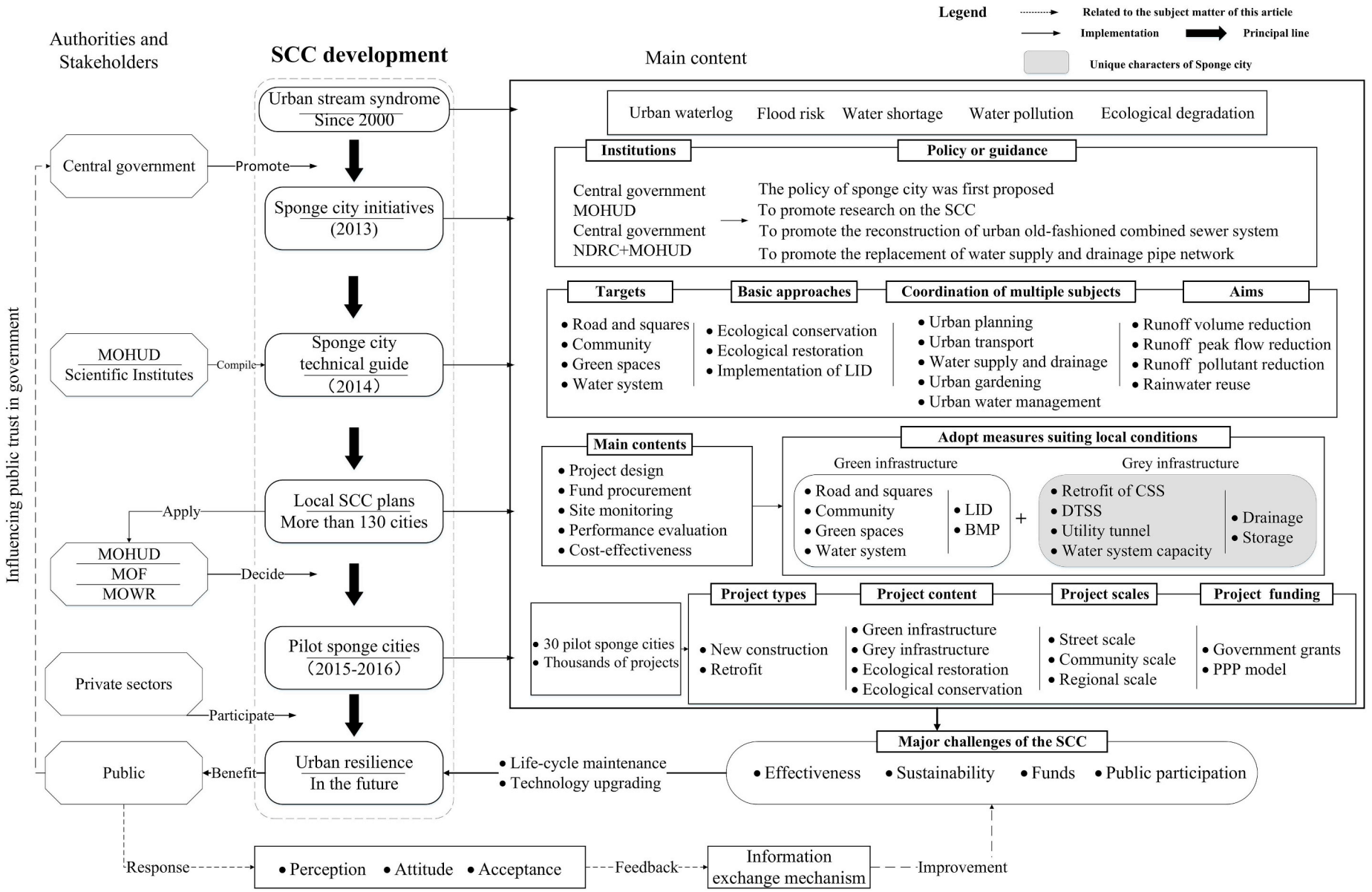

Fig. 1. Developmental framework of the Sponge City Construction initiative (Chan et al., 2018; Jia, Yu, & Qin, 2017; Li, Ding, Ren, Li, & Wang, 2017; Liu, Jia, & Niu, 2017; Xia et al., 2017).
CSS: Combined sewer system; DTSS: Deep tunnel sewerage system; PPP: Public-private partnership; MOHUD: Ministry of Housing and Urban-Rural Development of China; MOF: Ministry of Finance of China; MOWR: Ministry of Water Resource of China; NDRC: National Development and Reform Commission. All abbreviations in this study are defined in Table A1.

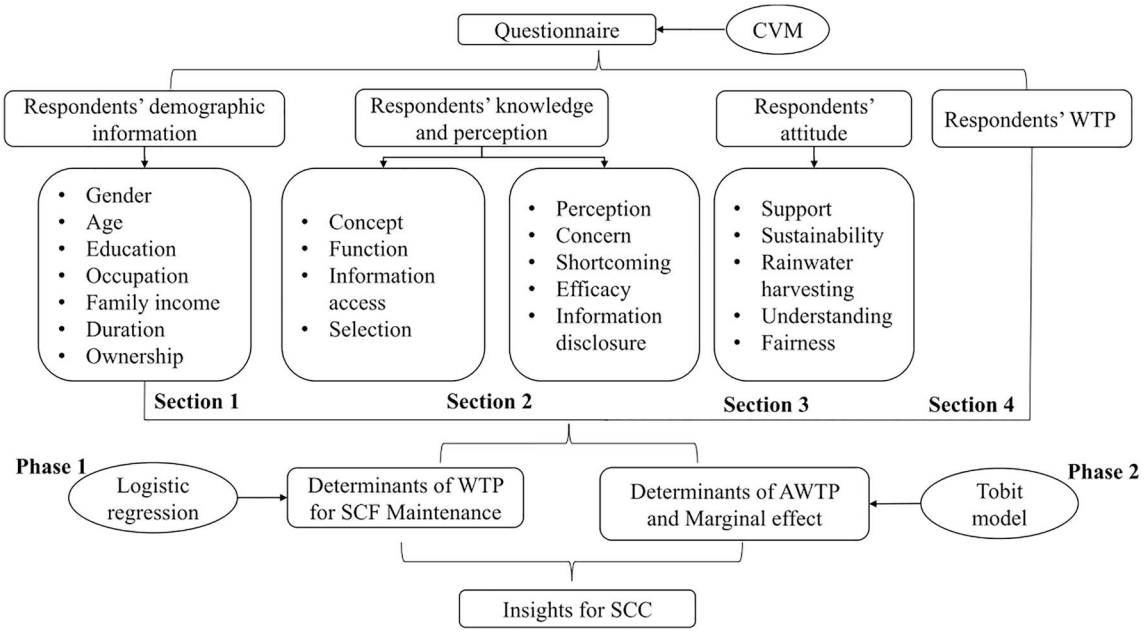

Fig. 2. Questionnaire structure and measurement items.

the resilience of the city through improving the USM are still rare.

Life-cycle maintenance and a potential low public acceptance are also barriers to implementation of SCC. This paper extends the analysis of the public's perceptions and attitudes towards one rapidly developed USM practice (SC) as a case study and explores the determinants that may have influence on public willingness to contribute to LCMF. The results were compared with data from other countries during the implementation of USM practices. The information provided in this paper may offer help in dealing with the controversy of whether public perception and attitudes towards the long-term effectiveness of SCFs and information communication can significantly affect their WTP.

The purpose of this investigation was to study the public perception of SCC, the public's WTP for the maintenance of the SCFs and the determinants of WTP on a community scale. Data for this study were collected through a questionnaire-based survey administered face-to-face in three pilot sponge cities: Shenzhen, Zhenjiang and Xi'an. In addition, to deal with the large number of zero WTP bids obtained, a Tobit model was applied. The objectives of this study included the following: 1) to assess public knowledge of, perception of and attitude towards the SCC initiative, 2) to estimate the public's WTP for the life-cycle maintenance of the SCFs, and 3) to explore the determinants of the public's WTP.

2. Materials and methods

2.1. Study area

Shenzhen, Zhenjiang and Xi'an, China, were chosen as the survey sites. The three cities are respectively located in the south, east and northwest regions of China, which are all characterized by rapid urbanization, high population density and the frequent occurrence of urban waterlogging. These cities were chosen for this investigation for several reasons. First, the three pilot sites have been actively seeking solutions to the urban waterlog issue in recent years, and some initial pilot projects with green infrastructure and LID practices have been conducted. Second, with technology and financial support from the local government, some community-scale sponge city projects were completed rapidly. Thus, residents who have already been living (for approximately two years) in the newly built or retrofitted community areas will have a relatively long experience with these changes predating our investigation. Third, the clear difference in the hydrologic, socioeconomic and demographic conditions of the three cities can provide less biased results than would be obtained from homologous cities (Table A2).

In addition, a presurvey with 50 respondents was carried out in Shanghai's Lingang New Town district before the final questionnaire was designed. The results were analyzed to determine the scale of the WTP bid in the formal survey and to avoid possible misinterpretations of the questions.

2.2. Methodology

2.2.1. Questionnaire design

The questionnaire included four main components (Fig. 2); all the questions and associated options are presented in the Appendix (Table A3). In the first section, information regarding respondents' socioeconomic characteristics, including gender, age, education, occupation, family income and the duration of residence in the community, were collected. In the second section, the question about respondents' knowledge and perceptions of the SCC initiative were asked. The concepts of SCC, the understanding of SCFs, the information access approach, and opinions regarding the site selection of the pilot cities were designed to estimate respondents' knowledge of the SCC initiative. Additionally, five questions included in the second section inquired about the respondents' perceptions of the differences before and after SCC, concerns about the waterlogging issue, the shortcomings of the SCFs, the efficacy of the SCFs, and information disclosure by the regional government. In the third section, the respondents' attitudes towards the SCC initiative were investigated. Five questions about the respondents' willingness to support SCC, beliefs regarding sustainability, acceptance of rainwater reuse, acceptance of environmental impacts and the fairness of the pilot sponge city site selection were included to understand the respondents' attitudes. Finally, the last section asked about the respondents' WTP for the maintenance of the SCFs. We conducted a presurvey by setting a series of bid amounts representing a monthly payment from 5 to 2000 CNY (from 0.76 to 305.6 USD) as selections to obtain a basic evaluation of the WTP among respondents. On the basis of the presurvey results, 5 bids (10, 20, 30, 50, and 100 CNY, i.e., 1.5, 3, 4.5, 7.5, and 15.2 USD) were used in the payment card choice task using the payment card contingent valuation method (PC-CVM) in the final questionnaire survey. The respondents

were asked whether they were willing to pay for the LCMF. If the respondents agreed to pay, they were asked to choose a bid from among the five numbers on the payment card. If the answer was no, then respondents were asked about the reason for their response.

2.2.2. Variable explanation

This study used four groups of independent variables to estimate WTP. The first group represented a respondent's perception of the SCC. Risk concern is crucial for the understanding of involvement in the environment and opposition to technology in many countries (Sjöberg, 2010). Therefore, five variables were included in this group. “Concern” represented the anxiety level of the respondents if the SCC were not built, to examine if a risk concern of urban waterlogging affected their decision to support the SCC practice and WTP (Botzen & van den Bergh, 2012). “Perception” indicated what environment change the respondents sensed before and after the SCC had been completed, and “Efficacy” illustrated respondents' perceptions of the effectiveness on the SCFs. These two variables indicated not only respondents' perceived effectiveness of the SCC policy but also of specific facilities. Perceived efficacy is one of the most important possible factors affecting the public's WTP, because perceived effectiveness would have a psychological impact on the public's preference, judgment of value and perceived benefits of the environmental goods (Loomis, 2011; Piquero & Steinberg, 2010). “Shortcoming” demonstrated people's feelings about the shortcomings of the SCFs. This variable captured public perception of the defects of the SCFs and their views on the sustainability of the practice, which may affect their WTP and especially how much to invest. “Information disclosure” measured whether the respondents had perceived or gotten access to sufficient information about SCC from the local government. This variable demonstrated the importance of government in introducing the SCC, public willingness to obtain corresponding knowledge and their right to know.

The second group focused on describing the public attitude towards the SCC, which consisted of five variables. “Supportive” indicated the respondents' supportive attitude towards building SCFs in the community they lived in. Residents' preferences and trust may be important determinants of their support for construction of environmental facilities, which could also affect their WTP (Mankad et al., 2015). “Sustainability” was measured based on respondents' trust in sustainable use of the SCFs under life-cycle maintenance of the government. This variable demonstrated the essentialness of government in maintaining environmental facilities and allowed for detecting relations between social and political perception for USM practice (Halkos & Matsiori, 2016). “Rainwater harvesting” illustrated the public's attitude towards supporting rainwater recycling. According to previous research, the abatement of recycling rainwater quality significantly affected residents' attitudes towards USM practice (Jorgensen & Syme, 2000). Therefore, “Rainwater harvesting” was included in the model. Doing one's fair share is a frequently mentioned consideration that correlates with WTP responses (Ajzen, Rosenthal, & Brown, 2010). Therefore, “Fairness” was incorporated to measure peoples' attitudes towards the fairness of site selection of the pilot SCC and to determine whether decisions that corresponded to the WTP of the SCC were impacted by pilot site selection. “Understanding” illustrated the respondents' attitudes towards and understanding of the environmental impact occurring during the SCC. Noise pollution, which would bring inconvenience to public daily life, may negatively affect residents' attitudes towards and WTP for the SCC to a certain extent.

The third group of variables described respondents' knowledge and cognitions towards the SCC. Different settings of knowledge may generate different perceptions of the public good among the respondents, which would affect public WTP (Paradiso & Trisorio, 2001). In addition, public knowledge, awareness and WTP for improving the local environmental quality play vital roles in the implementation of the strategy and the legislation introduced by the government (Afroz, Masud, Akhtar, & Duasa, 2013). Therefore, the concept cognition of the SCC strategy (“Concept”) and function of the SCFs (“Function”), information access issues (“Information access”) and pilot site selection factors (Selection) were included in the third group.

Variables in the fourth group collected respondents' sociodemographic features. In contingent valuation investigations, respondents' social and demographic features were frequently involved in order to test if they had an effect on public WTP under different scenarios (Botzen & van den Bergh, 2012; Savage, 1993; Wang, Sun, Yang, & Yuan, 2015; Zhou & Li, 2015). For instance, “Duration” indicated the duration of residence, and “Ownership” represented for respondents' renting or owning status of their accommodations (Che et al., 2013). These two variables may have a significant impact on residents' willingness to invest in their own living environment. Based on previous studies, seven sociodemographic variables were collected in our sample, including “Age”, “Gender”, “Education”, “Occupation”, “Family income”, “Duration”, and “Ownership”. The abbreviations of the variables are presented in Table A1, and the variable conversion process is described in Table A3.

2.2.3. Econometric models

A two-phase decision process analysis was carried out. The first phase was to analyze the respondents' decision of whether or not to pay for LCMF. The second phase was to estimate the determinants of the amount of money the respondents were willing to pay (AWTP) and its marginal effects. In the first phase, the respondents' decision of whether to pay took the form of dichotomous variables, which could be solved by a cumulative probability distribution function. Both logistic and probit model could be used to deal with qualitative variable cases, but the logistic model better fit survey data than experiment data in comparison to the probit model (Wang, Sun, M, Yang, X, & Yuan, 2015). The binary-choice model falls into the category of utility maximization models, which incorporate the microeconomic theories of consumer behavior and psychological choice behavior. Therefore, a binary-choice logistic model was selected to deal with the WTP issue in the first phase. The respondents' WTP was collected in binary form (YES = 1, NO = 0). The probability that respondents would be willing to pay for LCMF was defined by

$$\text{logit}[\Pr(Y=1)] = log_e[odds(Y=1)] = log_e\left[\frac{\Pr(Y=1)}{1-\Pr(Y=1)}\right] \quad (1)$$

where $Y = 1$ expresses the observed result of WTP, $Y = 0$ denotes for refusal of payment, and Pr represents the probability of WTP. The slopes of the logistic regression quantify the relationships between the explanatory variables and the dependent variables involving the parameters, called the odds ratio (OR). The OR is defined as the ratio of the probability that WTP will occur divided by the probability that WTP will not occur (Halkos & Matsiori, 2016).

The typical problem in logistic model calculation is the existence of zero values, i.e., unwilling to pay. Because the zero values reported by the PC-CVM may not indicate the true WTP of the respondents, there will be strategic bias in the estimated results if the zero values are simply excluded or are directly included in the analyzed samples (Tobin, 1958). The Tobit model applies a censored dependent variable without considering the sources of the zero responses and ignores the zero responses due to nonparticipation decisions, which is suitable in dealing with cases of data with zero values (Halkos & Matsiori, 2016). The two issues i.e. a) whether the respondents have a willingness to pay for LCMF and the determinants, b) how much money did the respondents intend to pay for LCMF and its determinants. That the logistic regression and Tobit model were applied to explore were not independent because the determinants of them may be different, but the process of analysis using the two methods were independent of each other.

Therefore, a Tobit model was formulated in the second phase of analysis (Halstead, Lindsay, & Brown, 1991; Liu, Tang, Yang, Liu, & Xue, 2015), to address the issue of zero values in analyzing

determinants of respondents' AWTP. The normal TYPE-I Tobit model can be represented by the following formula (Zhou & Li, 2015):

$$y_i = \begin{cases} 0, \ if \ y_i^* = 0 \\ y_i^*, \ if \ y_i^* > 0 \end{cases} \tag{2}$$

$$y_i^* = X_i\beta + \mu_i, \ \mu_i | X \sim N(0, \sigma^2), \ i = 1, 2, \cdots n \tag{3}$$

which y_i^* is the observed actual AWTP for LCMF of the respondents, y_i is the latent (unobservable) AWTP censored at zero. X_i is the vector of independent variables that are hypothesized to have impact on AWTP theoretically, β indicates the corresponding vector of undetermined coefficients, and μ_i is the error term (normal distribution curve with 0 means and variance σ^2).

Following George Halkos and Hasanul Banna et al.'s work (Banna et al., 2016; Halkos & Matsiori, 2016), the latent variable regression can also be written by $y_i^* = X_i\beta + \mu_i, \mu_i | X \sim N(0, \sigma^2)$, $i = 1, 2, \cdots n$, then the standard form of Tobit model is derived,

$$y_i = \begin{cases} 0, & if \ y_i^* = 0 \\ X_i\beta + \mu_i, \ if \ y_i^* > 0 \end{cases} \mu_i | X \sim N(0, \sigma^2), \ i = 1, 2, \cdots n \tag{4}$$

The truncated median and mean value of and marginal effects of AWTP applying the Tobit Maximum Likelihood estimation. The Maximum Likelihood estimation is derived as follows (Cragg, 1971; Jie, Zou, Lin, Ying, & Wang, 2014):

If (X_i, y_i^*) is a random selection, The density of y_i^* can be formulated using the following equation:

$$(2\pi\sigma^2)^{-\frac{1}{2}} \exp\left[\frac{(y - X_i\beta)^2}{(2\sigma^2)}\right] = \frac{1}{\sigma}\varphi\left(\frac{y - X_i\beta}{\sigma}\right), \ y_i^* > 0 \tag{5}$$

$$\mathrm{p}(y_i = 0 \mid X_i) = 1 - \varnothing\left(\frac{X_i\beta}{\sigma}\right) \tag{6}$$

where φ() is the standard normal probability density function, and ∅ is the standard cumulative normal distribution function. Log likelihood function is gained from of the i th observation, namely

$$l_i(\beta, \sigma) = l(y_i = 0) \ln\left[1 - \varnothing\left(\frac{X_i\beta}{\sigma}\right)\right] + l(y_i > 0) \ln\left[\frac{1}{\sigma}\varphi\frac{y_i - X_i\beta}{\sigma}\right] \tag{7}$$

Through a summation of l_i, the logarithmic likelihood function of a random sample with capacity of N can be obtained, namely

$$l = \sum_{y_i | y_i = 0} \ln\left[1 - \varnothing\frac{X_i\beta}{\sigma}\right] + \sum_{y_i | y_i = 0} \left[\ln\frac{1}{\sqrt{2\pi\sigma^2}} - \frac{1}{2}\frac{(y_i - X_i\beta)^2}{\sigma^2}\right] \tag{8}$$

This formula is consist of two parts, where the first formula is corresponded to all uncensored cases, and the second and formula is corresponded to all censored cases. By maximizing the upper summations, the maximum likelihood estimation of β and σ can be obtained. To appoint $\gamma = \beta/\sigma$ and $\theta = 1/\sigma$, we can get the following formula:

$$\ln L = \sum_{y_i > 0} -\frac{1}{2}[\ln(2\pi) - \ln\theta^2 + (\theta y_i - X_i'\gamma)^2] + \sum_{y_i = 0} \ln[1 - \varnothing(X_i'\gamma)] \tag{9}$$

After γ and θ have been estimated, we use $\gamma = \beta/\sigma$ and $\theta = 1/\sigma$ to estimate β and σ.

The marginal effect of an independent variable X_i on the expected value of AWTP is calculated by the following formula:

$$E(AWTP) = \frac{\partial E(WTP)}{\partial X_i} = \beta \mathrm{F}(X_i\beta/\sigma) \tag{10}$$

The Tobit model was applied in this study to estimate the median value of respondents' AWTP, as well as the determinants of the AWTP. In addition, the marginal effects of various factors were estimated. Strictly speaking, distinguishing public attitudes from their actual behavior and WTP can be better estimated by revealed preferences surveys (Gomez, Papanikolaou, & Vassallo, 2017; Halkos & Matsiori, 2016; Liu, Tang, & Miranda, 2015). However, to compare public perceptions with stated-preferences selection from the affected of the SC practice by applying a two-phase use of logistic and Tobit models can also be a valuable method to cope with that issue. This method could make the result clear and easy to understand, which will offer more efficient policy recommendations. SPSS.20 and STATA.20 were used for the logistic model and Tobit model, respectively.

3. Results

3.1. Respondents' demographic information

A total of 481 questionnaires were distributed in Shenzhen (151 respondents from 3 communities), Zhenjiang (162 respondents from 3 communities) and Xi'an (168 respondents from 4 communities). The effective sample was 453 (94%) after invalid questionnaires were deleted. The profiles of the respondents are shown in Table 2. All of the respondents were living in the community that was built as part of the sponge city projects. Age and gender were reasonably distributed in the three investigation sites, and 54% of the respondents owned the house in which they lived. The respondents showed a relatively high level of education: 42% of them had received a college education or above. In terms of

Table 2
The demographic information of the respondents.

Item	Status	Percentage (%)	Item	Status	Percentage (%)
Gender	Male	52	Occupation	Civil servant	13
	Female	48		Enterprise	11
Age	18	4		Doctor	1
	18–25	22		Teacher	3
	26–35	36		Worker	27
	36–45	13		Famer	2
	46–55	10		Science researcher	2
	> 55	16		Merchant	3
Family income (monthly, CNY)	< 2000	3		Student	11
	2000–3000	10		Retired	14
	3000–5000	23		Self-employed	6
	5000–8000	25		Unemployed and other	9
	8000–100,000	16	Family employed in an environment-related career	Yes	13
	> 100,000	23		None	87
Housing ownership	Owner	54	Education level	Primary school or below	17
				Middle school	17
				High school	24
	Renter	47		Undergraduate	38
				Undergraduate above	4

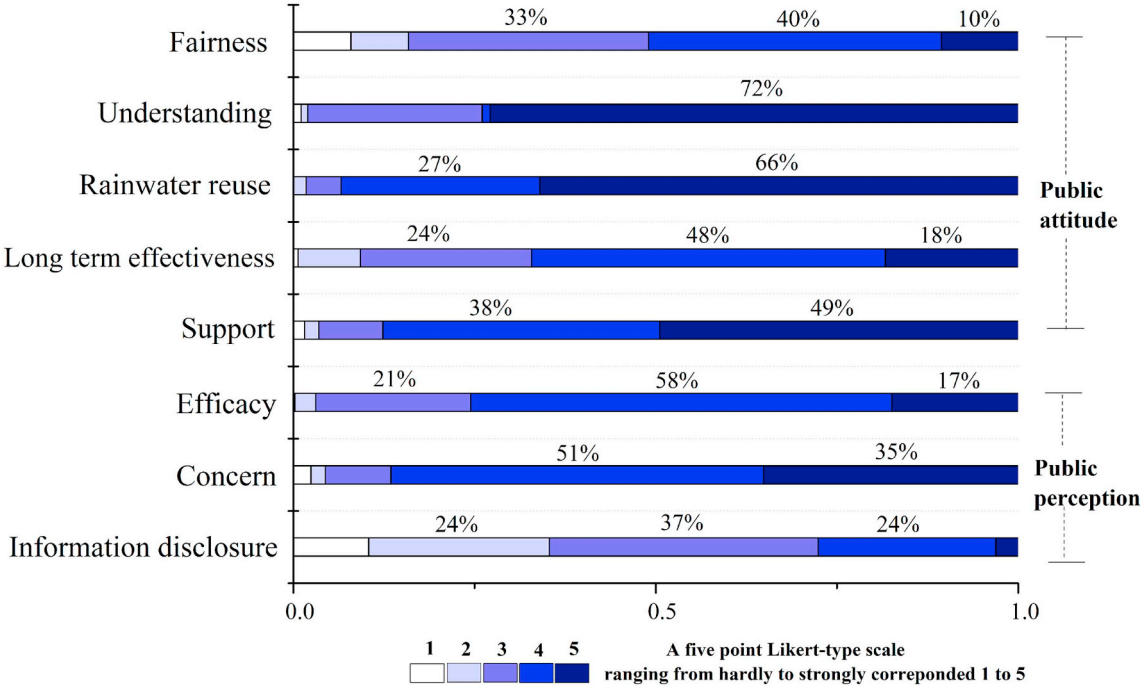

Fig. 3. Distribution of public perceptions and attitudes towards the SCC initiative.

wealth level, 39% of the respondents had a monthly family income of > 8000 CNY (1220 USD). Additionally, 13% of the respondents and their family members were engaged in an environment-related occupation.

Among all valid samples, 88% of the respondents had experienced urban waterlogging events, and 89% expressed that they were "very familiar" or "familiar" with SCFs. Generally, respondents had a good understanding of the contents and concept of SCC. These results could effectively void the possibility of error caused by the hypothesis requirement of a high level of knowledge for the CVM method.

3.2. Respondents' knowledge, perceptions and attitudes towards the SCC initiative

The respondents' knowledge of the SCC initiative was evaluated by five questions that tested their familiarity with SCC-related concepts, their familiarity with the SCFs, their understanding of the SCFs' functions, their access to information and their opinions on the selection of pilot sites. When questioned about their familiarity with the SCFs, 47% of the respondents chose "very familiar" or "familiar," and 75% of respondents considered the main function of the SCFs as to solve the waterlogging issue, followed by landscape improvement (61%) and urban heat island alleviation (53%; Fig. A2). The respondents mainly obtained information from the internet (45%) and publicity from the community council (34%); the results indicated that the public has relatively good knowledge of the SCC initiative but still lacks a deep understanding (Table S1).

The respondents' perceptions before and after SCC were investigated. The results show that 86% of the respondents had a relatively "strong concern" or "concern" about the occurrence of urban waterlogging without SCC. In terms of the respondents' perceptions of the effectiveness of SCC, 76% believed the SC strategy was an effective way to solve the urban waterlogging issue. Nevertheless, 39% of the respondents were not satisfied with the government's information disclosure about the SCC initiative in the community. Some of the results are shown in Fig. 3; the rest of the results are attached in the Appendix.

In addition, the respondents were questioned about their perceptions regarding the efficacy of SCC for the projects that were accomplished. The results show that 71% of the respondents thought the occurrence of waterlogging decreased after the construction of the SC, and 52% of the respondents considered the project to have improved the quality of the environmental landscape (Fig. A3). Next, problems and shortcomings perceived by the respondents were investigated (Fig. A4). The results show that 56% of the respondents thought there would be no life-cycle operation and maintenance after the project was completed, 43% believed the SCFs should be assessed based on their long-term performance, and 42% of the respondents stated that the disclosure of information about the SCC initiative was insufficient.

Five questions in the questionnaire examined public attitudes towards the SCC initiative (Table A3). Fig. 3 shows that 87% of the respondents supported the construction of the SCF in the area near their house, and 66% believed the SCFs could be effective over the long term. In the total sample, only 17% of the respondents regarded the selection of the SCC sites as unfair. The results indicate a relatively positive public attitude towards the pilot SCC initiative.

3.3. Factors influencing respondents' WTP

Among the 453 respondents, approximately 76% were willing to pay for the LCMF. A logistic regression method was used to explore the relationship between a positive WTP and respondents' demographic characteristics, knowledge, perceptions and attitudes. The results are shown in Tables 3–5. Through a filter procedure from the forward stepwise (likelihood ratio) method, at total of 10 variables that had significant impact on the probability of respondents' WTP were included in the final models, with statistical significance at the 10%, 5% or 1% levels. Standard errors (SE) were corrected using White heteroskedasticity. The Hosmer and Lemeshow (H&L) statistical test was used to test the logistic model fit. The H&L's *P*-values demonstrated that the model's estimate adequately fit the data (Kostakis & Sardianou, 2012).

As shown in Table 3, the respondents' ages and the durations they had lived in the residential community had significant, negative relationships with their WTP ($P < 0.1$ and $P < 0.01$, respectively). As the respondents' aged decreased, the odds of their WTP increased. This demonstrates that an increase in age will negatively affect the probability of WTP for LCMF. In contrast, DUR played a more important role in affecting the respondents' WTP than did their age, according to the

Table 3
Results from the binary logistic regression accounting for the respondents' demographic factors influencing WTP.[a]

Factors	B	SE	Wald	Sig	Exp(B)
Age	−0.298	0.166	3.238	0.072	0.742
Duration	−0.003	0.001	7.822	0.005	0.997
Constant	2.035	0.346	34.568	0.000	7.653
C&S R^2	0.037				
H&L Sig	0.932				
Chi-square	2.558				

Note: All of the binary logistic regression results were weighted to achieve sample representativeness. Standard errors are in parentheses.

[a] B denotes partial regression coefficients, SE denotes standard error, Wald denotes Wald statistic, Sig denotes the significance, and Exp (B) denotes the odds ratio.

Table 4
Results from the binary logistic regression accounting for the respondents' knowledge and perception factors influencing WTP.

Factors	B	SE	Wald	Sig	Exp(B)
Perception1	0.428	0.253	2.865	0.091	1.535
Concern	0.251	0.134	3.492	0.062	1.285
Shortcoming1	0.523	0.244	4.598	0.032	1.686
Efficacy	0.583	0.177	10.827	0.001	1.791
Information4	0.877	0.362	5.861	0.015	2.404
Information6	−5.16	0.293	3.114	0.078	0.597
Constant	−2.518	0.744	11.472	0.001	0.081
C&S R^2	0.094				
H&L Sig	0.218				
Chi-square	10.714				

Perception1: Respondents who believed that the occurrence of urban waterlogging events decreased after the sponge projects. Shortcoming1: Respondents who considered the government's information disclosure about the SCC initiative to be insufficient. Information4: Respondents who received the SCC-related information from the smartphone app. Information6: Respondents who received information through government publicity.

Wald coefficient. In addition, education level and family income had no relationship with WTP. This result was not consistent with some previous studies (Ren, Che, Yang, & Tao, 2016; Shang, Yue, Yang, & Yu, 2012; Wang et al., 2017), as these studies consider that people with higher education levels would have a stronger awareness of environmental protection. Income had a statistically insignificant relation with WTP mainly due to the respondents' stated preferences varying over time depending on their experience, knowledge and perception.

As shown in Table 4, with regard to public knowledge and perception-influencing factors, the respondents who perceived a reduction in the frequency of waterlogging occurrences had a significant, positive WTP ($p < 0.1$). Indeed, it was found that respondents with a good perceived efficacy, or a strong belief that SCC is an effective method for solving urban water issues, reported higher willingness to pay, as EFF and PER1 were found to have statistically significant relations with WTP at the 1% and 10% levels of significance, respectively. EFF was also the most important variable in this model, according to the Wald coefficients.

As expected, there was a positive relationship between WTP and a concern about the urban waterlog risk. Public concerns for unknown risks may motivate their WTP on USM practices as a demand for low-probability risk insurance (Botzen & van den Bergh, 2012). Interestingly, respondents who used a smartphone app to receive SCC-related information had a significantly positive WTP. According to the OD, respondents who used a smartphone app as medium for information access regarding the SCC had 2.404-fold greater willingness to pay for it than others. Another interesting finding was that the respondents who were not satisfied with the government's information disclosure still had a significantly positive WTP. In addition, the environmental impacts caused by SCC, which were reported as a major factor leading to negative public perception, were found to have no significant correlation with respondents' WTP.

In terms of public attitude, a supportive attitude about the SCC initiative was significantly positively correlated with WTP, which was consistent with expectations. The OD was significantly higher (2.156) with a higher supportive level of the respondent, which emphasized the very importance of public support.

Moreover, the respondents who believed there ought to have been more fairness in the construction site selection were significantly less likely to exhibit WTP. Fairness issues may have led to respondents' zero WTP, due to some people believing that they should have enjoyed the convenience and value of USM facilities because they already paid taxes or management fees to the community. Other respondents admitted to the value of the SCC but refused to pay because of financial limitations, which did not reflect their true willingness. In addition, a belief in the long-term effectiveness of the SCFs and support of environmental impacts during the SCC process did not have a significant relationship with WTP.

Table 5
Results from the binary logistic regression accounting for the respondents' attitude factors influencing WTP.

Factors	B	SE	Wald	Sig	Exp(B)
Support	0.768	0.141	29.678	0.000	2.156
Fairness	−0.191	0.111	2.948	0.086	0.826
Constant	−1.633	0.624	6.843	0.009	0.195
C&S R^2	0.083				
H&L Sig	0.899				
Chi-square	3.624				

3.4. Determinants of respondents' AWTP

Among all the respondents with a willingness to pay, 42% selected 10 CNY per month as their AWTP (Table 6). The Tobit model was established to estimate the respondents' AWTP for the LCMF and to explore determinants of the AWTP. Moreover, the marginal effects of explanatory variables on the respondents' AWTP were also estimated. All factors affected respondents' WTP detected in the logistic model, and possible factors on WTP, including GEN, EDU and INC, were included as explanatory variables in the final Tobit model to account for differences.

As shown in Table 7, respondents' AGE and DUR had significant, negative impacts on their AWTP. That indicated that elderly people and residents who had a longer duration of residence in the community were willing to pay less for the LCMF. This result is in line with Chui (2016)'s (Chui & Ngai, 2016) research on SuDS practices in the UK.

Conversely, trust regarding the perceived efficacy of the SCFs as well as support for SCC in the respondents' neighborhoods had significant, positive effects on individuals' AWTP. Rijke (2013) also noted that a high perceived efficacy of the facilities resulted in a positive public attitude

Table 6
The cumulative distribution of respondents' AWTP.

AWTP (CNY)	Number of respondents	Percentage of all respondents (%)	Percentage of respondents willing to pay (%)
10	142	31	42
20	77	17	22
30	56	12	16
50	53	12	15
100	18	4	5
WTP > 0	346	76	100
WTP = 0	107	24	

Table 7
Results of the Tobit model.

Explanatory variables	Coefficient	Marginal effects of AWTP	Std. Error	*P* value
AGE	−7.6506***	−5.4388	2.2765	0.0007
GEN	1.2645	0.8989	2.7728	0.6483
DUR	−6.1125**	−4.3453	2.5097	0.0148
EDU	−0.5243	−0.3727	1.8792	0.7802
INC	2.1365	1.5188	2.0394	0.2948
CON	1.9090	1.3571	1.7699	0.2807
EFF	5.5310**	3.9319	2.4146	0.0219
PER1	4.7889	3.4044	2.9753	0.0636
SHO1	5.3747*	3.8208	2.7863	0.0537
SUP	3.8385*	2.7288	2.0699	0.0636
IIF4	7.0600*	5.0189	3.6220	0.0512
FAI	−1.9338	−1.3747	1.3106	0.1400
INF6	−3.0186	−2.1459	3.5865	0.3999
Constant	−7.8656	/	14.0584	0.5758
Left censored: 112		Right censored: 18	Total: 453	
Pseudo R^2: 0.0208		Log-likelihood: −1647	Wald: 60.73	

Notes:
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

about resilient urban water systems (Rijke, Farrelly, Brown, & Zevenbergen, 2013).

In particular, choosing to receive the SCC information from smartphone apps had a significant, positive effect on individuals' AWTP. Generally, respondents who believed the government's information disclosure about the SCC was insufficient were willing to pay more money. The results of the Tobit model revealed that the determinants that had a significant impact on WTP might not necessarily have a significant impact on AWP, which may be the effect of zero values (Halkos & Matsiori, 2016).

Then we can work with the statistically significant variables to rewrite our empirical Tobit model formulation:

$$y_i = \beta_1 \mathrm{AGE} + \beta_2 \mathrm{DUR} + \beta_3 \mathrm{EFF} + \beta_4 \mathrm{SHO1} + \beta_5 \mathrm{SUP} + \beta_6 \mathrm{IIF4} + \mu$$

where the dependent variable y_i expresses the value of AWTP, μ is a disturbance term. The median and mean value of the AWTP is estimated using the whole sample data including zero responses.

According to the estimation results of the Tobit model, respondents' minimum AWTP for the LCMF was 15.34 CNY (2.35 USD), while the median was 16.57 CNY (2.53 USD). Because the average may be skewed by the extreme value of the residents' reported AWTP, it is common to use the median to represent the AWTP (Zhou & Li, 2015). Thus, respondents' AWTP, which is much closer to the reality of the LCMF expenses, was 16.57 CNY (2.53 USD) per month per capita.

4. Discussion

4.1. Respondents' zero WTP and AWTP

Wang et al. investigated public WTP for SC initiatives in two Chinese cities, their study determined that approximately 36% of the respondents did not want to pay for SCC (Wang et al., 2017a). The unwillingness to pay for the maintenance of the SC espoused by 26% of the respondents in our study, conducted two years after the SC project was completed. One possible reason for the lower unwillingness to pay in this study was residents' positive environmental perceptions. The results of the survey show that the respondents had a relatively good understanding of the SCC initiative and believed that the SCFs could effectively solve the urban waterlogging issue. However, nearly one-third of the respondents still rejected the idea of paying for LCMF. Among those who were unwilling to pay, a majority (72%) argued that the expenses should be paid by the government rather than by individuals. Many respondents stated that it is not reasonable for them to pay extra for the ecological services provided by SCC, because they ought to have good ecological services from the community infrastructure, since taxes and management fees are already being paid periodically. This is consistent with some previous studies using those respondents choosing zero WTP or those protesting payment due to the belief that their taxes were already too high (Andrews, Ferrini, & Bateman, 2017; Jie et al., 2014). Additionally, the respondents' perceived lack of efficacy of the SCFs might be another factor influencing the percentage of respondents with zero WTP. Financial constraints were not the main obstacle for respondents who were unwilling to pay, since only 6% chose this option.

Although studies on economic valuation of LCMF are rare, other WTP investigations on other USM practices or green infrastructures have been conducted. Chui and Ngai (2016) applied the CVM to evaluate individual WTP for SuDS in Hong Kong and revealed the median AWTP of public to be 11.3 and 19.4 USD per year for public spaces and private properties, respectively (Chui & Ngai, 2016). Verlicchi, Aukidy, Galletti, Zambello, and Zanni (2012) evaluated the AWTP for a project to reuse effluent from a pilot wastewater treatment plant for irrigation and to develop recreational use based on experimental investigation, and they found each family was willing to pay 54€ (61.59 USD) total for the construction of the facility (Verlicchi et al., 2012). Andrews et al. (2017) assessed values for a proposed urban park in the UK: the results demonstrated the estimated average public AWTP for creating new urban parks was 23.14£ (29.81 USD) (Andrews et al., 2017). Varying AWT*P* values may generally result from differences in survey sites and time points, environmental goods and service type, evaluation methods, question formats and respondents included in the sample. Botzen and van den Bergh (2012) elicited individual risk beliefs and the WTP for low-probability, high-impact urban flood insurance using the CVM, reporting the assessed mean respondents' AWTP for flood insurance was between 2.29€ (2.61 USD) and 6.32€ (7.2 USD) per month, which is relatively close to our respondents' AWTP (Botzen & van den Bergh, 2012). These results indicate that WTP estimation can provide possible comparability among different cases and serve a key role during the decision-making process. Up until now, CVM is a practical and relatively reliable method to estimate environmental goods' values under the condition of insufficient information.

4.2. Determinants of WTP and AWTP for the life-cycle maintenance of SCFs

4.2.1. The effect of demographic attributes

Demographic attributes mainly refer to the heterogeneity of the individual and family socioeconomic characteristics of the respondents. In the field of environmental goods valuation, different results are often gained by researchers in various cases or by applying different methods (Chatterjee, Triplett, Johnson, & Ahmed, 2017; Knapp et al., 2018; Osiolo, 2017; Shang et al., 2012). According to the logistic regression and Tobit model results in our study, age and respondents' duration living in the community had significant, negative effects both on WTP and the AWTP. The marginal effects of AGE and DUR factors on AWTP were −5.438 and −4.345, respectively. This indicates that the respondents' AWTP will be reduced by 5.438 CNY (0.84 USD) per month if the age factor increases by one unit. This result is not consistent with those found in some previous studies (Jie et al., 2014; Wang et al., 2017). Young people are more likely to accept new ideas, and they are always more eager to break through their comfort zones and to try new things than older people. Shang et al. assessed local communities' WTP for water environment conservation in China and found that young people's awareness of environmental conservation was higher than that of their elders (Shang et al., 2012). In addition, as the period factor increased, the AWTP was found to decrease by 4.34 CNY (0.67 USD) per month. For residents who have lived in one community for a long

time, a relatively stable consumption mode or normal life habits are formed. There may be a steady preference for “often do” or “used to do.” Thus, these respondents probably do not want to improve a life service model, even it is not a good one. In contrast to many research findings (Chatterjee et al., 2017; Ren et al., 2016; Wang et al., 2015), the level of education and family income had no significant effect on WTP or AWTP. This may be caused by a lack of respondents with a low-level education and household income in this study. In our survey, only 34% of the respondents had a high school degree or less, and only 13% of the respondents had a family income of < 3, 000 CNY (464.4 USD). It has been proved that the SCC can significantly improve the regional landscape and help provide better living standards for residents. Currently, nearly all residents, whatever their education level may be, are attaching great importance to better living conditions, which explains that little difference was found between choices made by respondents with different education levels. In addition, the reason why family income was not significantly related to WTP may lie in the lowest AWTP value set by the questionnaire. Because the lowest AWTP value involved in the payment card may hardly cause economic pressure to respondents, thus ignoring the possibility that although people are positive with SCC, they may not be willing to pay because of heavy economic burden.

4.2.2. The effect of respondents' knowledge and perceptions

The results showed that respondents' knowledge and perceptions have an important effect on their WTP. The respondents who believed that the occurrence of urban waterlogging events decreased after the SC projects were completed expressed a significantly positive WTP. However, the correlation between PER1 and the AWTP was not significant. After many SC projects at different community scales are completed, the ecological benefits of the SCFs can be visually and physically perceived. The residents' expectations that they would receive long-term services from the SCFs led to the possibility of increasing their WTP. Among all samples in the three pilot cites, 42% of the respondents thought that urban waterlog risk had significantly decreased, while a higher percentage (49%) believed that SCC improved only the landscape view within its boundary. Moreover, with respect to respondents' opinions regarding the shortcomings of SCC, 43% of the respondents believed the efficacy of SCFs must be examined over a longer time period and under different rain conditions, especially heavy rain events. This result may explain the reason why people had a positive WTP but hesitated to pay more, as they were not sure how long the SCFs would perform effectively.

Meanwhile, the respondents with a high perception of the efficacy of SCC had a more positive attitude about their WTP and gave a higher AWTP. The results of the Tobit model demonstrate that people will pay 3.93 CNY (0.6 USD) more per month for the LCMF per unit increase in the perceived efficacy of the SCFs. Perceived efficacy is considered to have an important impact on respondents' acceptance (Mankad & Tucker, 2013). Perceptions of efficacy pertaining to new methods support robust predictions of people's intentions to adopt new technologies around their homes (Lam, 2006). The perceived efficacy of the SCFs makes it easier for respondents to accept an idea and change their living conditions accordingly.

Previous studies have claimed that risk perception or concern regarding environmental hazards has a significant, positive effect on WTP (Che et al., 2013; Ren et al., 2016; Veronesi et al., 2014). As expected, the logistic regression analysis denoted that risk concerns about urban waterlogging had significant, positive effects on respondents' WTP for the LCMF. Among all the respondents, 87% believed that the urban waterlogging events would probably occur if the SC strategy was not implemented. This result indicates considerable concern about the urban waterlogging risks among the respondents. Nevertheless, the concern factor did not have a significant association with the AWTP. Savage found that when the probability of a risk is considered unknown and unpredictable, people have a lower AWTP to reduce the hazards of the risk (Savage, 1993).

Urban waterlogging induced by extreme precipitation events and land development on impervious surfaces has been an increasing concern for many major cities in China (Harris, 2015; Yao, Chen, & Wei, 2017). During our investigation, respondents with a positive WTP frequently claimed that the SC policy must be implemented through a long-term urban development process, rather than short-term pilot projects. Residents have a clear understanding of the perniciousness of urban waterlogging, which encouraged their WTP for precautionary measures. However, the magnitude of the risk and the possible loss cannot be accurately predicted or estimated, which may lead to residents' lower investment in risk prevention (Botzen & van den Bergh, 2012).

With regard to respondents' perceptions of the shortcomings of SCC at present, “insufficient information disclosure” had a significant positive effect on WTP and the AWTP for the SCF maintenance expenses. People who believed there had been insufficient information disclosure about the SCC initiative were willing to pay 3.82 CNY (0.59 USD) more per month. Among all respondents, 42% were not satisfied with the government's information disclosure. This result may also indicate a strong willingness to receive information and high expectations for SCC. This might be a good sign that demonstrates that the public has a positive attitude towards the SCC initiative. Respondents may have a higher AWTP and potential willingness to participate in the SCC process if they are provided with more corresponding information and knowledge.

Wang et al. found that the public has a high willingness to participate in the SCC process to address the problem of waterlogging (Wang et al., 2017). In our investigation, design shortcomings or potential safety hazards of the SCFs were already identified by the public, but an efficient communication mechanism with other stakeholders is lacking. This might potentially be reducing the respondents' WTP.

In the initial period of the SCC initiative, accurate and transparent information disclosure may significantly improve residents' trust. In our study, we found that receiving SCC-related information from smartphone apps had a significant, positive effect on WTP and the AWTP. The marginal effect of respondents' information reception medium indicated that people who selected smartphone apps as an information source would pay 5.01 CNY (0.78 USD) more per month. However, choosing governmental publicity had a significantly negative effect only on WTP. Smartphone apps are becoming one of the mainstream platforms for public information interaction; these platforms spread information more efficiently than conventional media channels (Felisoni & Godoi, 2017). In addition, a great deal of information is pushed to the smartphone subscriber, which increases the possibility that the public will acquire SCC-related information. This may help smartphone users gain a better understanding of the SCC initiative. By contrast, traditional means of information dissemination, such as publicity from the government or community committee, may have limitations with regard to timeliness and accessibility and therefore have a negative impact on public attitude and acceptance of a new policy.

4.2.3. The effect of respondents' attitudes

Policy trust is a factor that increases residents' acceptance of the sponge city concept. A supportive attitude of building the SCFs around respondents' homes has a significantly positive effect on their WTP and AWTP. Respondents who express a supportive attitude will pay 2.72 CNY (0.42 USD) more per month according to the marginal effect results. Residents are always sensitive and sometimes respond strongly to public construction projects around their homes (Feng, Tao, Li, & Fei, 2017). This indicates that trust in government policies is an important factor in improving public acceptance and participation (Jie et al., 2014). Public trust in governmental policy is likely to be influenced by past experiences (Ho, Shaw, X, & Chiu, 2008). In recent years, the residents' trust in policies has gradually improved in China; the main reason for this change may be the increasing investment in construction projects benefiting the public.

Anderson et al. found that public demand for policy fairness has significant effects on the public's WTP for climate change reduction (Anderson, Bernauer, & Balietti, 2017). In our study, 47% of the respondents thought the selection of the SC project site was fair. However, according to the logistic regression results, a belief that it is fair and reasonable to build the SC project around residents' homes had a significant, negative effect on the WTP. The selection of the SC project site at the community scale may be based on many factors, such as historical waterlogging occurrences and the cost-effectiveness of the SCFs based on the site condition. The respondents in our investigation were already living in or near a community that had been built or retrofitted as a SC project. Thus, there was no financial cost regarding the environmental benefits for them, since funding for the current SCC projects mainly came from government financial subsidies and PPP cooperation. Respondents' beliefs that it is fair to build sponge city projects around their homes may be due to psychological self-interest.

However, with the technology of SCC projects improving, there will be more sponge city projects in future urban development plans, at which point the fairness of the site selection process might be raised. According to Gross's research, decisions concerning the location of infrastructure development or the use of natural resources have the potential to damage a community's social well-being if the outcomes are perceived to be unfair (Gross, 2007). Therefore, it is necessary to study the public's attitudes regarding the fairness of site selections in future research.

4.3. Policy recommendations on sponge city as a USM practice

Our results indicate that well-performing SCFs would have positive effects on respondents' attitudes and WTP for maintenance costs. The SCFs had a relatively strong performance in terms of the respondents' perceptions. However, some technical challenges for the SCC initiative still exist. One of the most important challenge is the life-cycle performance of the SCFs. Insufficient studies focus on life-cycle maintenance, and management of SCFs is becoming increasingly prominent, since SCC is rapidly developing in urban cities. The unaddressed life-cycle maintenance costs may be another limitation on the efficacy of the SCFs. Thus, attention should be paid to the operation and maintenance of the SCFs, and ongoing studies of the SCFs should be carried out to gain practical experimental results to ensure a long-term effectiveness of the SCFs and upgrade the technologies of future sponge city construction projects.

4.3.1. Attending to the life-cycle maintenance, management and monitoring of facilities

After the construction of an USM project was completed, life-cycle operation, maintenance and management of the facilities became extremely important to ensure the long-term effectiveness of the project, which may negatively affect the public perception and attitude according to our results. Therefore, to formulate a life-cycle maintenance and management mechanism is crucial in order to exposure the problems and shortcomings of the facility generating during the operation process, which can offer help to repair the problem facilities and to improve the design defects of the facility.

Monitoring and evaluation of a facility is an important part of life-cycle maintenance and management. Sufficient and regular monitoring can provide useful information to help managers and engineers conduct normal operations and maintenance. Facilities problems, such as the blockage of permeable pavement or conduit, lost efficacy of filler material in rain gardens, and willingness to provide feedbacks to developers and designers. Through that way, a sustainable effectiveness of the USM facilities could be better ensured.

A life-cycle-based facility monitoring mechanism should be considered in USM plans and technical guidance. One of the major restriction on technical progress of USM practice is a lack of long-term performance monitoring under various operation conditions or scenarios (Stovin, 2010). However, the provisions on life-cycle monitoring are normally insufficient in local technical guides (Mitchell, 2006). For instance, the technical manual of LID in Minnesota, US, only saw site or field monitoring conducted before and after the project to evaluate whether the project met the requirements of the local construction standard. In Australia, monitoring is generally limited to the requirements for system operation (Mitchell, 2006). The current technical guidance of the SCC also professes ignorance about the long-term monitoring of the facilities. Measuring the benefits and efficacy of LID would fill an urgent need to have long-term dataset provide results with better accuracy. Mayer et al. (2012) studied the ecological impacts of green infrastructures using a six-year dataset and concluded that even six years' monitoring might still be insufficient (Mayer et al., 2012).

The Urban Water Resources Research Council of the US formulated an open BMP database that can evaluate and share existing BMP designs and performances through collecting data from different projects. The database aims at gathering sufficient technical design, performance information and studies to address BMP-related problems (Clary, Urbonas, Jones, Strecker, & Quigley, 2002). To present, the database has collected over 600 BMP cases together with evaluation reports and project documentation which can be accessed online. To provide basic information to support LCMF, to estimate cost-effectiveness and ecosystem service value and to improve function design, an information-sharing platform having a similar function to that of a BMP database can be considered for development during both the pilot process of SCC in China and other USM practices in the world.

It may be a smart and effective way to include the public in the maintenance and management mechanisms in areas or projects where people have a good perception of the USM practice and a strong willingness to participate (Wang et al., 2017). The public can provide visual assessment and feedback on whether the facility works effectively, whether there are issues, whether there are design deficiencies that might cause safety risks and by participating as volunteers. The public can gain better understanding about USM facilities, therefore yielding a positive impact on perception and attitudes towards the USM strategies, both for the participants and their family members.

4.3.2. Attending to information disclosure and public guidance

The importance of information disclosures should be recognized. Our analysis suggests there is a strong interest in SCC, but according to public opinion, there has been insufficient information disclosure by the government. The government should enhance the timeliness of information disclosure and increase the frequency of publicity among residents. Additionally, a wide range of channels for information dissemination are also needed. For example, professional and official smartphone apps can be developed as an option to improve the veracity of SCC-related information and the efficiency of its transmission as well as to reduce the transmission of misleading information to the public.

A variety of information should be provided to the public. Scientific information regarding the causes and consequences of urban waterlogging disasters and the effectiveness of SCC as a solution to these problems should be included. Additionally, the character and function of SCFs should be included to improve the public's familiarity with them. This information may help to eliminate public concern about urban waterlogging risks and improve the public's attitude towards the SCC initiative. In addition, the effective, successful practices of other pilot cities should be incorporated. This information will help people understand that it takes time for the effects of SCC to become apparent. The information source could involve different entities, including government, universities, scientific institutes and environmental NGOs, to ensure its validity.

A long-term communication mechanism is also needed to promote public participation in the SCC process. During our survey, a lack of effective communication channels to connect stakeholders and residents was detected (Fig. A5), which is an obstacle to the public's favorable perception of the SCC initiative. For instance, imperfections and shortcomings of the SCFs might be perceived by residents after the sponge city project is completed, but there is rarely a way to provide feedback to the SC designers or government agencies. Other environmental impacts, such as the

breakdown of the facilities or the mosquito problem, may have negative effects on residential life. Building a communication mechanism can help with the adaptation and improvement of the SCC initiative and may enable evaluation of the performance of the SCFs from the public's perspective. Moreover, public preferences could be incorporated with the policy-making mechanism to improve the public's sense of identification with the government.

5. Conclusion

The unaddressed life-cycle maintenance costs could be an insurmountable challenge to the sustainability of SCC. Our study applied a PC-CVM questionnaire-based survey to investigate three pilot sponge cities (Shenzhen, Zhenjiang, Xi'an) in China in order to study the effects of public knowledge, perception and attitudes towards the implementation of SCC practice at the community scale and to explore the public's WTP for the life-cycle operation and maintenance of the SCFs. A logistic regression model and Tobit model were used to estimate the WTP and AWTP for the SFCs' long-term maintenance and its determinants. The following three major results were identified: 1) among 453 qualified samples, 76% of the respondents have a positive WTP for the SCF maintenance expenses, 2) respondents' estimated median AWTP is 16.57 CNY (2.56 USD) per month, and 3) respondents' age and length of residence in the community have significant, negative relationships with both WTP and the AWTP, whereas factors such as perceived efficacy, information disclosure and support for SCC, have a significant, positive effect on both WTP and the AWTP. Although several respondents considered that LCMF expansion should already be covered by paid fees and taxes, a positive attitude towards SCC and a WTP for LCMF suggest that a public contribution could serve as a crucial and possible funding source. To ensure a good quality of the SCFs, to establish a long-term monitoring and maintenance mechanism, to keep high transparency of government information disclosure and policy-making process and to ensure an effective channel for information communication and feedback are the key factors to further improve public attitude and WTP, which should be given priority considerations in the future. Therefore, the WTP estimated by our study could be an appropriate premium for SCC projects as one of the global USM practices. Future investigations should be carried out in line with the implementation of new policies and increased service time of the facilities and considering the impact of geographical differences.

Acknowledgments

This research was supported by the National Key R&D Program of China (Grant No. 2017YFC0505701), the Science and Technology Commission of Shanghai Municipality (Grant No. 15DZ1203606), and the Shanghai Municipal Education Commission and Shanghai Education Development Foundation (Grant NO. 16SG24). The authors acknowledge Gen Li, Li Chen, Jingyi Xiang, Can Zou, Mengjie Yang, Yukun Wang, Ruihui Chen, Yihan Xie, Huaxiang Wang, Peng Zeng and Dr. Yichong Cui from East China Normal University for their assistance with the field investigation.

Conflicts of interest

The authors declare no conflict of interest.

Appendix A

Table A1
Abbreviations in the study.

Description	Abbreviation	Description	Abbreviation
Terminology		Model variables	
Sponge city	SC	Age	AGE
Sponge city construction	SCC	Gender	GEN
Sponge city facility	SCF	Education	EDU
Low impact development	LID	Family income	INC
Green infrastructure	GI	Occupation	OCC
Best management practice	BMP	Concept	CONC
Life-cycle maintenance of the Sponge city facilities	LCMF	Duration of residence	DUR
Urban stormwater management	USM	Perception1	PER1
Willingness to pay	WTP	Concern	CON
Amount of money the respondents' were willing to pay	AWTP	Pilot	PIL
Combined sewer system	CSS	Support	SUP
Deep tunnel sewerage system	DTSS	Fairness	FAI
Public private partnership	PPP	Shortcoming1	SHO1
Ministry of Housing and Urban Rural Development of China	MOHUD	Understanding	UND
Ministry of Finance of China	MOF	Efficacy	EFF
National Development and Reform Commission	NDRC	Information4	INF4
Contingent valuation method	CVM	Information6	INF6
Statistical indicators		Information disclosure	INFD
Partial regression coefficients	B	Function1	FUNC1
Standard error	S.E.	Function2	FUNC2
Wald statistic	Wald	Ownership	OWN
Significance	Sig		
Odds ratio	Exp (B)		

Table A2
Hydrologic, socio-economic, and demographic information for the three cities investigated.

Pilot cities	Annual average rainfall (mm)	Annual average evaporation (mm)	Annual average temperature (°C)	Population (million)	GDP per capita (million CNY)	Respondents
Shenzhen	1837	1675	14.3	10.77	17.92	140
Zhenjiang	1063	1277	16.1	3.11	11.91	153
Xi'an	520	1481	22.4	8.71	7.43	160

Table A3
Question profiles in the questionnaire and variable transformation.

Section	Abbreviation	Description	Option settings	Variable transformation
Respondents' demographic attributes	Gender	/	Single selection	Dichotomous
	Age			Continuous
	Education			Nominal
	Family income			Continuous
	Occupation			Nominal
	Duration	The duration of residence in the community.		Continuous
	Ownership	The respondents' ownership of the house in the SCC area.		Dichotomous
Respondents' knowledge of the SCC initiative and the SCFs	Concept[b]	Are you familiar with these concepts?	A five-point Likert-type scale ranging from "hardly know" to "know very well"	Ordinal
	Function1[b]	Are you familiar with the functions of the SCFs?	A five-point Likert-type scale selection	Ordinal
	Function2[a]	In your opinion, what is the dominant function of the SCC initiative?	Multiple choice	Nominal
	Information[a]	How do you receive information about the SCC initiative?	Multiple choice	Nominal
	Pilot[a]	What factors do you think should be considered for SCC site selection?	Multiple choice	Nominal
Respondents' perceptions	Perception[a]	What changes do you observe when comparing before and after the SCC?	Multiple choice	Nominal
	Concern[b]	Are you concerned about waterlogging issues if the sponge city is not built?	A five-point Likert-type scale selection	Ordinal
	Shortcomings[a]	What shortcomings do the SCFs have, in your opinion?	Multiple choice	Nominal
	Efficacy[b]	Do you believe that SCC is an effective way to prevent urban waterlogging?	A five-point Likert-type scale selection	Ordinal
	Information disclosure[b]	Do you think the information disclosure about the SCC initiative is sufficient?		Ordinal
Respondents' attitudes	Support[b]	Will you be supportive if the government plans to build SCFs around your home?		Ordinal
	Sustainability[b]	Do you believe that the SCFs will function sustainably and effectively?		Ordinal
	Understanding[b]	Will you be supportive if there are environmental impacts during the SCC period?		Ordinal
	Fairness[b]	What is your opinion about the fairness of site selection of the pilot SCC sites?		Ordinal

Note:
[a] Nominal variables were recoded into a binary variable form.
[b] Initially measured from 'hardly' to 'strongly,' corresponding to 1–5, a five-point Likert-type scale selection ranging from 'low' to 'high.' For example, the selection for familiarity with the SCC initiative ranges from 'hardly know' to 'know very well.'

Variables were recorded applying a five-point Likert scale (SUP, SUS, UND, FAI, EFF, INFD, FUNC1, CON), continuous (AGE, INC, DUR), dichotomous (GEN, OWN) responses and nominal (SHO, PER, PIL, INF, FUNC2, OCC, EDU). For analysis purposes, all five-point Likert scale were transformed into ordinal variables, questions with multiple choice were transformed into nominal variables and then transformed into a binary variable form respectively, like INF1, INF2, INF3.

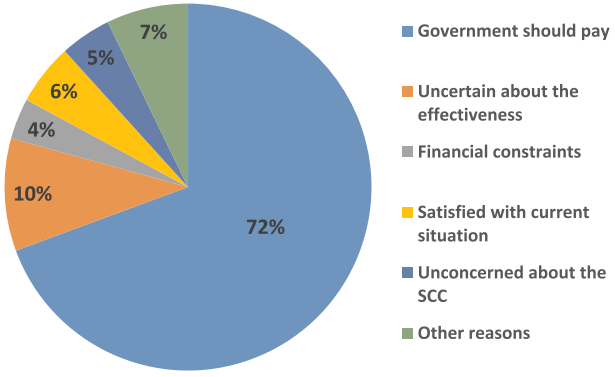

Fig. A1. Respondents' reasons for refusing to pay.

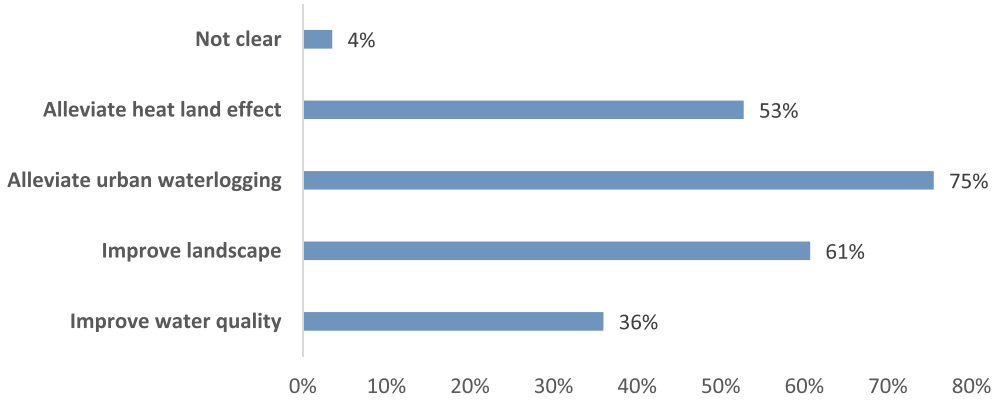

Fig. A2. Respondents' perceptions of the dominant function of the SCC initiative.

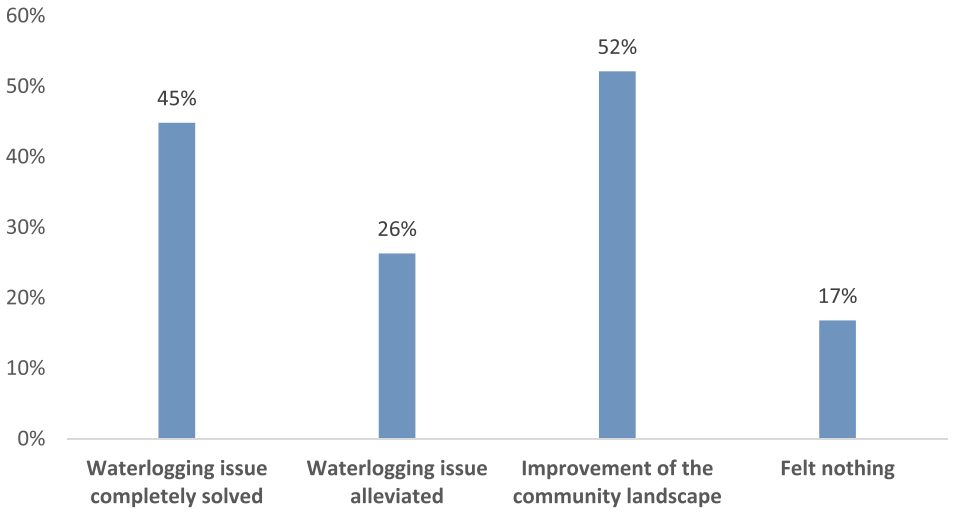

Fig. A3. Changes felt by the respondents comparing before and after SCC.

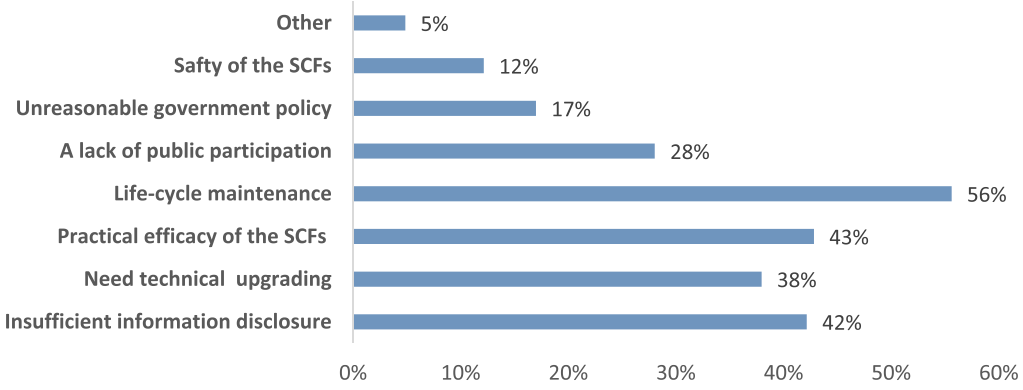

Fig. A4. Shortcomings of the SCFs as perceived by the respondents.

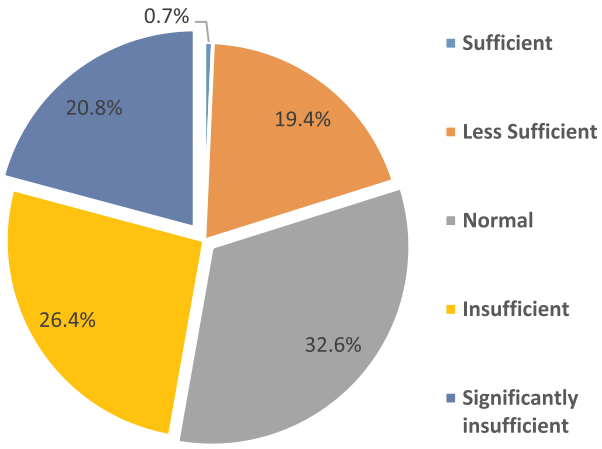

Fig. A5. Shortcomings of the SCFs as perceived by the respondents.

Appendix B

Logistic model specification:

The cumulative logistic model can be presented as:

$$L_i = \ln\left(\frac{P_i}{1-P_i}\right) = \alpha + \beta_i X_i \tag{1}$$

where L is the log of the odds ratio (OD) which is a linear function of the explanatory variables. P_i is the probability of WTP of the i th individuals, the vector X_i includes attributes of respondents' social-demographic, and β is the corresponding unknown regression coefficients to be estimated. The probability P_i ranges between 0 and 1 and is nonlinearly related to the X_i attributes. The cumulative logistic distribution function in Eq. (1) can be defined as

$$P_i = E(Y = 1 \mid X_i) = \frac{1}{1 + e^{-(\alpha+\beta_i X_i)}} \tag{2}$$

If P_i is the probability of WTP for LCMF, then (1-P_i) is the probability of unwilling to pay can be expressed as:

$$1 - P_i = \frac{1}{1 + e^{-(\alpha+\beta_i X_i)}} \tag{3}$$

The OD is expressed as:

$$\frac{P_i}{1-P_i} = \frac{1 + e^{(\beta_1+\beta_i X_i)}}{1 + e^{-(\beta_1+\beta_i X_i)}} = e^{(\beta_i+\beta_i X_i)} \tag{4}$$

The OD denoted for the ratio of favorable to unfavorable cases of WTP. This preference depends on the values of explanatory variables. Taking the natural log of Eq. (4), Eq. (1) can be obtained.

The model is estimated using the log likelihood function method. The probability of respondents to pay for LCMF can be predicted by calculating the coefficients of the logistic regression.

Appendix C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cities.2019.04.007.

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