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Public preferences and willingness to pay for low impact development: a comparative case study of pilot sponge cities in China

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ABSTRACT

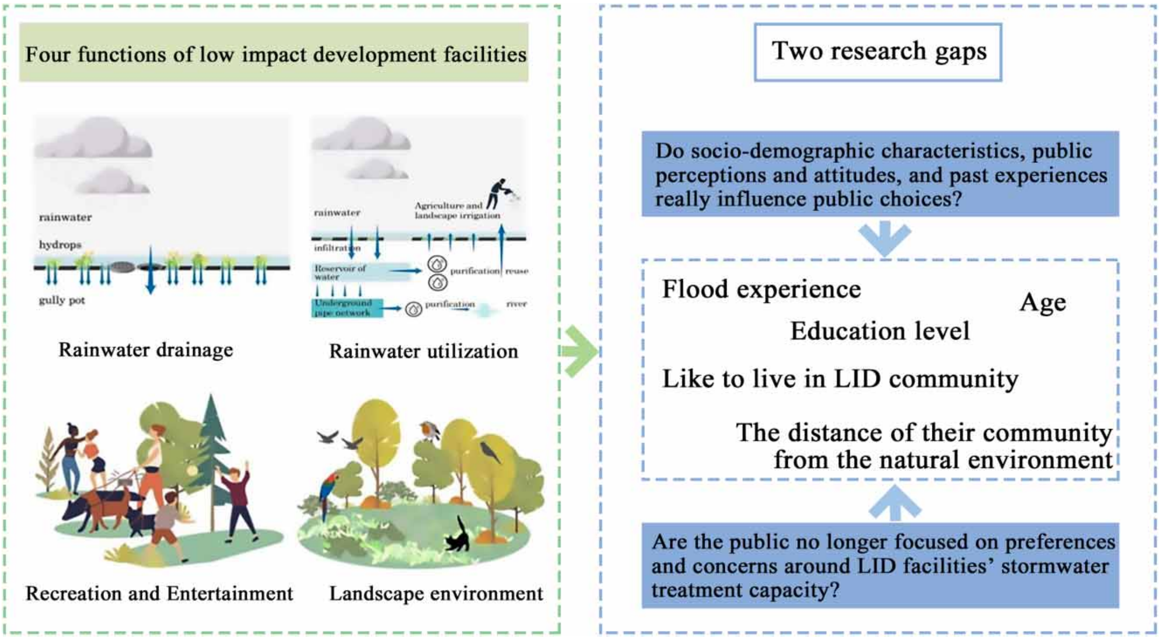
Increased urbanization and climate change globally have increased the frequency of extreme weather, especially rainstorms and flooding. Low impact development (LID) has been adopted for several decades to reduce urban pluvial flooding and cope with urban climate change. However, LID hasn't been widely used due to the lack of sustainable funding. In this article, a discrete choice experiment method was used to understand public preferences and willingness to pay (WTP) for the functions of LID facilities. Four attributes were selected, and after that, 958 and 646 valid questionnaires were collected in the pilot sponge cities of Zhengzhou and Hebi, respectively. The results showed that respondents showed a significant WTP for LID facilities, with a desire to support rainwater drainage, recreation and entertainment, and the landscape environment. Experience of flooding had a significant effect on Zhengzhou respondents, but not on Hebi respondents. We have concluded that rainwater drainage should still be considered the most important function of LID facilities. At the same time, educational level and flood experiences may not affect the public's WTP. This article can provide a reference for cities that would like to implement LID and create a stormwater fee system to adapt to global change.

Key words: discrete choice experiment, flood experiences, low impact development, public preference, willingness to pay

HIGHLIGHTS

- Explorations of public preferences and willingness to pay (WTP) for LID facilities in China.
- Respondents had a significant WTP for LID facilities functions.
- Rainwater drainage should still be considered the most important function of LID facilities.
- Flood experience may not be the direct influencing factor for the public's WTP for LID facilities.
- Education level is not a factor affecting the public's WTP.

GRAPHICAL ABSTRACT



1. INTRODUCTION

1.1. Background

Continuous climatic change and rapid urbanization have led to the frequency of pluvial flooding increasing in cities around the world (Wang *et al.* 2017; Qiao *et al.* 2018; Azari & Tabesh 2022; Espinal-Giron *et al.* 2023). This has not only challenged conventional piped drainage systems, but has also affected people's lives and the sustainable development of the economy (Wang *et al.* 2017; Takeuchi *et al.* 2018; Meng *et al.* 2019; Yang *et al.* 2023). Green infrastructure (GI), which deals with stormwater runoff by mimicking natural processes, has been suggested as an alternative to conventional piped drainage systems for decades (Zalejska-Jonsson *et al.* 2020; Taguchi *et al.* 2020; Dong *et al.* 2023; Wang *et al.* 2023). GI-based approaches have different explanations in different parts of the world, e.g., low impact development (LID) in the United States (Qiao *et al.* 2019), sustainable urban drainage systems in the United Kingdom (Eckart *et al.* 2017), and water-sensitive urban design in Australia (Qiao *et al.* 2018). In this article, we refer to all GI-based approaches as LID, which was intended to preserve or restore predevelopment hydrologic conditions in an urban watershed by retaining and infiltrating stormwater close to its source (Bhaskar *et al.* 2016; Eckart *et al.* 2017; Liu *et al.* 2021). LID facilities, including rain gardens, bio-retention swales, retention and detention ponds, are all types of GI (Danfoura & Gurdak 2016; Liang *et al.* 2020; Darnthamrongkul & Mozingo 2021; Rezaei *et al.* 2021). Many cities have implemented LID facilities in demonstration zones in recent decades to reduce the impact of urban flood damage (Shafique & Kim 2017; Chang *et al.* 2018; Liu *et al.* 2021; Suresh *et al.* 2023). However, LID facilities have not been widely implemented in practice (Zalejska-Jonsson *et al.* 2020; Qiao & Randrup 2022). A lack of funding is thought to be one of the main challenges (Bowman *et al.* 2012; Zhan & Chui 2016).

Public participation in paying for the implementation and maintenance of LID facilities is considered to be an important solution to this challenge (Ding *et al.* 2019; Wang *et al.* 2020; Novaes & Marques 2022). Public payment of stormwater fees has been implemented in many developed countries (Veiga *et al.* 2021; Qiao & Randrup 2022; Zhang *et al.* 2023). For example, in Germany, since the 1990s, several municipalities have introduced stormwater fees based on the polluter-paying principle (Novaes & Marques 2022). In the United States, users have been charged to ensure the cost of implementing and maintaining urban drainage systems (Campbell *et al.* 2016). However, in developing countries, stormwater fees have not yet been implemented (Ding *et al.* 2019; Wang *et al.* 2020; Qiao & Randrup 2022). Most developing countries still need to invest heavily in water and sanitation service infrastructure to close the 'access gap' in these services (Trémolet 2011; United

Nations 2015). Therefore, it is important to understand public preferences and willingness to pay (WTP) for LID facilities in developing countries.

1.2. Literature review

1.2.1. Different functional preferences affect the public's WTP

The public has been shown to have different preferences for LID facilities' functions. Both environmental benefits (Zhang *et al.* 2020) and recreational function (Wang *et al.* 2022a) have been reported as influencing the public's WTP (Derkzen *et al.* 2017; Macháč *et al.* 2022). Regarding the rainwater drainage function, residents had different preferences in WTP. Residents in studies by Wang *et al.* (2022b) and Zhang *et al.* (2018) in China were not interested in the rainwater drainage function, while in the study by Ando *et al.* (2020), the public's WTP for flood reduction was significant in Chicago and Portland, USA. Meanwhile, the amount of the public's WTP for their preferred LID facilities' functions was varied. Brent *et al.* (2017) found that the public in Melbourne and Sydney, Australia, would be willing to pay $5.60/month to prevent flash flooding, while Ando *et al.* (2020) found that the public in Chicago and Portland, USA, would like to pay $0.50/month to reduce flooding. Ureta *et al.* (2022) found that the public in South Carolina, USA, would like to pay $3/month to improve water quality, while Ando *et al.* (2020) reported that the amount was $0.47/month.

Regarding recreational and educational function, Wang *et al.* (2022b) found that for the Chinese residents, recreation and education were more likely to receive financial support than stormwater treatment and planting aesthetics. Verlicchi *et al.* (2018) found that each household in Ferrara, Italy, would be happy to pay $51/year for recreational benefits, while in the study in South Carolina, USA, by Ureta *et al.* (2022), the amount was $3.9–4.9/year. Wang *et al.* (2022b) found that each household would be willing to pay $14.8/year for education in four China cities. In addition, there were also other functions preferred by the public. For example, residents of Melbourne, Australia, were reported as being happy to pay $195/year and $42.7/year to improve the health of local creeks and reduce peak urban temperatures, respectively (Brent *et al.* 2017). South Carolina residents would like to pay $12.50–$42.90/year for the nearest pond with buffer vegetation and wildlife (Ureta *et al.* 2022).

Since the results of WTP were different and their preference for different LID functions influenced the amount of WTP, it is worthwhile to continuously study public perceptions on LID facility functions.

1.2.2. Different factors affecting public WTP

Sociodemographic characteristics such as age, gender, and education level affect public WTP. For example, younger respondents with lower incomes have higher WTP compared to older respondents (Zhang *et al.* 2020), and they have higher WTP to live in an environment with high-quality LID facilities (Mell *et al.* 2016). In a study in Hong Kong, older people had extremely high WTP for green spaces that provided places for outdoor recreation, which might be related to high-density living conditions (Lo & Jim 2010). Some researchers have reported that women were slightly less sensitive to price in the medium-sized Czech city of Liberec, meaning that they had higher WTP for their preferred attributes than men (Macháč *et al.* 2022). However, some studies found women consistently had lower WTP values. People with a bachelor's degree were slightly less price sensitive and had higher WTP for their preferred attributes (Macháč *et al.* 2022).

Meanwhile, experiencing special events like flooding could influence the public's WTP. Wang *et al.* (2017) found that the experience of urban flooding significantly raised respondents' perceptions of the possibility of urban flooding in their city and the severity of the damage. As reported, Sydney residents would be happy to pay $60/year to reduce flooding (Brent *et al.* 2017). However, it was also found that despite experiencing different flooding histories in three towns of Dundas in Hamilton, Ontario, and Canada communities, there were no differences in payment behaviors for green stormwater facilities (Drescher & Sinasac 2020).

Austrian psychologist Alfred Adler proposed that what happens in one's past has no bearing on future choices (Bischof *et al.* 1970). Adler's theory of purpose implied that people's current choices were not influenced by past experiences, but rather they made choices toward a purpose (Lee 2022). The public's need and purpose for LID facilities may be the real reason for the difference in their choices. As shown earlier, many conflict studies exist regarding public preference and the influencing factors of WTP. It indicates that sociodemographic characteristics, public perceptions and attitudes, and experience of flooding may not necessarily influence public choices and WTP.

In this article, two research gaps were identified: (i) Are the public no longer focused on preferences and concerns around LID facilities' stormwater treatment capacity? (ii) Do past flood experiences really influence public choices and attitudes to LID facilities?

On the basis of the discrete choice experiment (DCE) method, we selected four functional attributes of LID facilities and conducted a comparative case study of two Chinese pilot sponge cities. We hope this article can provide strategic suggestions for the design and configuration of LID facilities and for stormwater fee systems in developing countries.

2. CASE SELECTION

In this article, we selected the pilot cities Zhengzhou and Hebi in Henan Province, China, as the case cities (Figure 1). They were chosen for the following reasons. On the one hand, they have some similarities. (i) Both case cities were pilot sponge cities and have built many LID facilities. In April 2014, the Chinese central government started the Sponge Cities initiative to alleviate urban rainfall and flooding problems (Xia *et al.* 2017; Qiao *et al.* 2019; Leng *et al.* 2020), with special funding provided for 16 selected pilot cities. Hebi is 1 of the 16 selected national pilot sponge cities. In 2018, Zhengzhou was selected as the Henan provincial-level pilot sponge city. (ii) Both cities are located in the same temperate monsoon climate zone. The annual average precipitation was 632 mm in Zhengzhou and 600 mm in Hebi. (iii) Zhengzhou and Hebi all experienced a flooding event in July 2021. From 17 to 20 July 2021, Zhengzhou city received 617.1 mm of rainfall in 3 days, and the extraordinarily heavy rainfall caused serious casualties (380 people dead) and property damage (a direct economic loss of about 40.9 billion RMB) (Li *et al.* 2023). Due to severe waterlogging in the urban area, many subway stations were flooded, and the entire Zhengzhou subway network was suspended from operation. The accumulated rainfall in the Jinshui District was close to 700 mm, and in the Zhengdong New District, it was close to 500 mm. Similarly, from 17 to 22 July 2021, Hebi experienced the most extreme rainfall in its history, with an average precipitation of 562.1 mm. The flood killed 33 people and caused a direct economic loss of about 100 million RMB. On the other hand, they were comparable. There are differences in the scale and level of sponge city construction between the two cities. It is worth noting that during the flooding disaster, compared with Zhengzhou, in Hebi, the flooding damages mainly took place in rural areas. Thus, it is valuable to compare residents' perceptions of the two cities toward the preferences for the construction of LID facilities.

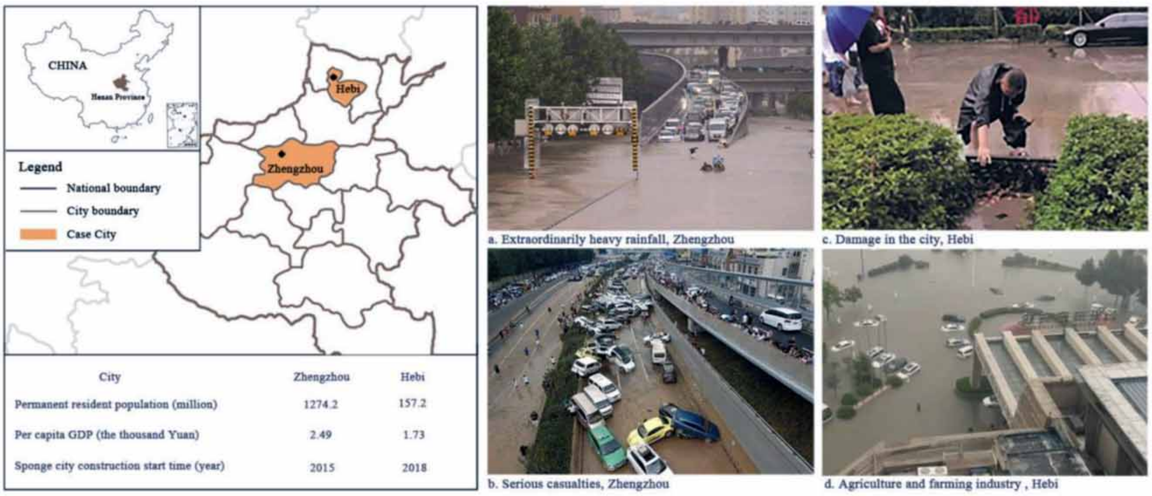


Figure 1 | Illustration of pilot cities.

3. DISCRETE CHOICE EXPERIMENT AND MODEL SPECIFICATION

3.1. Questionnaire design

3.1.1. Attributes and levels

In this article, we defined four attributes of LID facilities based on the literature review, policy interpretation, and expert interviews. The four attributes included rainwater drainage capacity, rainwater utilization, recreation and entertainment, and landscape environment (Table 1). The implementation of LIDs may reuse rainwater in cities

Table 1 | Attributes and level values of LID facilities

Attributes	Function configuration scheme (horizontal value)
Rainwater drainage	Rainwater drainage 30% Rainwater drainage 50% Rainwater drainage 70%
Rainwater utilization	After purification, discharge is not reused After purification, water reuse for agricultural water areas and general landscape After purification, water can be used for general industrial water area and recreational water area
Recreation and entertainment	Provides recreation and entertainment functions No recreation or entertainment function.
Landscape environment	Single landscape green environment. Rich landscape green environment. Rich and sustainable landscape environment.
Payment	(Zhengzhou) \$0, \$1.5, \$4.4, \$7.38, \$10.3, \$13.3, \$17.7 (Hebi) \$0, \$0.7, \$1.5, \$2.2, \$2.9, \$3.7, \$4.4

Note: \$1 = 6.78 RMB.

through harvesting and infiltration (Ahiablame *et al.* 2012; Yuan *et al.* 2022) and is also an important source for water reuse (Dhakal & Chevalier 2016, 2017). Thus, rainwater drainage capacity and rainwater utilization were selected as two main attributes. Recreation and entertainment is another function provided by LID facilities (Meenar *et al.* 2020; Wang *et al.* 2022b). The LID facilities can increase the biodiversity of the community environment to some extent (Filazzola *et al.* 2019). The potential benefits of these green spaces can affect the health and safety of local residents. Thus, recreation and entertainment, and landscape environment were selected as two main attributes. Each attribute includes two or three levels.

In addition, a cost attribute was associated with each plan scenario to determine the responders' WTP. The cost attribute refers to the sum each household would need to pay for LID facilities per year. The amount of stormwater fees was set according to the actual national conditions of China, the urban development of the research sites, and the proportion of population and relevant factors. The final cost for Zhengzhou was \$1.5–\$17.7, and the cost for Hebi was \$0.7–\$4.4. The status quo cost 0 was assigned the lowest level utility, and for all attributes, there was an 'opt-out' option.

3.1.2. Choice sets

An orthogonal experimental design was conducted by using the Ngene1.2 software, which was specifically designed for the DCE questionnaire design. In total, 48 choice sets were generated. In the choice design, the D error and A error of Zhengzhou were 0.003448 and 0.043235, respectively, while the D error and A error of Hebi were 0.005629 and 0.037635, respectively. This indicated that the software had completed selecting the optimal design. The 48 choice sets were then grouped into 12 versions of the questionnaires, with each questionnaire version including four different choice sets. A choice set contained three options, with one status quo option. In addition, illustrations were provided to facilitate the respondents' understanding of the options. A sample choice set is shown in Figure 2.

3.1.3. Questionnaire design

The questionnaire consisted of three parts. The first section introduced urban flooding, the concept of a sponge city, and the functions of LID facilities to facilitate respondents' familiarity with the subsequent attribute selections. Questions were asked about respondents' knowledge of sponge cities, flooding experience, the community LID facility situation, rainwater pollutants, and their willingness to live in a community with LID facilities. The second part consisted of four choice sets. Each choice set contained three options, two alternatives, and one status quo option. Each alternative consisted of four different combinations of attributes and levels. All attributes and levels were presented with images and text descriptions to facilitate ease of understanding for the respondents. The third section asked for respondents' demographic and socioeconomic information (gender, age, education, occupation, monthly income, housing situation, and length of residence).

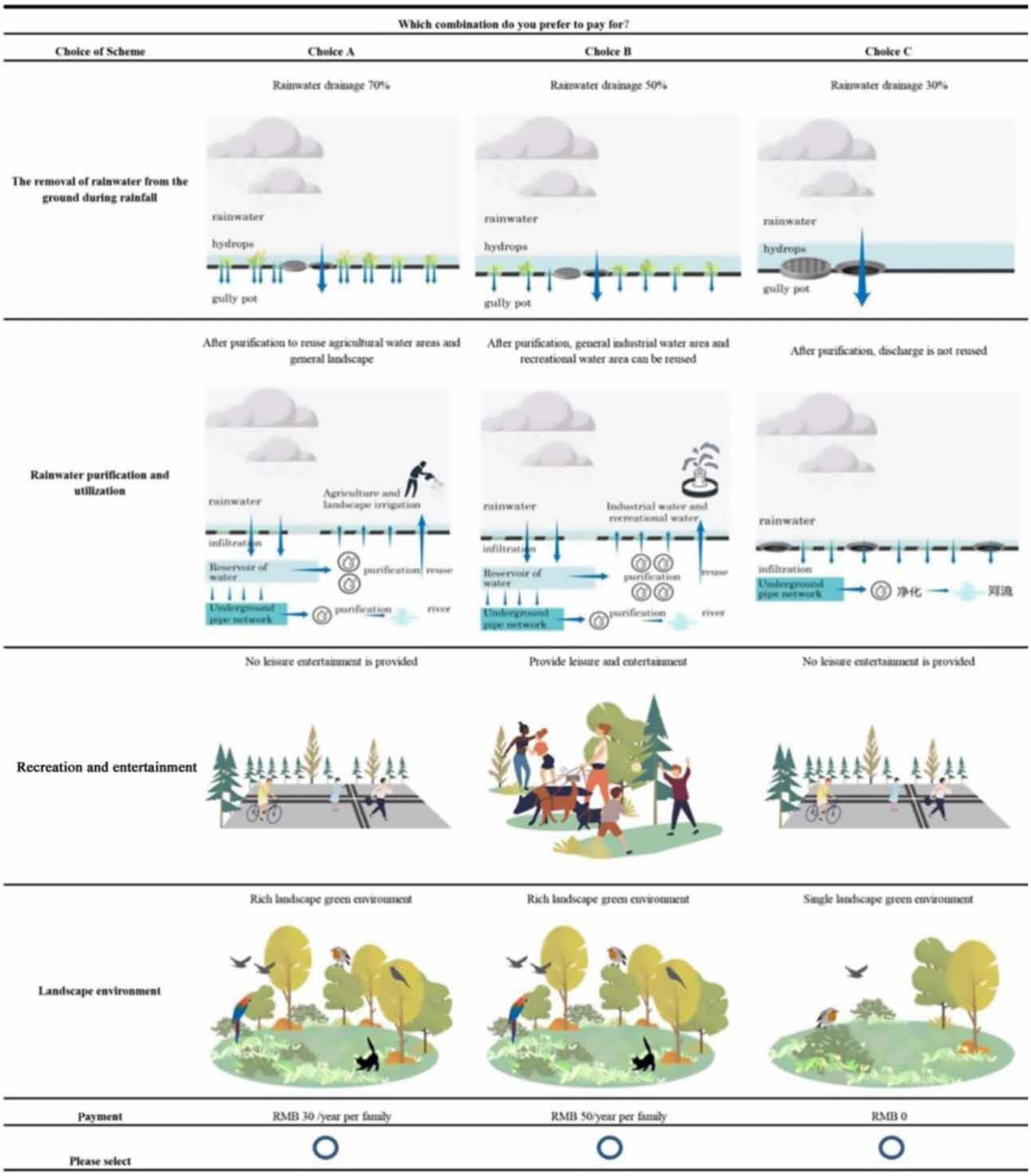


Figure 2 | A sample choice set of the LID functions. *Note:* $1 = 6.78 RMB.

3.2. Questionnaire survey

The face-to-face interview surveys were conducted by 12 trained researchers from 1 to 13 August 2022. The survey locations included city plazas, shopping malls, residential areas, and parks with LID facilities in Zhengzhou and Hebi. The purpose of the survey and the meaning of attributes and levels in the questionnaire were explained to adult respondents, and they were given sufficient time to think and answer the questions. Researchers' phones were used to collect data via online e-questionnaires. In total, 958 valid questionnaires were collected in Zhengzhou and 646 valid questionnaires were collected in Hebi.

3.3. Model specification

DCE is based on the random utility models, in which respondents choose from the available values of a hypothetical good (Train 2009), analyzing respondents' preferences for different options; respondent n makes a choice based on the utility maximization principle, and the utility U_{nj} is obtained by respondent n from j options.

$$U_{nj} = V_{nj}(\beta_n) + \varepsilon_{nj} = \delta \times \text{ASC} + \propto'_n \times X_j + \gamma_n \times (-\text{pay}_j) + \varepsilon_{nj} \tag{1}$$

U_{nj} is divided into a linear representation of the utility and a random part ε_{nj}. The representation utility is a linear function consisting of a substitution for a specific constant (ASC), a vector of LID-related attributes ($X =$ [rd ru ed le]), and the payment attribute (pay_j). rd refers to rainwater drainage, ru refers to rainwater utilization, ed refers to entertainment design, and le refers to landscape environment. The individual-specific parameters are denoted as $\beta_n = (\delta, \alpha_n, \gamma_n)$, which denotes the degree of preference for each attribute.

ASC is a dummy variable defined as 1 when the payment for the alternative (status quo option) is 0 and is 0 otherwise; it acts as a proxy for the baseline utility of the status quo (Kosenius 2010). In addition, to analyze the heterogeneity of WTP for LID attributes, the individual-specific variables (Z) with ASC interaction were used to improve the explanatory power of the model. In this case, the representative utility has been specified as follows:

$$V_{nj}(\beta_n) = \text{ASC} \times (\delta_0 + \delta'_n Z_n) + \propto'_n \times X_j + \gamma_n \times \text{pay}_j \tag{2}$$

where Z denotes respondents' perceptions, attitudes, and demographic characteristics, and δ denotes the systematic heterogeneity of LID attribute preferences.

According to the estimated utility function with the continuous probability density function (Train 2009), the respondents' WTP for each marginal change in the attribute can be obtained using the full calculus equation from the following equation:

$$\text{WTP}_{ni} = -(\partial V_{ni}/\partial x_i)/(\partial V_{ni}/\partial \text{pay}_i) = \alpha_n/\gamma_n \tag{3}$$

WTP_{ni} denotes the corresponding attribute x_i, which is defined by the marginal rate of substitution between the nonmonetary and payment attributes. Depending on a particular choice in a particular scenario, it can be found using the following equation:

$$\text{CS}_n = (\alpha'_n \times X_j^1 - \alpha'_n \times X_j^0 - \delta - \delta'_n Z_n)/\gamma_n \tag{4}$$

where the value X_j^0 denotes the level of the attribute in the status quo, and X_j^1 denotes the level of the attribute in the specified LID scheme.

4. RESULTS

4.1. The sample

Table 2 shows the descriptive statistics for the valid samples from Zhengzhou and Hebi. The majority of respondents in Zhengzhou and Hebi were females, 56.2 and 63.5%, respectively. The average age of respondents in Zhengzhou was 30–40 years, while the average age of respondents in Hebi was 41–65 years. Zhengzhou had a higher proportion of higher-income groups than Hebi. A total of 23.4% of respondents in Zhengzhou earned \$448–746/month, while only 10.7% of respondents in Hebi were at the same level. A total of 43.3% of respondents in Zhengzhou had a bachelor's degree, while 41.8% of respondents in Hebi had a high school degree, and more than half of respondents in both Zhengzhou and Hebi had lived in the city for more than 5 years.

4.2. Model estimation

Since the LID facility attributes and levels were designed as discrete variables, it was necessary to take one of the parameters as the benchmark in the model simulation. For the convenience of model estimation, 30% of the rainwater was set to be excluded, no reuse or recreational activities were provided, and a single environment was used as the reference. The ASC and WTP price index parameters were fixed parameters, allowing us to obtain the estimation results. Four LID facility, function index parameters were random parameters obeying normal distribution; the model estimation results are shown in Table 3.

In general, the chi-square statistics for Zhengzhou and Hebi were significant. This indicates that these two groups of models were statistically significant. In terms of the standard deviation of random parameters, all

Table 2 | Descriptive statistics of the sample Zhengzhou ($N = 958$) and Hebi ($N = 646$)

		Mean		Standard deviation (S.D.)	
Variables	**Description**	**Zhengzhou**	**Hebi**	**Zhengzhou**	**Hebi**
1. Do you know about sponge cities?	Yes = 1; no = 0	0.3350731	0.7260062	0.4722626	0.4463514
2. Have you experienced flooding?	Yes = 1; no = 0	0.7797495	0.6346749	0.414632	0.4818943
3. Does the community promote LID?	Yes = 1; no = 0	0.0835073	0.6114551	0.276792	0.4877972
4. Distance of residence from nature.	Within 1 km = 1; 1–3 km = 2; 3–5 km = 3; more than 5 km = 4	2.34238	1.868421	0.980318	1.003726
5. Which is a greater cause of pollution, city sewage or rainwater?	Rainwater pollution is worse = 1; urban sewage is worse = 0; unsure = 0	0.0991649	0.1981424	0.2990394	0.3989089
6. Does the community have LID?	Yes = 1; no = 0	0.131524	0.620743	0.3381491	0.4855781
7. What pollutants does rainwater carry?	If A (suspended impurities), B (nitrogen, ammonia chemistry, organic pollutants), and C (pathogenic microorganisms) are selected, the seventh option = 1; otherwise = 0	0.1962422	0.1873065	0.3973613	0.3904597
8. Can LID mitigate rain and flooding?	Yes = 1; no = 0	0.5803758	0.8034056	0.4937552	0.397731
9. Willingness to live in a community with LID?	Yes = 1; no = 0	0.756785	0.9009288	0.429248	0.2989891
10. Gender	Male = 0; female = 1	0.561587	0.634675	0.4964518	0.4818943
11. Age	18–29 years = 1; 30–40 years = 2; 41–65 years = 3; above 65 years = 4	1.803758	2.309598	0.8583638	0.9318486
12.Education	High school/junior college and below = 1; college = 2; bachelor = 3; master and above = 4	2.34238	1.941176	0.9444881	0.9062785
13.Occupation	School students = 1; company employees = 2; private professionals = 3; government workers = 4; Others = 5	3.164927	3.716718	1.589523	1.516401
14.Monthly income	Under \$224 = 1; \$224,448 = 2; \$448,746 = 3; \$746,1044 = 4; above \$1044 = 5	2.989562	2.366873	1.345256	1.194335
15. Housing situation	Renting = 0; living in your own house (including living with your family) = 1	0.707724	0.95356	0.4550458	0.2105983
16. Length of residence	Within 1 year = 1; 1–3 years = 2; 3–5 years = 3; more than 5 years = 4	3.070981	3.633127	1.107198	0.7973319
Rainwater drainage	Percentage reduction in rainwater drainage	1.427975	1.430341	0.7529325	0.7453893
Rainwater utilization	Percentage of rainwater utilization	2.0762	1.952012	0.7136799	0.7650428
Recreation and entertainment design	Whether to provide recreation and entertainment functions	1.339248	1.393189	0.4737016	0.4888367
Landscape environment	Degree of landscape environment	1.58977	1.71517	0.8587735	0.9095457
Payment	Annual per household payment for rainwater	86.1691	21.17647	24.83468	7.528332

indicators passed the 1% significance test. This suggests that the respondents' preferences for these facilities were significant in terms of heterogeneity and randomness. Meanwhile, the mean value of WTP in the fixed parameter was significantly negative. This means increasing expenditure reduces the utility level of respondents. Respondents tended to want to pay less money to get better utility of LID facilities. This was consistent with theoretical expectations. The mean values of ASC in Zhengzhou and Hebi were significant. These results imply that the public in Zhengzhou and Hebi do not prefer the 'status quo solution'.

Table 3 | Mixed Logit model estimation results Zhengzhou ($N = 958$) and Hebi ($N = 646$)

Variable	Model *Zhengzhou* 1	Model *Hebi 1*	Model *Zhengzhou* 2	Model *Hebi 2*
Fixed parameter				
ASC	−0.5049576* (0.1970054)	1.870516** (0.0159923)	2.001839* (0.5365864)	−0.1428739 (0.8580435)
Payment	−0.0297792* (0.002617)	−0.0356139* (0.0159923)	−0.24805* (0.0021871)	−0.044061* (0.0151395)
ASC × flood experience			−0.9879207* (0.2605255)	
ASC × promotion activities			−1.69966* (0.5333029)	
ASC × distance (the distance of their community from the natural environment)				0.4112988** (0.1806772)
ASC × LID community (Does the community have LID facilities?)			1.386959* (0.3590994)	
ASC × attitude (Is it believed that sponge cities can alleviate flooding?)			−1.059392* (0.2889641)	
ASC × LID community (Would you like to live in an LID community?)			−2.501959* (0.3085308)	−3.2148* (0.6132224)
ASC × age			0.8977065* (0.1423852)	1.555057* (0.2480725)
ASC × education			−0.5370086* (0.1378054)	
Random parameters				
Mean of rainwater drainage (50% reduction)	1.794951* (0.184344)	2.607429* (0.3977816)	1.6335446* (0.1505283)	2.31203* (0.361262)
Mean of rainwater drainage (70% reduction)	3.041563* (0.2694008)	4.348377* (0.4285393)	2.769983* (0.225946)	3.896945* (0.5405313)
Mean of rainwater utilization (purified and reused for agricultural water areas and general landscape)	1.04229* (0.1772592)	0.4189825 (0.6756434)	0.8172703* (0.1541673)	0.2240941 (0.2704208)
Mean of rainwater utilization (purified and reused for general industrial water areas and entertainment water areas)	1.041752* (0.1659675)	0.6013948** (0.3036771)	0.8053727* (0.1424768)	0.5742905** (0.2662619)
Mean of recreation and entertainment (provide recreation and entertainment functions)	1.385945* (0.176271)	1.640289* (0.2986857)	1.242349* (0.1449826)	1.551529* (0.2778523)
Mean of LE (rich green environment)	0.9427699* (0.2036953)	3.167724* (0.3127037)	0.712157* (0.1730344)	2.938919* (0.3869335)
Mean of landscape environment (rich and sustainable landscape)	1.701837* (0.2295538)	3.705824* (0.4575799)	1.486856* (0.1909817)	3.455138* (0.438551)
S.D. of rainwater drainage				
50% reduction	2.700685* (0.2674931)	3.120502* (0.6117063)	1.848703* (0.2189966)	2.657423* (0.4947831)
SD of rainwater drainage				
70% reduction	2.919337* (0.3638755)	7.068243* (1.191705)	2.60488* (0.2905772)	5.837201* (0.9104185)
SD of rainwater utilization (purified and reused for agricultural water areas and general landscape)	1.930769* (0.2542443)	2.977222* (0.4872668)	1.692023* (0.2059231)	2.672012* (0.4302596)
SD of rainwater utilization (purified and reused for general industrial water areas and entertainment water areas)	1.822999* (0.3027656)	3.193479* (0.5982557)	1.503542* (0.2860728)	2.683666* (0.4769722)

(*Continued.*)

Table 3 | Continued

Variable	Model *Zhengzhou* 1	Model *Hebi 1*	Model *Zhengzhou* 2	Model *Hebi 2*
SD of recreation and entertainment (provide recreation and entertainment functions)	2.556102* (0.2475502)	3.452008* (0.5081846)	1.734791* (0.2130131)	3.032052* (0.4233742)
SD of landscape environment (rich green environment)	3.062244* (0.3280666)	2.937294* (0.7274985)	2.442133* (0.2572083)	2.806887* (0.556101)
SD of landscape environment (rich and sustainable landscape)	3.489441* (0.3278855)	4.174208* (0.7409312)	2.799639* (0.2732084)	3.466103* (0.5766537)
Log likelihood	−2938.0921	−2018.0289	−2756.4132	−1957.1693

Note: *$p < 0.01$, **$p < 0.05$.

Among the random parameters, the mean values for rainwater drainage, rainwater utilization, recreation and entertainment, and landscape environment were all positive. The results implied that the improvement of these four random parameters could improve the utility level of respondents. In addition, the mean coefficients of each evaluation index reflect the relative preference of respondents for different LID facilities' ecological service functions. For example, in Zhengzhou, the mean coefficients of 50 and 70% for the stagnant water removal rate were 1.795 and 3.042, respectively, implying that the respondents' preferences for increasing the stagnant water removal rate from 30 to 70% was about 1.69 times that of the preference for a change from 30 to 50%.

In Zhengzhou, social demographic information, such as respondents' monthly income, length of residence, gender, and housing conditions, did not affect the respondents' choices. Seven factors seemed to influence Zhengzhou respondents' WTP and their choices. The willingness to live in a sponge city community had the greatest impact on the respondents' payment, with a characteristic coefficient of −2.501959. The second was whether the community had promoted the sponge city concept, with a characteristic coefficient of −1.69966. Those who knew of the sponge city concept had higher WTP. Whether or not they had experienced flooding also had an effect, with a characteristic coefficient of 0.9879207, indicating that flooding experienced could result in a higher WTP. Respondents who believed that sponge cities could mitigate flood disasters had a higher WTP, with a characteristic coefficient of −1.059392. Moreover, in Zhengzhou, older respondents had lower WTP, and respondents with higher education levels had lower WTP.

In Hebi, three factors had the greatest influence on public WTP. It was found that the further the community was from the natural environment, the more the public was willing to pay. Whether they were willing to live in a community with LID facilities had the greatest influence on public WTP, with a characteristic coefficient of −3.2148. Those willing to live in a community with LID facilities had higher WTP. In comparison, it was interesting to find that whether or not they had experienced flooding did not affect public WTP in Hebi. In addition, as with Zhengzhou, the older respondents in Hebi had lower WTP, with a coefficient of 1.555057.

4.3. WTP estimation

In Zhengzhou, the function of rainwater drainage had a significant effect on respondents' utility. The households would be happy to pay $14.59/year for improved rainwater drainage, and these estimates were statistically significant at the 1% level. There was no significant difference between the two levels of public preference for the ability to purify and reuse rainwater. Regarding the availability of recreation and entertainment activities, the public would be willing to pay $6.65/year/household. These estimates were statistically significant at the 1% level. Furthermore, the public was willing to pay $8.16/year/household for access to higher community environmental opportunities, and these estimates were statistically significant at the 1% level (Table 4).

In Hebi, the function of rainwater drainage also had a significant impact on the utility of respondents. Households were willing to pay $17.44/year for rainwater drainage, and these estimates were statistically significant at the 5% level. Respondents were not interested in rainwater purification and reuse, but they were willing to pay $14.86/year/household to live in a better community environment. Also, they would like to pay $6.58/year/household for the availability of recreational activities, which was estimated to be statistically significant at the 5% level (Table 4).

Table 4 | Marginal willingness to pay attribute level and status quo

Choice (mean WTP)	Zhengzhou	Hebi
Constant	−16.95672* (6.193337)	52.52207** (29.83622)
Rainwater drainage 50%	60.27532* (6.187779)	73.21378*** (32.06785)
Rainwater drainage 70%	102.1372* (9.540904)	122.0977*** (53.14298)
After purification water reuse for agricultural water areas and general landscape	35.00064* (5.584728)	11.76457 (10.83526)
After purification, water reuse for general industrial water area and recreational water area	34.98253* (5.565661)	16.88652 (10.45819)
Provide recreation and entertainment	46.54071* (5.791197)	46.05753*** (20.83587)
Rich landscape and green environment	31.65867* (6.918104)	88.94627*** (38.43701)
Rich and sustainable landscape environment	57.1485* (7.511897)	104.0555*** (43.28533)

Note: $*p < 0.01$, $**p < 0.1$, $***p < 0.05$.

5. DISCUSSION

5.1. Public preferences on LID facility functions

5.1.1. Rainwater drainage capacity

Based on our research, the rainwater drainage function is still the most basic and important LID facility function prioritized by the public. In both case cities, residents' WTP for rainwater drainage capacity was significantly higher than other attributes. In fact, rainwater drainage capacity has always been the top priority for government officials and was viewed as the most important LID benefit in some studies (Wang *et al.* 2022b). In some areas where flooding was common, respondents were willing to pay more for flood protection than for any secondary benefit (Thistlethwaite *et al.* 2018). However, this has not been the case in all studies. Residents in Nanjing, China, had a higher preference for educational programs (MWTP = $19.46 per year) than for improved flood risk management facilities ($8.03-$12.77) (Zhang *et al.* 2019). Similarly, in Chicago, a 10% reduction in flooding ($7.2/year) had a low but significant WTP, and the public did not appear to have a higher preference for flood reduction (Ando *et al.* 2020). The reason for the differences in these research results may be that the public's cognition of the functions of LID facilities varies in different regions. Some regions may lack promotion of the capacity of rainwater drainage of LID facilities, leading to the public being attracted to directly profitable attributes such as recreation and entertainment benefits (Tanaka *et al.* 2022). Thus, it is necessary to highlight the basic and important rainwater drainage capacity of LID facilities in any future promotion of the sponge city concept.

5.1.2. Recreation and entertainment, and landscape environment

The public in Zhengzhou and Hebi was willing to pay about $6.6/year for recreation and entertainment facilities. This demonstrated the significance of LID facilities in terms of entertainment value to the public. This result matched with some existing studies. For example, Deely & Hynes (2020) found that almost half of the respondents placed scenic value and recreational value among the most important benefits. Wang *et al.* (2022b) also found that people were willing to pay $14.80/year for entertainment. We speculate that recreation and entertainment is a function that the public can directly use and gain value from, so the public is willing to pay for recreation and entertainment (Tanaka *et al.* 2022).

The public in Hebi ($14.86/year) has a higher WTP than in Zhengzhou ($8.16/year) in terms of community landscape environment. This may be because the public in Hebi had received greater landscape benefits from LID facilities than those in Zhengzhou. This is similar to the findings of Meenar *et al.* (2020), who found that the key factor in the acceptance of bio-pits by residents was predicated on aesthetic appearance (Meenar *et al.* 2020). LID facilities located in parks and playgrounds were found to be more attractive to the public because of their entertainment and aesthetic value. The public's understanding of the benefits of a facility is often direct, so LID facilities should be designed in such a way that their benefits are clearly understood and more aesthetically pleasing.

5.1.3. Rainwater utilization

Many studies have reported that the public was willing to pay for rainwater utilization. It has been reported that the public in Chicago was willing to pay $294/year per household to improve water quality and the public in

Portland volunteered their time to improve water quality and aquatic habitat (Ando *et al.* 2020). Seventy-one percent were willing to pay higher annual local taxes to reduce the risk of sewage spills into rivers and lakes (Veronesi *et al.* 2014). Citizens valued the improvement of water quality and were willing to pay $40/year to avoid further degradation of streams (Londoño Cadavid & Ando 2013). These results differed from those of our study. The public was reluctant to pay for rainwater utilization in both Zhengzhou and Hebi. Rainwater utilization can improve water quality and conserve resources to some extent, but the process is usually performed out of sight of the public, which may be one of the reasons why the public is reluctant to pay for it. Another reason may be the idea that the public is not actually unwilling to pay for this function, but that they are unsure of what exactly this function can do for the public and what kind of life improvements it can directly bring (Tanaka *et al.* 2022). The public needs to have some direct benefit from this function in order to judge how much they are willing to pay for it.

5.2. Influencing factors for WTP

5.2.1. Flood experience

Researchers have found that flooding may increase the public WTP. For example, Chui & Ngai (2016) found that respondents in flooded areas had higher WTP. Torgersen & Navrud (2018) found that the public with flooding experience had a sense of insecurity, which meant that they were more prepared to pay to avoid future flooding. Chinese residents who experienced the major flooding events in the year of 1998 were more interested in mitigating the problems caused by rain and weak drainage systems (Zheng *et al.* 2022). However, our results were not in line with the previous studies. Although both Zhengzhou and Hebi experienced heavy rainfall, leading to pluvial flooding, the flood experience only positively affected public WTP in Zhengzhou. This indicates that flooding experience may not be a direct influencing factor for public WTP. This may be interpreted as the result of the excellent functioning of LID facilities in Hebi. Residents in Hebi have already enjoyed the benefits of LID facilities, while most residents in Zhengzhou have not yet enjoyed them. Zhengzhou residents who have experienced floods need LID facilities to help them complete their drainage purposes. It may suggest that the public made choices toward a purpose rather than being influenced by past experiences, according to Adler's theory of purpose as mentioned in Section 1.

5.2.2. Educational level

It has been reported that educational level affected public WTP (Wang *et al.* 2017, 2020; Odonkor & Adom 2020), and normally those with a higher education level had a better understanding of the benefits of LID and had higher WTP. However, in our study, the education level of the public in Hebi did not affect their WTP, while the education level of the public in Zhengzhou negatively affected their WTP. This could be due to education levels representing cognition, which in turn affects public WTP (Iles *et al.* 2022). The excellent construction of LID facilities in Hebi leads to a high level of public cognition, so their WTP is not affected by the level of education. This needs to be further studied in the future.

6. CONCLUSIONS

In this article, we used a DCE to compare public WTP for four types of LID facility functions in the sponge cities of Zhengzhou and Hebi, China. We found that the public had positive attitudes to LID facilities in their living environment and were willing to pay for their rainwater drainage capacity, recreation and entertainment, and landscape environment benefits. Positive WTP from the public is based on a clear need for LID facilities' value. Even though the public may be influenced by past flooding experiences, their choices are driven by the need to access a particular feature of LID facilities to meet the current needs of the public. The public will make choices based on their own direct experiences and perceptions, but cognitive biases can lead to a mismatch between needs and the functional design of LID facilities. Therefore, more consideration should be given to the needs of the public when building LID facilities and deciding stormwater fees.

This study also suggests that rainwater drainage should still be considered an important functional measure of LID facilities, and LID facility features should be designed to be more visible and aesthetically pleasing. At the same time, the public's cognitive education about the benefits of LID facilities should be increased. It is hoped that this study can provide a reference for LID facility construction in sponge cities so that it can play a better role in adapting to global climate change.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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