Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2014.964327

56 (2015) 2817–2823
December

Taylor & Francis
Taylor & Francis Group

Cost–effectiveness analysis on LID measures of a highly urbanized area

Zhenliang Liao*, Hao Chen, Fei Huang, Huaizheng Li

United Nations Environment Program-Tongji Institute of Environment for Sustainable Development, College of Environmental Science and Engineering, Tongji University, 1239 Siping Road, Shanghai 200092, China, Tel. +86 2165981650; Fax: +86 2165986313; email: zl_liao@tongji.edu.cn (Z. Liao), Tel. +86 131 6255 6627; email: chenhao_722@163.com (H. Chen), Tel. +86 188 0179 6499; email: andrewhuang@yeah.net (F. Huang), Tel. +86 181 2113 3128; email: lihz@tongji.edu.cn (H. Li)

Received 30 November 2013; Accepted 7 September 2014

ABSTRACT

Studies on the cost–effectiveness analysis on low impact development (LID) measures are demanded for guiding the plan, design, and construction of LID in rapidly and highly urbanized regions, such as many cities in China. In this paper, five single LID measures are given, including bio-retention (BR), infiltration trench (IT), porous pavement (PP), rain barrels (RB), and grass swale (GS), and three composite measures including IT + PP, IT + RB, and PP + RB. A detailed cost–effectiveness analysis on LID is presented using the case of Caohejing in Shanghai, China. Life cycle cost method is adopted to calculate the costs of these measures. Storm recurrence interval, without waterlogging of the drainage system, is applied as the effectiveness of a LID. In consideration of adding LID measures, an approach to calculate the storm recurrence interval without waterlogging is constructed. The aftermath indicates that RB, IT and their combination, IT + RB, are the three most suitable cost–effective measures to the study area.

Keywords: Cost–effectiveness; Low impact development (LID); Urbanized area; Waterlogging

1. Introduction

As a commonly applied measure across the US and Europe to alleviate the negative impacts of urbanization on the hydrological cycle, low impact development (LID) has not been widely used in highly urbanized areas yet, especially in rapidly urbanizing cities, in developing countries like China. In our previous study, an analysis on LID for highly urbanized areas' waterlogging control was demonstrated with the example of Caohejing in Shanghai, China [1]. The aftermath shows that LID practices have significant effects on storm water management in highly urbanized areas. Nevertheless, in consideration of the investment for the plan, design, construction, and operation of LID, good effect does not always mean pretty fit. Thus, the relationship of project cost and its effect should be taken into account comprehensively.

Cost control is one of the main concerns in the process of promoting LID measures [2–4]. For cost estimate, life cycle cost analysis (LCCA) is often adopted to characterize the complicated and varied LID strategies in terms of initial cost, annual operation and maintenance costs, salvage values (SV), and, particularly, the lifespans [5,6]. Under such circumstances, people can compare the equivalent uniform annual costs of the alternatives based on their own service lives [7].

Currently, there are few studies on the cost–effectiveness analysis on LID in highly urbanized regions.

*Corresponding author.

But these kinds of studies are urgently demanded for guiding plan, design, and construction of LID in rapidly and highly urbanized regions, as it happens to be the case in many cities in China. In this paper, a detailed cost–effectiveness analysis on LID is demonstrated based on our previous study using the case of Caohejing in Shanghai. The purpose of this study is to provide a reference to the methodology, comparisons, and parameters for the cost–effectiveness analyses on LID measures in highly urbanized regions.

2. Methodology

2.1. Case description

The Caohejing drainage system is located in Xuhui District, Shanghai, China, which occupies an area of 3.74 km^2. Land use in Caohejing includes green spaces, industrial lands, residential areas, roads, and squares. The system was constructed in 1986. The storm recurrence interval of this system is one year and the runoff coefficient is 0.5. Tianlin pumping station is the flood control pumping station for the system which is equipped with six axial flow pumps that discharge water to the Puhui River. Due to the large quantity of dry weather flow, two additional sewage interception pumps are equipped.

Based on the digital elevation model (DEM) of the system, the whole area is divided into 58 sub-catchments, through ArcGIS, which include 560 nodes and 566 pipes (see Fig. 1).

The US Environmental Protection Agency's storm water management model (SWMM 5.0.022) is selected to track the quantity of runoff generated within each sub-catchment. SWMM is a widely used dynamic precipitation–runoff simulation model for the urban runoff quantity and quality simulation of a single or long-term rainfall incident or long-term [8,9]. The process of developing the model refers to our previous study [1]. The design formula of storm intensity in this study is shown as Eq. (1) [10]:

$$i(\mathrm{mm/min}) = \frac{9.45 + 6.7932\,\lg P}{(t + 5.54)^{0.6514}} \tag{1}$$

where i is storm intensity, mm/min; P is storm recurrence interval, year; and t is rainfall duration, min.

Area of LID practices accounts for 9.30–15.20% of each sub-catchment. We analyzed the effectiveness of the five LID measures including bio-retention (BR), infiltration trench (IT), porous pavement (PP), rain barrels (RB), and grass swale (GS) [1]. This paper emphasizes the cost–effectiveness analysis on these measures and some of their compositions, i.e. IT + PP, IT + RB, and PP + RB. In each composition, the area proportion of each measure is equal to the whole LID area, i.e. 50%.

Costs' calculation for LID measures consists of initial case cost (ICC), cost of operation and maintenance (COM), and SV, as figure up from the whole life cycles. The drainage system's storm recurrence interval without waterlogging is implemented as the effectiveness of

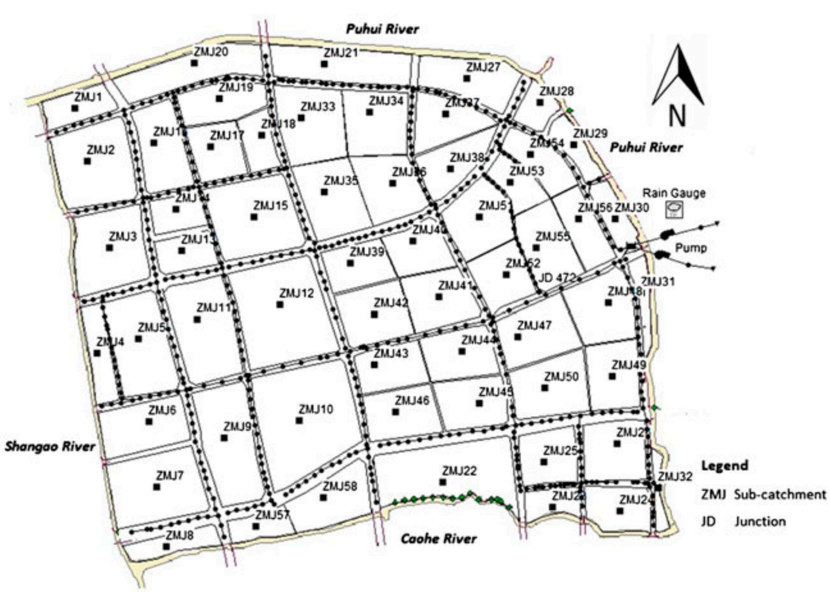

Fig. 1. Sub-catchments of the study area.

a LID measure, i.e. after the LID measure is added, the area survives a bigger storm without waterlogging than before, and the tolerable bigger storm recurrence interval is regarded as the effectiveness.

2.2. Methods for costs' calculation

The financial data are collected by our estimation and comparison with comparable literatures [11–13].

2.2.1. For ICC

Initial case cost, which is abbreviated as ICC, only appears in the initial phase of construction. It includes the construction cost, occupancy cost of land, design and planning cost, excavation cost [14], etc. (see Table 1).

For different countries, provinces, or areas, even for the same area but different locations, the land prices could vary. The research area of this project is located in the center part of the metropolis. According to the land transaction of this area in December 2012, the land price is 5,746.27 USD/m^2 [20]. This parameter is used to calculate the land cost in the paper.

2.2.2. For COM

The COM, which includes manpower, material, energy, and equipment investment [21], is usually calculated in terms of the time unit "year".

In rainstorm management practices' literature, there is seldom concrete data of practical COM. In many cases, only prediction of costs or the percentage of construction costs can be achieved. Therefore, generally the percentages of annual COM to the total construction cost would be recorded in the manuals [22]. The COMs of measures mentioned above are listed in Table 2.

2.2.3. For SV

While the age of a LID measure approaches to the designed life year, its usability may not descend to the lowest acceptable level, which means that there is a residual life. The value of residual life is termed as SV [23]. SV should be taken into account in economic analysis, and it could be approximately calculated in several ways. In this paper, SV is determined by the percentage of residual life to life expectancy, as shown in the following equation.

$$SV = \left(1 - \frac{L_A}{L_E}\right)\mathrm{COM} \tag{2}$$

where SV is Salvage value of a LID measure; L_A is interval number from last maintenance year to designed life year; L_E is designed service life of a LID measure; and COM is annual cost of operation and maintenance.

We assume that all the measures are maintained year by year, so the interval number from the last maintenance year to designed life year should be set as 1. Table 3 shows the SV for each measure according to Eq. (2).

2.2.4. For whole LCC

Whole life cycle cost (WLCC) assessment is a technique-based analysis on several selectable long-term economic benefits [25]. It can be applied to find the best cost–benefit (B/C) analysis point of rainstorm control. Therefore, it is widely used for industrial analysis in relevant domains such as water supply design [26], water treatment [27], and also for the assessment of rainwater control measures [28].

WLCC mainly consists of initial cost, operation and maintenance cost, and SV. Present value of costs

Table 1
Unit ICC of each LID measure

LID measure name		Unit construction cost	Unit design and planning cost
BR cell (/m^2)		102.72 [15]	3.39
PP (/m^2)	Porous concrete	28–90 [6,12,16]	3.36
	Porous asphalt	67–85 [6]	
	Porous brick	75–150 [12]	
	Features pavement	–	
IT (/m^3)		360 [17]	0.46
Grass/vegetable swale (/m^2)		26.25 [18]	0.36
RB/cistern (/m^3)		140–170 [19]	0

Notes: (1) There are five kinds of LID measures in SWMM, which do not include green roof and rain garden. So, the latter two measures' ICCs are not calculated in this table. (2) All the monetary units in this paper are US dollars, while the exchange rate of RMB to US dollar is calculated as in December 2011, which is 6.3281. (3) RB are industrial products, so the design costs are included in the construction costs.

Table 2
Annual COM of each LID measure

LID measure	Percentage of unit *COM* (%)	Unit *COM*
BR cell	5–7 [22]	5.14–7.19
PP (asphalt)	1 [6]	0.65–0.85
IT	5–20 [22]	18.00–72.00
Grass/vegetable swale	1–2 [12]	0.26–0.52
RB/cistern	1	1.40–1.70

Table 3
SV of LID measures

LID measure	Designed life (year)	*SV*
BR cell	20 [17]	5.86
PP (asphalt)	8 [6]	0.66
IT	20 [22]	42.75
Grass/vegetable swale	20 [22]	0.37
RB/cistern	20 [24]	1.47

(PVC) approach is used for the calculation of WLCC of LID engineering measures in this paper, which means that all the input or occurred costs in different times of life cycle or analysis cycle should be converted the as present value, in accordance with the scheduled discount rate [29] (see Eq. (3)).

$$PVC_{xi,n} = ICC_{xi} + \sum_{t=0}^{n} f_{r,t} g COM_t - f_{r,n} g SV_n \quad (3)$$

where $PVC_{xi,n}$: present value of whole cost in n years of life cycle of LID measure x_i; ICC_{xi}: initial fund cost of LID measure x_i in the initial period of construction; COM_t: annual cost of operation and maintenance in particular year t; $f_{r,t}$: present value factor of discount rate r in particular year t; $f_{r,n}$: present value factor of discount rate r in the end year n of designed life; and SV_n: SV of a LID measure in the end year n of designed life.

Present value factor $f_{r,t}$ is calculated as Eq. (4), and the discount rate r is 5% according to the Chinese central bank monetary policy in 2011 [29]:

$$f_{r,t} = \frac{1}{(1+r)^t} \quad (4)$$

2.3. Methods for effectiveness calculation

The previous simulation results showed that IT, RB, and PP could get better effects on reducing waterlogging, but BR and GS did worse [1]. On this basis, IT, RB, and PP are chosen as components of composite measures. The total LID areas of composite measures keep the same as single measures. The corresponding parameter settings are also the same. Meanwhile, the areas of the two components of the composite LID measures are equal.

For the application of LID measures, rainwater could be retained, osmosed, or stored in headstream. The quantity of rainwater discharged into the urban rainwater drainage system could be decreased through these ways, and thereby, the burden of the drainage system would be relieved. Therefore, the storm recurrence interval of the drainage system could also be prolonged to some extent.

Here, the prolonged extent of a recurrence interval is determined in a quantitative way. In consideration of adding LID measures, an approach to calculate the storm recurrence interval without waterlogging is constructed. As mentioned above, the recurrence interval without waterlogging is regarded as the effectiveness of waterlogging prevention, in this paper. The originally designed recurrence interval of this drainage system is one year, and the duration of rainfall is set as 60 min in calculation.

Under certain conditions including catchment, rainfall duration, and intensity, there is a definite relationship of the quantity of rainfall and waterlogging. Setting the duration of rainfall as 60 min and storm recurrence interval as 1–5 years, we can get a standard curve of conventional simulated rainfall quantity (or storm intensity)—waterlogging quantity [1], as shown in Fig. 2.

Thus, if the quantity of waterlogging is known, we can get the corresponding (1 h) rainfall quantity and

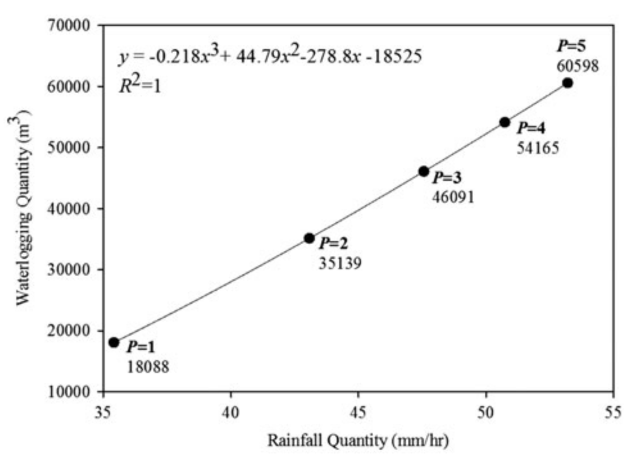

Fig. 2. Standard curve of rainfall quantity–waterlogging quantity of the study area (t = 1 h, p = 1–5 years).

(1 min) rainfall quantity, i.e. the storm intensity. In the next step, we can calculate corresponding storm recurrence interval with Eq. (1). This is the situation without adding LID measures (conventional simulation results, i.e. baseline waterlogging quantity). If the LID measures are added, the quantity of waterlogging can be cut down because if the storm intensity is decreased, then the storm recurrence interval is shortened. This means that the same drainage system can tolerate a stronger storm intensity and a longer storm recurrence interval after the LID measures have been added. For the case of Caohejing drainage system, we have conventional simulation results and different LID measures' simulation results, respectively [1]. Therefore, with Fig. 2 and Eq. (1), we can get the enhanced storm intensity and prolonged storm recurrence interval.

2.4. Methods for cost–effectiveness analysis

Cost–effectiveness was originated from the relevant domains of environment, public health, and safety, which emphasized the analysis of less tangible inputs and a maximum benefit achievement. In this paper, the cost–effectiveness of LID measures applied in the area is analyzed.

As shown in Eq. (5), B/C equals to the ratio of present value of benefit (PVB) to PVC.

$$B/C = \frac{\text{PVB}}{\text{PVC}} \tag{5}$$

B/C ratio could be used to illustrate the effectiveness of an investment, which has a strong relative attribute. The present benefit value of each measure is difficult to calculate actually, so we set the recurrence interval of the drainage system as the benefit of LID measure in this case. Present cost values of the LID measures in SWMM are calculated above. However, for different life cycles of these measures, the present values that are converted from operation and maintenance should be distinct. It means that this kind of comparison would be unreasonable. Therefore, the present value of each unit life cycle is converted to the annual average present value within the life cycle in the study.

3. Results and discussion

Table 4 shows LCC and average present value of each LID measure. Table 5 shows simulation results of different measures under the condition of t = 60 min, including equivalent waterlogging quantity, rainfall quantity, and storm recurrence interval. There into, equivalent waterlogging quantity means the waterlogging quantity without the LID measures (conventional simulation result) under the condition of the prolonged storm recurrence interval.

Five single measures and three composite measures have been introduced above. In the three composite measures, each of the two LID component measures gets the same area proportion. So, the unit average present values of the three composite measures are the sum of half of PVC of each component LID measure. Unit annual average values of B/C are shown in Fig. 3.

From Fig. 3, we know that B/C value of RB is the biggest among the eight measures, which reaches to 0.8129. The BR cell, IT + RB, IT and grass/vegetable swale follow it. The last three are PP + RB, IT + PP, and PP.

According to simulation results in our previous study [1], BR Cell would get good cutting effect on waterlogging in the recurrence interval extent of $p < 2$ year. When $p > 2$ year, its simulation results descended sharply, so it does not fit into this region very much. Besides, even if PP + RB, IT + PP, and PP have better cutting effects on waterlogging and flood peak, these compositions are unsuitable because their B/C values are very small.

Another point is, since there is no corresponding osmosis module of GS in SWMM, it will lead to bad

Table 4
LCC and average present value of each LID measure

LID measure	BR	PP	IT	GS	RB	IT + PP	IT + RB	PP + RB
Unit initial cost	5,852.38	5,830.164	6,106.735	5,772.883	5,901.275	–	–	–
Total present value of unit COM_t	220.25	8.278	1607.40	14.05	55.37	–	–	–
Present value of SV_n	15.54	0.97	113.42	0.99	3.91	–	–	–
Cost of life cycle	6,057.09	5,837.47	7,600.71	5,785.94	5,952.74	–	–	–
Designed life (year)	20	8	20	20	20	–	–	–
Unit annual average PVC (1,000 yuan)	1.916	4.618	2.405	1.831	1.833	3.512	2.119	3.226

Table 5
Simulation results of each LID measure under the condition of t = 60 min

	Equivalent waterlogging quantity (m^3)	Rainfall quantity (mm/h)	Storm recurrence interval (year)
Conventional simulation	18,088	35.41	1
BR	32,099	41.74	1.48
IT	32,172	41.81	1.49
PP	31,825	41.67	1.47
RB	32,173	41.81	1.49
GS	24,141	38.25	1.10
IT + PP	32,008	41.74	1.48
IT + RB	32,171	41.81	1.49
PP + RB	32,059	41.76	1.48

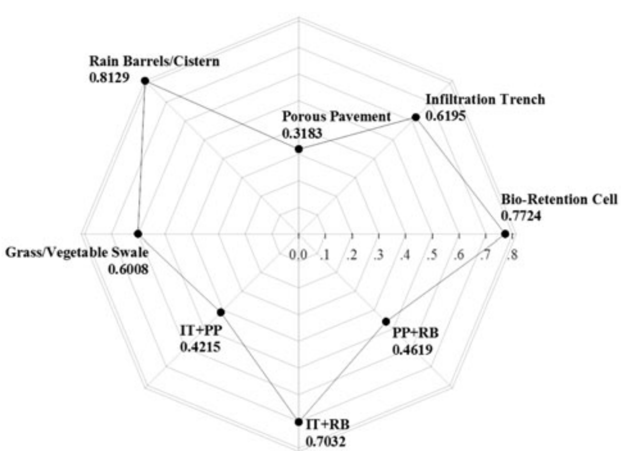

Fig. 3. B/C values of the eight measures.

simulation results for GS, and its B/C would be influenced. If an osmosis module is added in, its B/C value can increase to some extent, but the extent of this increase would still be undetermined.

The recurrence interval in this drainage system is one year. Normally in the condition of p = 1 year, there will be no waterlogging, but it does occur in the simulation process. The reason should be that the pipelines get blocked by the accumulated sediments, which considerably reduce the drainage capacity of the system. In this paper, for calculating the enhance extents of recurrence interval of drainage system, which are applied with the LID measures, we suppose that the effects of pipeline hybrid junction, blocking, and flow backward of underground water or river water are excluded. Based on the total waterlogging quantity and reduction quantity of Table 5, we assume that when the total waterlogging quantities are no more than 18,088 m^3 (as the baseline value, i.e. suppose no waterlogging, occurs in the system when below it), the drainage system could tolerate a storm which occurs by a one-year return period.

According to the above analysis, RB, IT, and their composite measure IT + RB can work better on waterlogging and flood peak cutting, and also be able to enhance storm recurrence interval of drainage system apparently. Meanwhile, they have larger B/C value, i.e. these three measures seem to have better application prospects on the assessed region.

It should be pointed out that the cost data here only have a relative but not an absolute significance. It will change with time and place. Concerning the methodology, the way is feasible.

4. Conclusions

(1) LCC is utilized for economic analysis of five kinds of LID measures in SWMM, which include calculation of the Initial Cost, operation and maintenance cost, and SV, and the unit present life cycle value of each LID measure is finally obtained. The unit present life cycle values of BR, PP, IT, GS, RB were 6,057.09, 5,837.47, 7,600.71, 5,785.94, and 5,952.74 dollars, respectively.

(2) After analysis of expense cost, the present cost value is converted to unit annual mean PVC. An approach to calculate drainage system's storm recurrence interval is constructed, and the recurrence interval of drainage system with adding LID is taken as PVB. The B/C analysis for each kind of LID is done, and PVB/PVCs of different LID measures are obtained. RB has the highest B/C, which is 0.8129. BR, IT + RB, IT and GS follow it successively, and their PVB/PVC values are 0.7724, 0.7032, 0.6195, and 0.6008, respectively. The last three are PP + RB, IT + PP, and PP, and their PVB/PVC values are 0.4619, 0.4215, and 0.3183, respectively.

(3) Comparing with PVB/PVC values of different LID measures, and the cutting effects on waterlogging quantity, coefficients of flood peak and runoff comprehensively, we get the optimum LID measures which are most suitable for this drainage system. They are RB, IT, and their composite measure IT + RB.

Acknowledgments

This work was supported by the National “twelfth five-year” major subject of science and technology for water pollution control and management (Grant No. 2013ZX07304-002) and Shanghai waterlogging project (Grant No. 13231201402).

References

[1] Z.L. Liao, Y. He, F. Huang, S. Wang, H.Z. Li, Analysis on LID for highly urbanized areas’ waterlogging control: Demonstrated on the example of Caohejing in Shanghai, Water Sci. Technol. 68 (2013) 2559–2567.
[2] K. Lee, H. Kim, G. Pak, S. Jang, L. Kim, C. Yoo, Z. Yun, J. Yoon, Cost-effectiveness analysis of stormwater best management practices (BMPs) in urban watersheds, Desalin. Water Treat. 19 (2010) 92–96.
[3] Y. Panagopoulos, C. Makropoulos, M. Mimikou, Reducing surface water pollution through the assessment of the cost-effectiveness of BMPs at different spatial scales, J. Environ. Manage. 92 (2011) 2823–2835.
[4] J.G. Lee, A. Selvakumar, K. Alvi, J. Riverson, J.X. Zhen, L. Shoemaker, F.H. Lai, A watershed-scale design optimization model for stormwater best management practices, Environ. Model. Softw. 37 (2012) 6–18.
[5] N.R.P. Bastien, S. Arthur, S.G. Wallis, M. Scholz, Runoff infiltration, a desktop case study, Water Sci. Technol. 63 (2011) 2300–2308.
[6] F. Montalto, C. Behr, K. Alfredo, M. Wolf, M. Arye, M. Walsh, Rapid assessment of the cost-effectiveness of low impact development for CSO control, Landscape Urban Plan. 82 (2007) 117–131.
[7] D.G. Newnan, J.P. Lavelle, T.G. Eschenbach, Engineering Economic Analysis, Oxford University Press, New York, NY, 2009.
[8] J. Gironás, L.A. Roesner, L.A. Rossman, J. Davis, A new applications manual for the Storm Water Management Model (SWMM), Environ. Model. Softw. 25 (2010) 813–814.
[9] S.Y. Jang, M. Cho, J.Y. Yoon, Y.N. Yoon, S.D. Kim, G.H. Kim, L.Y. Kim, H. Aksoy, Using SWMM as a tool for hydrologic impact assessment, Desalination 212 (2007) 344–356.
[10] Shanghai Urban Construction Design and Research Institute, Water Supply and Drainage Design Manual, Shanghai Meteorological Center, second ed., vol. 5 2004 (in Chinese).
[11] California Department of Transportation, BMP Retrofit Pilot Program Final Report, Report ID CTSW-RT-01-050, Sacramento, CA, 2004.
[12] USEPA, Storm Water Technology Fact Sheet: Porous Pavement (EPA 832-F-99-023), United States Environmental Protection Agency, Washington, DC, 1999.
[13] C.D. Houdeshel, C.A. Pomeroy, L. Hair, J. Moeller, Cost-estimating tools for low-impact development best management practices: Challenges, limitations, and implications, J. Irrig. Drain. Eng. 137 (2010) 183–189.
[14] C.Y. Fan, R. Field, F.H. Lai, J.P. Heaney, D. Sample, L.T. Wright, Costs of urban stormwater control, in: R.H. Hotchkiss, M. Glade (Eds.), Building Partnerships: Section: 10, ASCE, Alexander Bell Drive Reston, VA, 2000, pp. 1–10 (Chapter 2).
[15] Municipal Construction Committee, Construction engineering budget quota of Beijing, Beijing, 2001 (in Chinese).
[16] Conservation Research Institute, Chicago: Illinois Conservation Foundation, Changing Cost Perceptions: An Analysis of Conservation Development, 2005. Available from: http://www.chicagowilderness.org/files/1613/3087/0421/Cost_Analysis_Exec_Summary.pdf.
[17] California Department of Transportation, BMP Retrofit Pilot Program-Final Report, Appendix C3, Sacramento, CA, 2004.
[18] Southeastern Wisconsin Regional Planning Commission (SWRPC), Costs of Urban Nonpoint Source Water Pollution Control Measures, Waukesha, WI, 1991.
[19] H.J. Krishna, The Texas Manual on Rainwater Harvesting, third ed., Texas Water Development Board, Austin, TX, 2005.
[20] Shanghai Municipal Planning and Land Resources Administration, 2012. Available from: http://www.landlist.cn/market/d299e62c-f42b-456f-9907-15366240dd4b.html (in Chinese).
[21] A. Narayanan, R. Pitt, Costs of Urban Stormwater Control Practices, 2005. Available from: http://rpitt.eng.ua.edu/Class/StormWaterManagement/M4%20Stromwater%20controls/e%20costs/M4e%20Internet%20material/Microsoft%20Word%20-%20M4e2%20Costs%20of%20Urban%20Stormwater%20Control%20Practices%20Aug%2031%20200.pdf.
[22] P.T. Weiss, J.S. Gulliver, A.J. Erickson, The Cost and Effectiveness of Stormwater Management Practices. Minnesota Department of Transportation Research Services Section, Minneapolis, MN, 2005.
[23] L.J. Sun, Theory of the Asphalt Pavement Structural Behavior, People’s Traffic Press, Beijing, 2005 (in Chinese).
[24] S.L. Wang, The Research of Rainwater Utilization in Urban Landscape, Zhejiang University, Hangzhou, 2010 (in Chinese).
[25] J. Santos, A. Ferreira, Life-cycle cost analysis system for pavement management at project level, Int. J. Pavement Eng. 14 (2013) 71–84.
[26] J.R. Stokes, A. Horvath, Energy and air emission effects of water supply, Environ. Sci. Technol. 43 (2009) 2680–2687.
[27] A.I. Racoviceanu, B.W. Karney, C.A. Kennedy, Life-cycle energy use and greenhouse gas emissions inventory for water treatment systems, J. Infrastruct. Syst. 13 (2007) 261–270.
[28] S. Spatari, Z.W. Yu, F.A. Montalto, Life cycle implications of urban green infrastructure, Environ. Pollut. 159 (2011) 2174–2179.
[29] Y. Ren, Preventive Maintenance Time Research of Asphalt Pavement Based on Life Cycle Cost, Changan University, Xi’an, 2006 (in Chinese).