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Research Article

Research on Multiobjective Optimization of Sponge City Based on SWMM Model

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With the acceleration of urbanization, the hardened area of the city is increasing, the rainwater runoff is increasing, and the pressure on the urban drainage network is increasing, resulting in urban waterlogging which seriously endangers people's travel safety. SC (sponge city) should take the city as the catchment area, and through the self-regulation of the water system, reduce the consumption of water resources and the discharge of pollutants into the water environment to the maximum extent, meet the production and life of residents to the maximum extent, adapt to the climate change, and serve the ecological balance. Based on SWMM (stormwater management model) model, this study constructed an SC planning and design method based on the coupling of multiobjective optimization and comprehensive evaluation and established a multi-model based on fast classification and non-dominated genetic algorithm (NSGA-II). The results show that compared with the results calculated by other methods, the multiobjective comprehensive optimization model established in this study and the results calculated by the genetic algorithm NSGA-II shorten the optimization period by 1.44%, improve the quality reliability by 9.86%, reduce the total cost by 0.66%, and reduce the environmental impact by 0.93%. The conclusion shows that it reduces the average discharge flow of the discharge port, relieves the drainage pressure of the pipe network, reduces the risk of waterlogging in the city, etc., and it is more suitable for dealing with rainfall events in medium and small return periods.

1. Introduction

With the continuous advancement of urbanization, the proportion of the impervious area of urban underlying surface increases, which changes the hydrological conditions of the original area and threatens the stability of the urban water ecological environment. SC (sponge city) means that a city, like a sponge, has good elasticity in adapting to environmental changes and responding to natural disasters, absorbing water, storing water, seeping water and purifying water when it rains, releasing and utilizing the stored water when necessary, and increasing the rigid constraint of emission reduction at the source of urban runoff and rainwater. The rapid development of cities in China leads to the increasing proportion of impermeable surfaces, and the surge of runoff generated by urban surfaces, which increases the risk of waterlogging in urban areas [1]. The permeable surface such as green space has gradually been replaced, which has changed the geographical features and hydrological characteristics and seriously damaged the normal hydrological cycle process [2]. It breaks the original hydrological environment pattern, reduces the self-repairing and regulating ability of the ecological environment, and reduces the ability to cope with urban waterlogging [3].

In order to realize the management and control of urban rainwater accurately and effectively, domestic and foreign scholars use SWMM (stormwater management model) hydrological model to simulate and evaluate various SC source emission reduction measures. Li Fang SWMM model was used to study the influence of land use type change on waterlogging frequency in reclamation area [4], and the hydrological and hydrodynamic characteristics of the area under different design rainfall conditions were analyzed. The results showed that the change of land use type in reclamation area had a significant influence on waterlogging frequency, and its influence increased with the shortening of rainfall recurrence interval. Jiao et al. combined the SWMM model with Multi_O (Multiobjective Optimization) algorithm, and put forward the technical scheme optimization framework of LID (Low impact development), which was successfully applied to an engineering example [5]. Zhu et al. have studied the performance of green roofs in reducing runoff, peak value, and pollution control. The results show that roof greening is effective in reducing runoff and peak flow and delaying the arrival time of peak value [6]. Murazaki et al. studied how to coordinate the contradiction between multiple objectives [7]. Multiobjective problem is more and more common in real life, and it is closely related to human production and life, so the Multi_O problem gradually attracts people's attention. Therefore, we must seek practical and effective ways to reduce urban waterlogging, comprehensively improve the safety of urban waterlogging prevention, and provide a strong guarantee for better building ecological civilization and realizing sustainable development.

To ensure urban ecological security, reduce urban waterlogging disasters, solve urban non-point source pollution problems, make full use of rainwater resources, and guide urban sustainable development [8]. Under this background, this article studies the previous research results, collects relevant information, and analyzes the experience, research progress, and main technical measures of SC construction—combined with the technical measures of SC construction, determine the measuring scale, and provide guidance for reasonably determining the measuring scale of urban rainwater system. By optimizing the four objectives of construction period, cost, quality, and environment, the Multi_O of SC construction can be realized, so that SC construction can be carried out smoothly under the conditions of short construction period, high quality, low cost and low pollution, and the adaptability of urban environmental changes and the response-ability to natural disasters can be further effectively improved, thus accelerating the construction and development of new urbanization in China.

2. Related Work

2.1. SC Research Status. Tang et al. analyzed the role of LID measures in controlling rainwater runoff and purifying runoff water quality through field experiments of roof rainwater collection and surface runoff infiltration [9]; Benabdelwahed et al. made a comparative analysis of the characteristics of modern stormwater control systems and put forward some suggestions for solving urban water problems and establishing urban stormwater management systems in China [10]. Tian et al. used the SWMM model to study the effect of runoff control in SC renovation of buildings and residential areas. The results showed that the annual runoff control rate was about 78% ~ 82% when the green space rate of the building residential areas was 31.5% [11]. Zhai et al. collected 2000 feet of rainwater runoff from residential roofs by using 50-gallon rain buckets. The research results showed that the annual runoff from roofs decreased by 1.4%–3.1%, but the reduction rate of annual runoff could be increased by increasing the volume of rain buckets [12].

Finkler et al. found that an average of 40% of the toxic components in runoff rainwater occurred in 20% of the initial runoff, and an average of 90% of the toxic components occurred in 30% of the initial runoff. The toxicity of runoff water samples mainly came from heavy metals [13]. Fan et al. selected straw fragments with different sizes, proportions, and burial depths to carry out soil infiltration improvement experiments, and found that straw can effectively increase the permeability coefficient of soil, and the vertical infiltration distance of soil increases when it is buried in the depth of 10–15 cm [14]. Deng et al. tested the hydraulic performance of permeable pavement and concluded that the effect of permeable pavement was higher than or similar to that of vegetation, and it could reduce the flood risk and improve the sewage treatment system [15].

2.2. Multi_O Research. Because Multi_O problems exist widely in real life, and it is difficult to solve them, people spend a lot of energy finding solutions. Li et al. established a simple time-cost equilibrium optimization method. This method is realized by drawing the network diagram, specifically, drawing the whole project from the initial node to the final node, further compressing the number of days according to the project's time limit goal, and selecting the work with the lowest cost slope as the optimal cost on the compressed key route [16]. Muralitharan et al. established a mixed integer programming model based on the assumption of the traditional cost duration model. This model considered the incentive factors of the owner to the contractor and expressed the relationship between the cost and duration of the project with multiline segments [17]. Ahmadi et al. put forward a simplified gradient method [18] for solving constrained non-linear convex programming problems. This method takes hydraulic factors into account and achieves satisfactory results in pipe network optimization.

According to the pollution risk during urban floods, Chuong evaluated three different reconstruction schemes: increasing pipeline size, increasing depression system, and increasing biological detention facilities, with three evaluation objects: inundation depth, flood pollution risk, and reconstruction scheme cost. The results showed that the flooding risk and water pollution risk could be reduced by 59% and 26% by increasing the depression system [19]. Liu et al. proposed an optimization method to reduce the computation time by narrowing the search range [20]. Michalak uses simulation technology to simulate the unsteady flow of drainage systems, accurately analyze and calculate the hydraulic characteristics of drainage networks under various conditions, and realize the optimization of drainage network design and operation management by simulating the real flow process of water in the pipeline [21].

3. Research Method

3.1. Study on the Establishment of Regional SWMM Model

3.1.1. Overview of Research Area. City H is the central city in Central China. It is located in the east of Jianghan Plain. Its geographical location is 113° 41′ ~ 115° 05′ E and 29° 58′ ~ 31° 22′ n. City h belongs to the north subtropical monsoon (humid) climate, with the characteristics of abundant rainfall, sufficient heat, rain and heat in the same season, light and heat in the same season, cold in winter and hot in summer, four distinct seasons and, so on.

City H is the first city to enter the national sponge pilot list. H municipal government according to the actual situation of the city itself and its future development. According to the topography and land layout planning of the study area, the study area is divided into six rainwater drainage zones. The satellite map of the study area is shown in Figure 1.

Figure 1: Satellite map of research area.

3.1.2. Establishment of Model. SWMM is a comprehensive mathematical model, which can completely simulate the urban rainfall-runoff process and pollutant transport process. The simulation contents mainly include: surface evaporation, time-varying rainfall, snow melting and accumulation, precipitation interception caused by depressions, infiltration of precipitation into unsaturated soil layers, recharge of groundwater by infiltration water, surface runoff calculation, etc. SWMM joined the LID (Low impact development) control module, which provided favorable conditions for the design, planning, and promotion of LID [19].

SWMM model has good integrity, which can completely simulate and analyze the generation process of non-point source pollution load. In the runoff sub-module, it can simulate not only the process of surface depression, but also the process of infiltration and the recovery of infiltration capacity in dry season, and it also has different simulation parameter requirements for various land use types in the study area. SWMM can accept any number of water quality components defined by users to simulate the growth process of pollutants in the dry season and the accumulation of precipitation and runoff; for example, changes in water quality components in the drainage system, storage and treatment facilities, natural degradation process of pipe network, etc.

The design return period is an important index for the design of rainwater pipes and canals. It should be determined after technical and economic comparison according to the nature of catchment areas, types of towns, topographical features, and climatic features. If the selected design return period is low, the project cost can be reduced correspondingly. However, there may be poor drainage and water accumulation on the ground, which will affect traffic safety, people's life, and industrial production. Total runoff control generally adopts the annual total runoff control rate as the control target.

The annual total runoff control rate index refers to the proportion of the accumulated annual controlled (not discharged) rainfall in the site to the annual total rainfall through natural and artificial enhanced infiltration, storage, utilization, evaporation, transpiration, etc. Its conceptual diagram is shown in Figure 2.

When the total annual runoff is taken as the control target, the total regulated storage volume (excluding the regulated volume for peak flow reduction) specified in SC Construction Technical Guide is generally calculated as follows [3]:

$$V = 10H\phi_c F. \tag{1}$$

In the equation: V—Total designed storage capacity, m^3; H—Design rainfall, mm, the corresponding design rainfall is determined according to the annual total runoff control rate index, which is determined by the typical year method in this study;

ϕ_c—Comprehensive rainfall runoff coefficient;

F—Collecting area, ha.

Economic cost control has always been an important aspect of LID projects. In this study, LID economic cost control mainly considers the construction cost of LID, which varies with the economic development of different places. It is obtained according to the selected LID measure area and the unit price of local LID measures. The calculation formula is as follows:

$$M = \sum_{i=1}^{N} c_i \sum_{i=1}^{N} s_i. \tag{2}$$

In the equation: M—Total cost of LID facilities (RMB); c_i—Cost per unit area of LID facilities in each area (RMB/m^2); s_i—Area of LID measures in each area (m^2).

Infiltration is the process that precipitation passes through the surface and enters unsaturated areas in the soil. In the Green-Ampt method, the interface between dry and wet soil is assumed, and saturated soil is distinguished from unsaturated soil in simulation, which satisfies Darcy's theorem of saturated and unsaturated soil [11]. Parameters to be input: initial moisture content of soil, hydraulic conductivity and suction head.

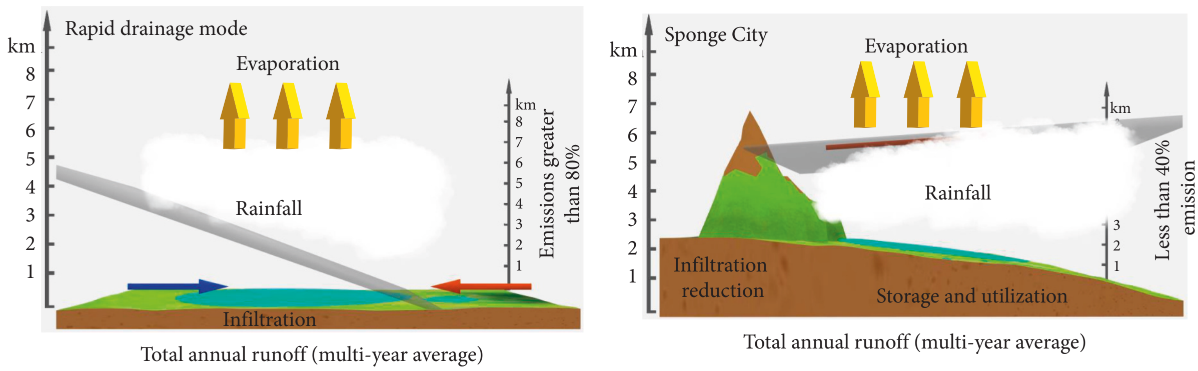

Figure 2: Concept diagram of annual total runoff control rate.

$$f_p = K_s\left(1 + \frac{S \times IMD}{F}\right). \quad (3)$$

In the equation: f_p—Infiltration rate, mm/h;

K_s—Saturated hydraulic conductivity of soil; S—Suction head, mm/h; IMD—Initial loss humidity, m; F—Total infiltration amount, mm.

The modified Green-Ampt method reduces the minimum rainfall that can be infiltrated, and the result is more accurate for simulating rainfall that is less than the saturated infiltration rate of soil for a long time.

The sensitivity analysis of the model indicates the influence degree of each parameter on the model by calculating the discriminant factor. Parameter sensitivity analysis of the model includes local sensitivity analysis and global sensitivity analysis [12]. If the parameters change, the Morris screening method is used as a local sensitivity analysis method which is widely used at present [14].

In this study, the modified Morris screening method is selected, and by changing the percentage of fixed step length, the average value of the Morse coefficient of multiple disturbances is calculated as the sensitivity discriminant factor S:

$$S = \frac{\sum_{i=0}^{n-1} \left(\left(Y_{i+1} - Y_i\right)/Y_0\right)/P_{i+1} - P_i}{n-1}. \quad (4)$$

In the equation: S—Sensitivity discrimination factor; Y_i—Output value of the model's ith run; Y_{i+1}—Output value of the model's $i+1$th run;

Y_0—Calculate the initial value of the result after the parameter is calibrated;

P_i—The percentage of the parameter value of the i-th model operation relative to the change of the parameter value after calibration;

P_{i+1}—The percentage of the parameter value of the $i+1$-th model operation relative to the change of the parameter value after calibration; n—Number of model runs.

In order to determine the reasonable scale of SC construction measures as a whole, this study adopts appropriate evaluation criteria and indicators and uses AHP to determine the comprehensive index, with the minimum comprehensive index as the overall objective function of the reasonable scale of SC construction measures. And determine the first level constraint conditions according to the specification requirements. The main principles to be followed are: the principle of higher economic benefits; the principle of better hydraulic performance; the principle of better social benefits. According to the evaluation criteria, the selected evaluation indicators are shown in Figure 3.

In this study, the construction cost of source emission reduction facilities, the comprehensive runoff coefficient of rainwater in the study area, and the comprehensive removal rate of pollutants from source emission reduction facilities are taken as the lowest factor layers, and the importance of each factor is sorted through the summary results of expert questionnaire survey, and a judgment matrix is constructed to obtain the weight coefficient of each factor. According to the weight coefficient and the normalized result, the comprehensive score index of each scheme in the Pareto optimal solution set is calculated to determine the optimal SC construction scheme.

3.2. Establishment of Multi_O Design Model. In this study, taking the total cost of LID and the annual runoff control rate as the objective function, and the area of LID facilities as the constraint condition, the Multi_O design model of LID facilities is constructed to obtain the optimization schemes of different scale LID facilities. The optimization process of this study is shown in Figure 4.

In this study, the construction area parameter of each sponge facility in each sub-catchment area in the SWMM model is regarded as a variable, the constraint conditions are determined according to the actual maximum allowable construction area of sponge facilities in Matlab software, and two optimization objectives of CSO (Combined Sewer Overflow) reduction rate and construction cost are set.

Aiming at the rainwater pipe network system, considering the cost and hydraulic performance of the whole pipe network, this study defines the rainwater pipe network Multi_O with annual cost as the objective function, total overflow and total accumulated water time as the objective functions, and determines the constraint conditions based on the hydraulic model to construct the rainwater pipe network Multi_O model.

According to the content of the cost model, aiming at the minimum annual cost of rainwater pipe network, when rainwater pipe network is gravity flow system, the objective function is as follows:

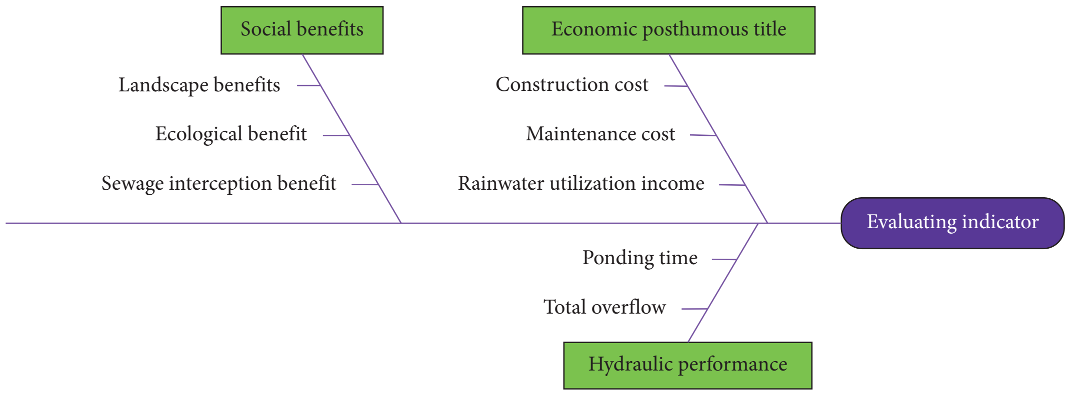

Figure 3: Comparison and evaluation index of SC rainwater system schemes.

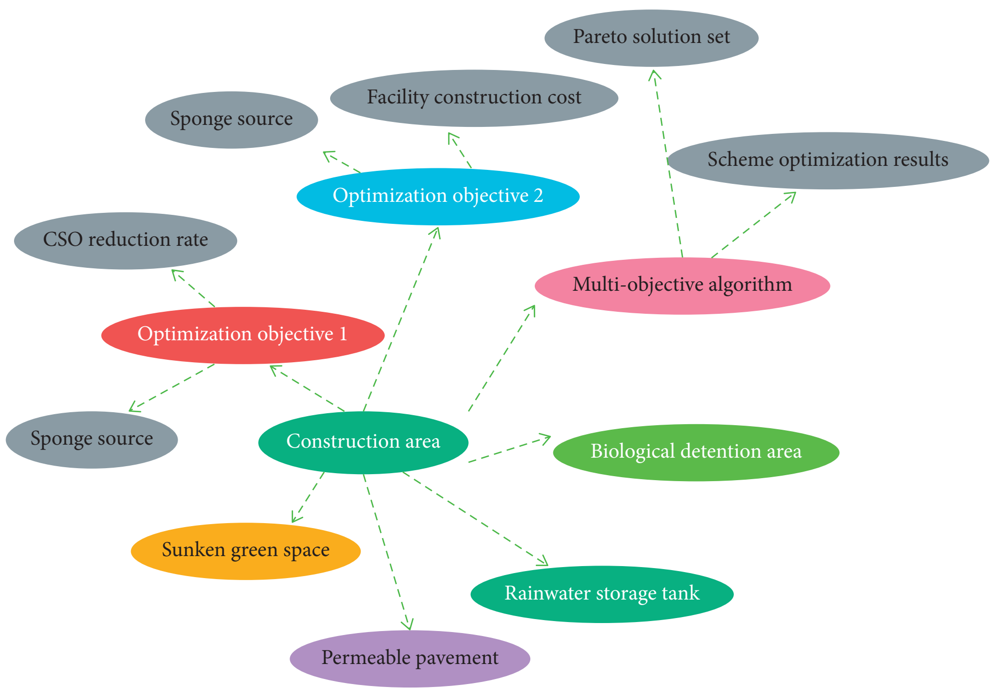

Figure 4: The Multi_O optimization process is studied.

$$f_1 = \min F_{1,1} = \min \left\{ \left(\frac{i(1+i)^n}{(1+i)^n - 1} \right) + e_i \right\} \sum_{i=1}^{m} C_{1,i} L_i. \quad (5)$$

The synthesis of the direct cost of each working procedure of the SC construction project constitutes the direct cost of this project. As the indirect cost of this project has few impact indicators that change with time, the author will use the linear function to describe its relationship with the duration of the working procedure.

Based on the general analysis of direct and indirect costs in the construction process of the SC construction project, the direct and indirect costs of this construction project can be expressed as follows:

$$\begin{aligned} DC &= \sum C_{ij} = \sum \left[b_{ij} + r_{ij} \left(t_{nij} - t_{ij} \right)^2 \right], \\ IC &= T_0 C_0. \end{aligned} \quad (6)$$

In the equation: IC—Indirect costs of the project;
C_0—Unit indirect cost within the contract period;
T_0—Contract duration;
DC—The direct cost of the project.

In practical engineering, the area that can be LID or reconstructed is limited, so the main constraint of this problem is the area limitation. For the biological retention unit, the upper and lower limits of the area that can be set by the biological retention unit can be determined according to the green area of the research area. The constraint conditions are as follows:

$$\begin{cases} 0 \le s_{brc} \le A_{brc}, \\ 0 \le s_{pp} \le A_{pp}. \end{cases} \quad (7)$$

In the equation: A_{brc} —The research area can set the upper limit of the area of biological retention unit, m^2; A_{pp}

—The upper limit of the area of permeable pavement can be set in the study area, m^2.

The Multi_O problem not only has certain resource constraints but also has problems of interaction and contradiction among multiple targets. The essential difference between Multi_O and single-objective optimization is that if one sub-objective of multiobjective function is improved, the performance of other sub-objectives will deteriorate. The optimization results that satisfy the constraints and all objective functions are provided to the decision-makers, so that the decision-makers can choose appropriate objective function values and make corresponding decision results according to their own characteristics or utility functions.

Multi_O algorithm is developing more and more widely, and there are many ways to solve it. This study mainly introduces a genetic algorithm NSGA-II based on fast non-dominated sorting with elite strategy, which is one of the most widely used and effective multiobjective genetic algorithms at present. The calculation of the NSGA algorithm is simpler and faster. Its calculation parameters include congestion degree and congestion degree comparison operator, which keeps the diversity of the population. It improves the operation speed and stability of the algorithm.

The general process of the NSGA-II algorithm is as follows:

(1) According to the relevant parameters of engineering data and using formulas, the cost and environmental impact index corresponding to the shortest time and longest time of each process are calculated respectively [14–16];
(2) Calculate the four target parameters of each individual in the initial population, and then substitute them into the comprehensive optimization model for calculation;
(3) The offspring obtained by fast non-dominated sorting and congestion calculation is subjected to the genetic operation, and when the evolutionary algebra reaches the specified algebra, the optimal solution set can be output.

When applying this method to solve problems, it is necessary to set the population size, genetic algebra, crossover, and mutation probability reasonably to ensure that the final curve is close to Pareto optimal. Whether the new offspring meet the constraint conditions should be considered in each step of crossover and mutation operation.

4. Result Analysis

4.1. Runoff Analysis. Planting grass ditch is a small-scale low-impact measure, which is generally formed by digging shallow surface ditches around buildings and laying grass on the ditches. According to the section shape, there are triangle, trapezoid, and parabola shapes. Its main function is to remove surface non-point source pollutants, and at the same time, it can retain, store and infiltrate rainwater.

Each section of the rainwater pipe network system has specific hydraulic constraints in diameter, slope, velocity, fullness, and buried depth, which must be between the maximum and minimum values of the corresponding parameters; For the pipe sections connecting upstream and downstream, it is required that the diameter of the downstream pipe section must be smaller than that of the upstream pipe section.

The SWMM model results report records the relevant results of surface runoff in detail. Through the surface runoff analysis, we can know the change of the underlying surface in the study area, and reflect the impervious rate of the ground. Table 1 and Figure 5 show the changes in surface runoff before and after adding LID in the study area.

It can be seen that in the study area, with the increase in rainfall recurrence period, rainfall, infiltration, runoff and runoff coefficient increase, and the runoff reduction rate decreases. When LID measures are not added, the increasing range of infiltration decreases after the return period is 5 years, which indicates that the soil water storage is gradually saturated at this time, and the increase of runoff coefficient indicates the increase of waterlogging risk.

After adding LID measures, when the return period increases from 1a to 10a, the 2-hour rainfall change process is the same as that without LID measures, but the infiltration amount and runoff change greatly. The infiltration amount increased from 18.69 mm to 50.16 mm, and the infiltration amount increased by 31.47 mm, with an increase of 168%.

The overall change process is roughly the same as that without LID. The runoff reduction rate has a great decline from 1a to 5a. The reason is that LID measures have a good effect in dealing with small rainfall events, but with the increase in return period, the LID efficiency gradually decreases, resulting in the decrease of runoff.

4.2. Reconstruction Effect of Midway Interception Pipe Network. SC construction measures, such as water storage, roof greening, concave green space, permeable pavement, can achieve the purpose of reducing the total runoff, peak discharge, and runoff coefficient, thus reducing the running pressure of the rainwater system and the risk of urban waterlogging. Under the influence of LID measures, the fullness in the pipeline decreases obviously at the peak, and there is a large surplus space in the pipeline.

A load of non-point source pollutants caused by rainfall and surface runoff is directly related to runoff. The concave depth of concave green space is generally 100–200 mm, which is mainly determined by considering the plant's waterlogging resistance and soil permeability. At the same time, an overflow port should generally be set in concave green space to ensure that when the infiltration amount exceeds the water storage capacity of concave green space, the rainwater can overflow and be discharged into the municipal rainwater pipe network.

In order to further study the law of the influence of pipe network transformation on the system, a set of pipe network transformation schemes with large transformation situation is selected, and the model is operated under the design rainfall and the measured rainfall with different rainfall intensities. The rainfall intensity and construction effect of

Table 1: Simulation calculation results of surface runoff.

Return period		Rainfall (mm)	Infiltration quantity (mm)	Volume of runoff (mm)	Runoff coefficient
1a	Without LID	33.63	12.33	19.96	0.58
	There is LID	33.63	18.69	5.42	0.16
5a	Without LID	65.32	20.19	54.37	0.72
	There is LID	65.32	32.03	28.49	0.35
10a	Without LID	88.69	20.11	66.03	0.74
	There is LID	88.69	41.28	36.79	0.36
15a	Without LID	110.24	20.17	95.53	0.81
	There is LID	10.24	50.16	54.16	0.51

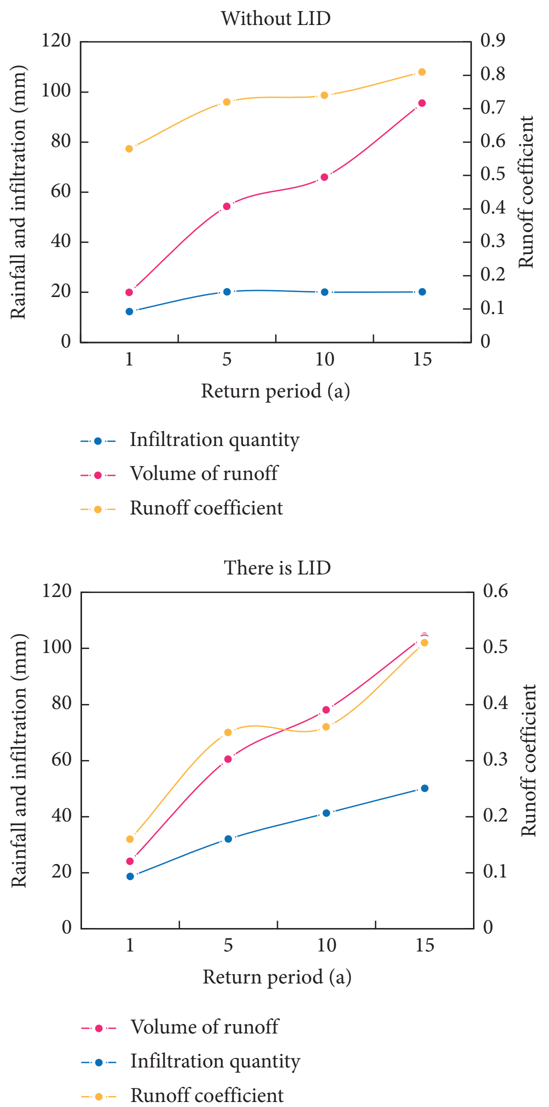

Figure 5: Change map of surface runoff before and after adding LID.

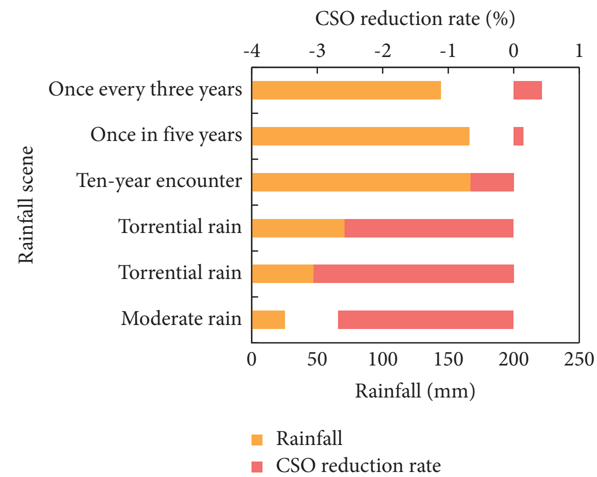

Figure 6: Construction effect under different rainfall scenarios.

different rainfall scenarios in the pipeline network reconstruction scheme are shown in Figure 6.

It can be seen that the regional CSO reduction rate of the pipeline network reconstruction scheme is negative under the rainfall scenarios of 3 years, 5 years, 10 years, and heavy rain, while it is positive under the actual rainfall scenarios of 55.01 mm and 25.38 mm, indicating that the reconstruction of the regional sewage interception pipe has a certain control effect on heavy rain and moderate rain, but the CSO reduction rate is still negative under the multiyear rainfall scenarios.

The rainwater pipeline near the source, the upstream intercepting pipe network, and the end of the intercepting pipe network in the combined drainage system of the study area are selected and named pipeline 1, pipeline 2, and pipeline 3, and their water level changes are shown in Figure 7.

As overflow port 3 is the front overflow port of the sewage treatment plant, the higher the pipeline flow rate, the more sewage that exceeds the treatment capacity of the sewage treatment plant, and the higher the front overflow flow rate of the sewage treatment plant. Therefore, it is more difficult to reduce the overflow of the overflow port 3. The reconstruction and expansion of the intercepting pipeline should be avoided as far as possible, and the pipeline inspection and leakage repair should be the main measures. In this chapter, the sponge reconstruction design adopts intercepting pipeline detection and leakage repair as the process scheme.

The main reason for the destruction of soil aggregates is water. When there is a high content of aggregates in the soil, it can effectively reduce the compactness of the soil, reduce

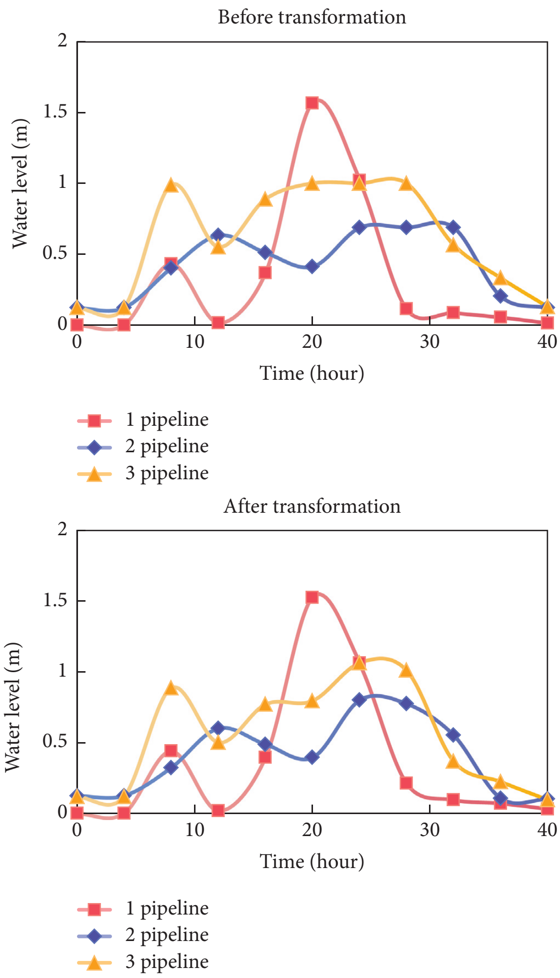

Figure 7: Changes of drainage capacity of pipe network before and after river closure reconstruction.

the soil surface crusting and the damage degree of soil aggregates during rainfall, and improve the water infiltration performance of the soil. Therefore, rainwater pipes with different diameters should have different minimum slopes. When the design fullness is given, the larger the pipe diameter, the smaller the corresponding minimum design gradient value. That is to say, the content of macroaggregates in the test soil samples is lower than that in the original soil, which indicates that organic wastes and soil structure improvers have no obvious improvement effect on the mechanical stability of macroaggregates.

4.3. Multi_O Result Analysis. Permeable pavement refers to permeable pavement with large pores and good permeability, which is called "breathable pavement". It can effectively reduce urban surface runoff, reduce runoff peak and interception runoff pollution, and promote groundwater replenishment. It can be roughly divided into permeable asphalt concrete, permeable cement concrete, and permeable brick. In order to generally check the accumulation of different scales between the measure layer and the criterion layer to the target layer, the total ranking vector of the measure layer to the target layer can be calculated on the premise that the ranking vectors of different evaluation indexes (criterion layer) to the best scheme selection (target layer) and the ranking vectors of different schemes (measure layer) to different analysis indexes (criterion layer) are known.

The main influencing parameters of infiltration and storage performance of concave green space are rainfall, stable infiltration rate of planting soil, and concave depth. The planting soil should meet the requirement of rainwater infiltration during the heavy rain return period. If it does not meet the requirement, it is necessary to select suitable improved materials and their dosage for infiltration enhancement. The maximum buried depth of the rainwater pipeline should meet the geological conditions of the region. When the designed buried depth of the pipeline reaches or exceeds this value, a rainwater pumping station should be set in the middle, and the buried depth of the upgraded pipeline should be considered as the minimum buried depth. When the slope of the pipeline is less than the slope of the ground, in order to ensure the minimum covering thickness of the downstream pipe section or reduce the buried depth of the upstream pipe section, the drop well connection should be adopted.

The 2-hour rainfall hydrograph with the peak position coefficient of 0.4 is used as the rainfall file. According to the actual situation of the study area and related references, the water storage in the permeable area, Manning coefficient in permeable area, water storage in the impermeable area, Manning coefficient in impermeable area, maximum infiltration rate, minimum infiltration rate, and attenuation coefficient in Horton infiltration model are taken as calibration parameters, as shown in Table 2.

When the decision-makers value the economy of the LID scheme because of the shortage of funds, they can choose scheme A, which has the lowest total cost when meeting the total runoff control target. When the decision-maker emphasizes the total runoff control target of LID scheme, scheme C can be selected to achieve the best annual total runoff control rate. In a balanced situation, you can choose scheme B. Which optimization scheme to choose depends on the investment ability of the decision maker and the requirement of total runoff control.

Compared with traditional development, adding water storage body can greatly reduce peak discharge and delay peak time. Each LID measure has a good effect on reducing the total runoff, peak flow, and runoff coefficient, and the concave green space has a relatively obvious effect. Compared with that without LID measures, the peak value is greatly reduced, and it is close to the peak value of traffic before development, which indicates that the LID measures taken by the community are effective and reflect the characteristics and requirements of SC.

MATLAB, a genetic algorithm, is used for programming, and the running environment is consistent with that of the comparison algorithm. After 100 cycles, the calculation is stopped, and the top ten sets of optimal solutions are obtained. The optimal results are obtained according to the fitness evaluation function, as shown in Figure 8. The calculation results of common algorithms used in the Multi_O

Table 2: Three kinds of representative scheme optimization results.

Plan	Area $(s_{brc}, s_{pp})/1 \times 10^4 m^2$	Annual total runoff control rate/%	Total cost/10,000 yuan
A	(7.33,14.01)	77.24	6241.87
B	(10.36,14.75)	81.63	7863.92
C	(12.06,14.89)	85.69	8829.04

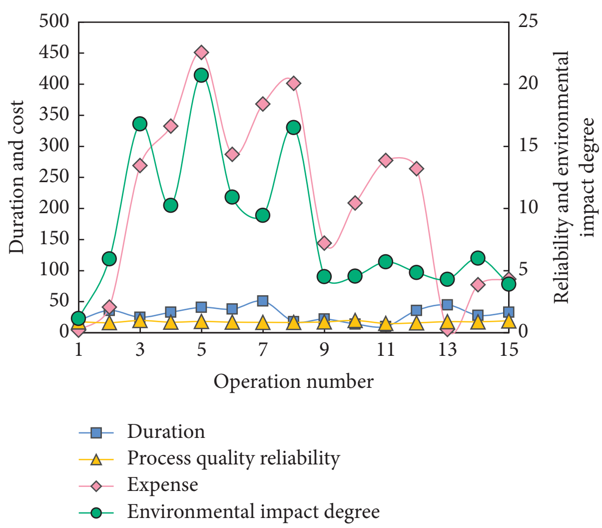

Figure 8: The optimal result of this method.

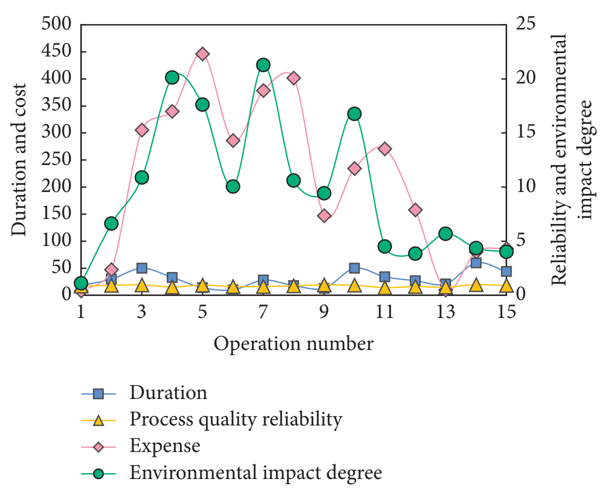

Figure 9: Optimal result of Ref [18] method.

research of construction projects studied by Ref [18] are shown in Figure 9.

It can be seen that compared with the results calculated by [18], the multiobjective comprehensive optimization model established in this study and the results calculated by the genetic algorithm NSGA-II shorten the optimization period by 1.44%, improve the quality reliability by 9.86%, reduce the total cost by 0.66%, and reduce the environmental impact by 0.93%, which shows that the optimization effect is better and the optimization result is more perfect.

This algorithm case proves the effectiveness of the genetic algorithm in Multi_O of the project construction management, which can make the project quality, time limit, cost, and environmental factors meet the contract requirements. By compressing the duration of the process, these four target factors can be balanced, and the balance optimization among multiple objectives can be realized. Compared with the algorithm in [18], this algorithm is more effective for this model and Multi_O of this kind of engineering.

5. Conclusion

SWMM model is used to simulate the planning and design scheme of SC construction in Yangtang residential area. By analyzing the control effects of different measures on total runoff, peak flow, peak time, and rainfall comprehensive runoff coefficient under different design rainfall conditions, it provides strong technical support for the promotion of SC construction technology in H city. The NSGA-IIMulti_O algorithm based on the comprehensive runoff coefficient of rainwater and the comprehensive removal rate of pollutants is put forward, and the SC optimization scheme design under the target control condition is realized by combining the analytic hierarchy process comprehensive evaluation method. Three kinds of LID schemes with different scales are available for decision makers to choose, which avoids the subjectivity and uncertainty of conventional decision-making, and enables decision makers to choose the appropriate optimization scheme according to the actual situation. Before the SC reconstruction planning, introducing the reduction effect of unit cost as the project evaluation index and combining the multiobjective reconstruction benefits for scenario simulation analysis can more vigorously promote the SC construction work.

Data Availability

The labeled dataset used to support the findings of this study can be obtained from the corresponding author upon request.

Disclosure

Jie Luo and Yingdong Yuan are the co-first authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

[1] C. Mei, J. Liu, H. Wang, Z. Yang, X. Ding, and W. Shao, "Integrated assessments of green infrastructure for flood mitigation to support robust decision-making for sponge city construction in an urbanized watershed," *Science of The Total Environment*, vol. 639, pp. 1394–1407, 2018.

[2] J. Li, B. Zhang, C. Mu, and L. Chen, "Simulation of the hydrological and environmental effects of a sponge city based on MIKE FLOOD," *Environmental Earth Sciences*, vol. 77, no. 2, p. 32, 2018.

[3] Q. Li, F. Wang, Y. Yu, Z. Huang, M. Li, and Y. Guan, "Comprehensive performance evaluation of LID practices for the sponge city construction: a case study in Guangxi, China," *Journal of Environmental Management*, vol. 231, pp. 10–20, 2019.

[4] F. Li, "Probabilistic seasonal prediction of summer rainfall over east China based on multi-model ensemble schemes," *Acta Meteorologica Sinica*, vol. 25, no. 3, pp. 283–292, 2011.

[5] W. Jiao and Z. Xu, "A distributed runoff model for the mountainous region of the Heihe River Basin (China) based on the spatial modeling environment (SME) II: model calibration and validation," *Environmental Earth Sciences*, vol. 69, no. 7, pp. 2189–2197, 2013.

[6] Z. Zhen-Tao, Z. Jing, L. Ping, and C. Xing-Guang, "An evolutionary model of urban bus transport network based on B-space," *Chinese Physics B*, vol. 17, no. 8, pp. 2874–2880, 2008.

[7] K. Murazaki, H. Tsujino, T. Motoi, and K. Kurihara, "Influence of the kuroshio large meander on the climate around Japan based on a regional climate model," *Journal of the Meteorological Society of Japan*, vol. 93, no. 2, pp. 161–179, 2015.

[8] Y. Bai, Y. Li, R. Zhang, N. Zhao, and X. Zeng, "Comprehensive performance evaluation system based on environmental and economic benefits for optimal allocation of LID facilities," *Water*, vol. 11, no. 2, p. 341, 2019.

[9] S. Tang, J. Jiang, Y. Zheng et al., "Robustness analysis of storm water quality modelling with LID infrastructures from natural event-based field monitoring," *Science of The Total Environment*, vol. 753, no. 2, Article ID 142007, 2021.

[10] I. Benabdelwahed, A. Mbarek, K. Bouzrara, and T. Garna, "Non-linear system modelling based on NARX model expansion on Laguerre orthonormal bases," *IET Signal Processing*, vol. 12, no. 2, pp. 228–241, 2018.

[11] Y. Tian, K. Govindan, and Q. Zhu, "A system dynamics model based on evolutionary game theory for green supply chain management diffusion among Chinese manufacturers," *Journal of Cleaner Production*, vol. 80, pp. 96–105, 2014.

[12] H. Zhai, S. Li, and Z. Qian, "Research on the application of SWMM in the planning of the building community in sponge city," *International Journal for Engineering Modelling*, vol. 31, no. 1, pp. 1–7, 2018.

[13] A. T. J. Finkler, L. F. de Lima Luz, N. Krieger, D. A. Mitchell, and L. M. Jorge, "A model-based strategy for scaling-up traditional packed-bed bioreactors for solid-state fermentation based on measurement of O2 uptake rates," *Biochemical Engineering Journal*, vol. 166, no. C3, Article ID 107854, 2021.

[14] F. Chen-jing, S. Shi-guang, W. Si-hui, S. Guang-hui, and W. Xin-yi, "Research on urban land ecological suitability evaluation based on gravity-resistance model: a case of deyang city in China," *Procedia Engineering*, vol. 21, pp. 676–685, 2011.

[15] Z. Deng, Y. Chen, J. Yang, and Z. Chen, "Archetype identification and urban building energy modeling for city-scale buildings based on GIS datasets," *Building Simulation*, vol. 15, no. 9, pp. 1547–1559, 2022.

[16] M. Li, S. Yang, and X. Liu, "Pareto or non-pareto: Bi-criterion evolution in multiobjective optimization," *IEEE Transactions on Evolutionary Computation*, vol. 20, no. 5, pp. 645–665, 2016.

[17] K. Muralitharan, R. Sakthivel, and Y. Shi, "Multiobjective optimization technique for demand side management with load balancing approach in smart grid," *Neurocomputing*, vol. 177, pp. 110–119, 2016.

[18] M. H. Ahmadi, M. A. Ahmadi, and F. Pourfayaz, "Thermodynamic analysis and evolutionary algorithm based on multiobjective optimization performance of actual power generating thermal cycles," *Applied Thermal Engineering*, vol. 99, pp. 996–1005, 2016.

[19] T. D. Chuong, "Nondifferentiable fractional semi-infinite multiobjective optimization problems," *Operations Research Letters*, vol. 44, no. 2, pp. 260–266, 2016.

[20] X. Liu and A. C. Reynolds, "Gradient-based multi-objective optimization with applications to waterflooding optimization," *Computational Geosciences*, vol. 20, no. 3, pp. 677–693, 2016.

[21] K. Michalak, "Evolutionary algorithm with a directional local search for multiobjective optimization in combinatorial problems," *Optimization Methods and Software*, vol. 31, no. 2, pp. 392–404, 2016.