The Establishment of Evaluation System for Rainwater-Friendly Community Construction Project Based on GAHP

Yan Li

Department of Architecture, Henan Technical College of Construction, Zhengzhou 450007, China
e-mail: 177256933@qq.com

Wenyan Cheng

School of Horticulture and Landscape Architecture, Henan Institute of Science and Technology, Xinxiang 453003, China;
e-mail: 326772570@qq.com

Yichuan Zhang

School of Horticulture and Landscape Architecture, Henan Institute of Science and Technology, Xinxiang 453003, China;
School of Urban Design, Wuhan University, Wuhan 430072, China;
Corresponding author e-mail: zhangyichuan2002@163.com

ABSTRACT

Affected by extreme climate and excessively high rate of impermeable underlying surface, urban community is frequently invaded and harassed by floods in summer, so constructing rainwater-friendly community is an important measure to deal with urban rain and flood problems. In this paper, a GAHP (Group-Analytic Hierarchy Process) model, which is composed of the target layer, the criterion layer and the index layer, is established, and four experts are selected to conduct group decision evaluation. The Yaahp software is used for calculation. The result shows that absorbability, reclamation and wisdom have higher weights; But in the general ranking, factors such as permeation and absorption, wisdom facilities, decontamination, utilization, collection and storage, administration cost and so on weigh more than others. They should be given more attention in the construction of Rainwater-friendly community.

KEYWORDS: rainwater-friendly community; construction evaluation; group decision; AHP

INTRODUCTION

In recent years, Chinese urban construction has developed quite rapidly. The environmental quality of the cities has been continually improved and the living environment is more pleasant as well. However, city disease still limits the healthy development of the city, such as problems of transportation and haze, and so on. Among them, the flood problem caused by summer rain is also one trouble that haunts the city. It seriously impacts the urban production and the public life and

causes relatively severe direct and indirect economic losses to the city[1]. Frequent rainfall flood disasters in summer are linked to characteristics of the underlying surface of the city. The underlying surface of the city is divided into two parts, the hard one and soft one: the hard part includes mainly buildings, roads and other facilities and often does not have water permeability; the soft parts include the green land, water systems and so on, and usually have higher water permeability[2]. Most of urban underlying surface is made of hard ingredients. Greater surface runoff will form when there is heavy rainfall intensity. And if rainwater cannot be drained away timely by city water pipes, urban rain flood will be caused.

Most cities have constructed enormous rainwater infrastructures. However, due to the deviations of design capacity, the variations of extreme climate as well as the aging of rainwater facilities and so on, rainfall floods still occur constantly in cities in summer. In order to deal with these problems, western countries have experienced long-term practice and research, ending up with rich achievements: models such as roof rainwater collection system[3], Low-Impact Development[4] and Best Management Practices[5] are widely applied into rainwater management. These models gradually shifts from single external drainage into internal impounding, which is able to not only reduce investment in infrastructures for rainwater but also make full use of rainwater resource and improve water situation within cities. In order to encourage cities to use rainwater resources reasonably, Chinese Ministry of Housing and Urban-Rural Development unveiled the strategy named "Sponge City", which covers sixteen cities such as Wuhan, Nanning and Hebi as the first group of pilot projects. Smart City is also one of the important city strategies put forward by China in recent years. The Ministry of Housing and Urban-Rural Development issued "The Notification about Developing the Pilot Work of National Smart City" in 2012, which aimed at improving the city efficiency and habitable degree through the intellectual technology based on the Internet, the Internet of Things and cloud computing. After years of development, intellectual technology has been widely applied to the fields such as transportation, community, medical treatment and agriculture, etc. It will greatly promote the development of the two causes by organically combining the construction of sponge city and smart city.

Urban community land accounts for about 30% of urban construction land, and it is the main location for the public lives. Construction of Rainwater-friendly community is an important component of the construction of sponge city. How to evaluate the results of constructing Rainwater-friendly community is vital to the development of this cause, thus establishing a corresponding evaluation system is very necessary.There are many ways of project evaluation, such as fuzzy evaluation method and[6] Artificial Neural Networks[7], etc. But these methods are not good for popularization and application because of the rather complicated evaluation process. AHP is a quite effective method which has been proved by practice. This method combines qualitative evaluation and quantitative evaluation together, owning the feature of being flexible and simple[8]. It is very necessary to add the amount of evaluating professors in order to increase the precise degree of AHP evaluating. Therefore, this research use the group decision AHP method to create the system of Evaluation System for Rainwater-Friendly Community Construction Project.

METHODS

Methods and Step

The application range of Group Decision AHP is large, while the technique is also relatively more mature. The steps applied to Evaluation System for Rainwater-Friendly Community Construction Project are as the following:

(1) Conduct deep analysis on the evaluation goals, and screen the influencing factors;

(2) Divide the system into several hierarchy ranks according to the influence factor's category, function difference and membership function;

(3) Establish a multi-level hierarchical structure to determine the level of correlation between adjacent elements in the hierarchical structure. By adopting group decision method, it is up to the experts to make judgements based on their individual understanding. By constructing pairwise comparison judgement matrix and comparing one another on 1-9 scale(Table 1), determine the order of importance of related elements in this layer to certain element in the upper layer: relative weights. The comparison result of every expert has to pass the consistency check namely C.R.<0.1, and when C.R.>0.1, which means it doesn't pass the check, the evaluation will be adjusted by the expert.

Table 1: The evaluation of the scale and meaning of matrix

Scale	Meaning (Comparison between two factors)
1	Same significance
3	The former is more important than the latter
5	The former is obviously more significant than the latter
7	The former is intensively more significant than the latter one
9	The former is extremely more significant than the latter
2 , 4,	Represent the median of the adjacent estimates mentioned above

(4) Synthetic weights of elements of all layers to the systematic target are calculated and sorted overall to determine the significant degree of elements in the lowest layer of hierarchical graph for the general target;

(5) To make appropriate decisions and countermeasures on the basis of analytical computed result.

Index Selection

Building Rainwater-friendly Community is a systematic engineering, which needs each part to cooperate and all kinds of facilities to coordinate.

Absorbability includes such two parts as osmotic absorption and storage. Promoting rainwater absorption is the first step of rainwater resources utilization. We should do our best to accelerate rainwater infiltration and reduce surface runoff by adopting various methods such as improving soil structure, optimizing cropping structure and ameliorating topographic slope. When rainfall exceeds the absorbing capacity of green fields, rainwater storage facilities should be built in proper places to save extra rainwater and to achieve zero rainwater release as much as possible.

Reclamation includes two parts that are purification and utilization. Air of modern city is polluted because of industries with complicated pollutants, usually including: aromatic hydrocarbon and heavy metal, etc. In some raindrops, there are even such harmful substances as pathogenic bacterium and parasites. Since rainwater will be used as landscape water, it must be purified according to its purpose prior to usage[9]; meanwhile, the utilization rate of rainwater is also a significant indicator.

Economy contains construction cost and administration cost. Rain resources utilization needs relatively large investment. Therefore, the construction cost of different plans shall be compared to make sure that the cost-benefit plan is applied. The final-period management of rain resources utilization needs a certain amount of manpower, material resources and financial resources. Therefore, we should reduce final-period management cost as much as possible, which is beneficial for the promotion and application of the technology.

Wisdom includes Wisdom facilities and Wisdom platform construction. Wisdom facilities include various types of sensors, automatic control equipments and communication facilities. Sensors include: soil sensors, meteorological sensors, water level sensors, runoff sensors, pollution monitoring sensors and so on; Automatic control equipments include: automatic control modules, variable frequency pumps, solenoid valve and so on; communication facilities include: 3G/4G networks, WIFI, optical fiber and so on. Wisdom platform includes intelligent softwares as well as hardwares like servers and computers.

Landscape includes facilities aesthetics and environment coordination. Facilities such as rainwater utilization facilities and wisdom facilities should have their own aesthetic characteristics and minimized volumes. Meanwhile, it should keep coordination with the environment as much as possible in terms of specific site selections, colors, materials and so on.

Layered Structure

The most obvious feature of hierarchical structure is to disintegrate a large complex system into several one-way dependent layers, which means each layer provides a group of functions that only depend on the elements within this layer. Therefore, functions of the level should be reasonably divided and the factors within the level be confirmed. According to the principle of hierarchy, this model constitutes three levels: target layer, the criterion layer and the index layer(Figure 1). The software Yaahp is adopted for calculation, which provides a simple procedural solution for the group-decision AHP method, so that experts could make decisions more easily. Four specialists with senior professional titles respectively from an institution of higher learning, Administration of Gardening and Afforestation, Academy of Urbanism and Urban Planning Administration Bureau were selected to make comments.

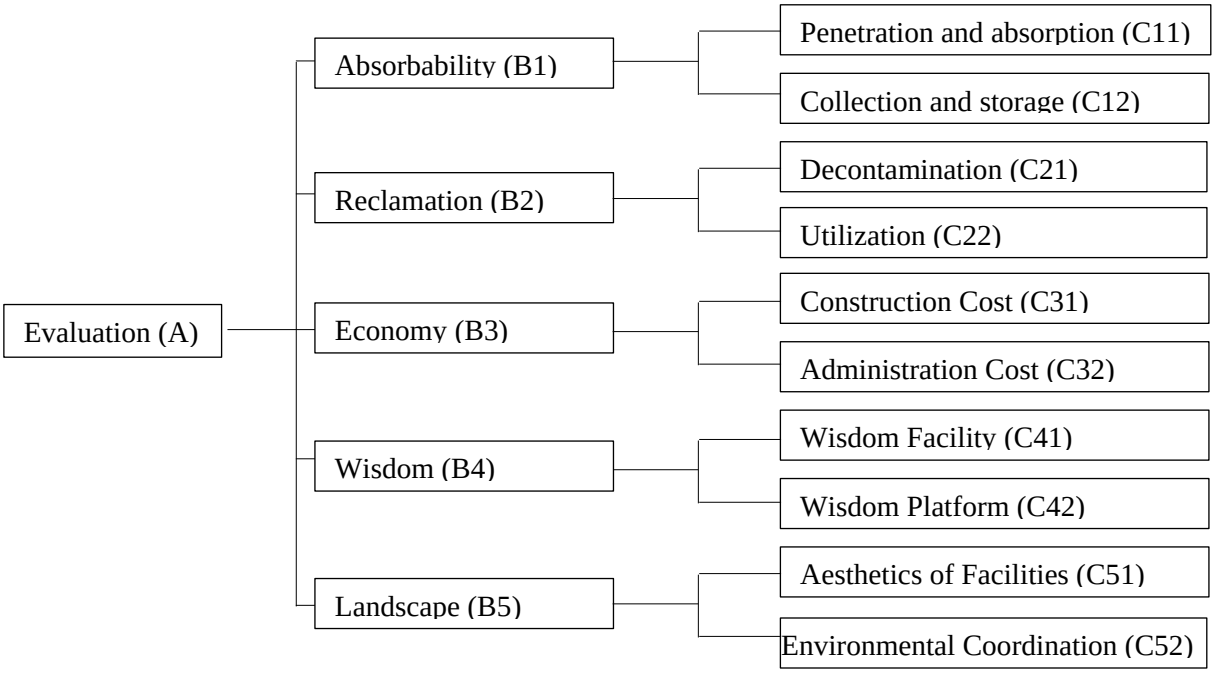
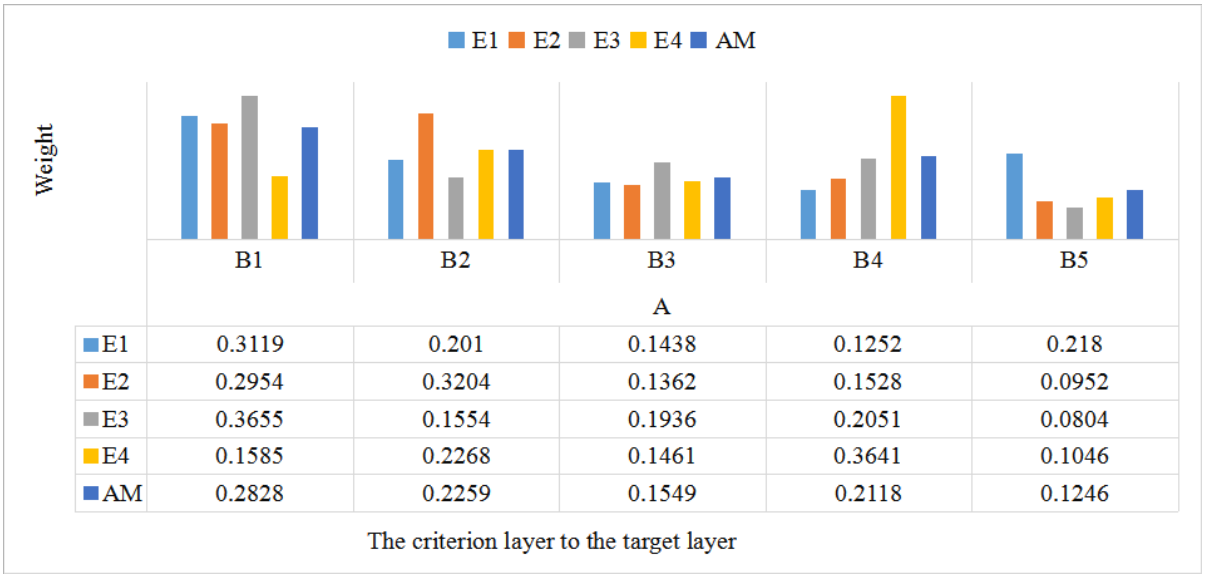


Figure 1: The hierarchical structure diagram of the evaluation system of the rainwater-friendly community construction project

RESULTS AND DISCUSSION

The criterion layer factor for the weight of the target layer (Figure 2): B1>B2>B4>B3>B5. This shows: Absorbing ability is the most important content for the utilization of the community rainwater. Only through the maximum absorption of rainwater resources can the surface runoff be effectively reduced. How to cleanly and effectively utilize the rainwater resources is also an important indicator to measure the Rainwater-friendly Community. The integration of wisdom technology can improve the efficiency of rainwater management. Although the weights of the economy and landscape are low, they are also part of the requirements that must be met.

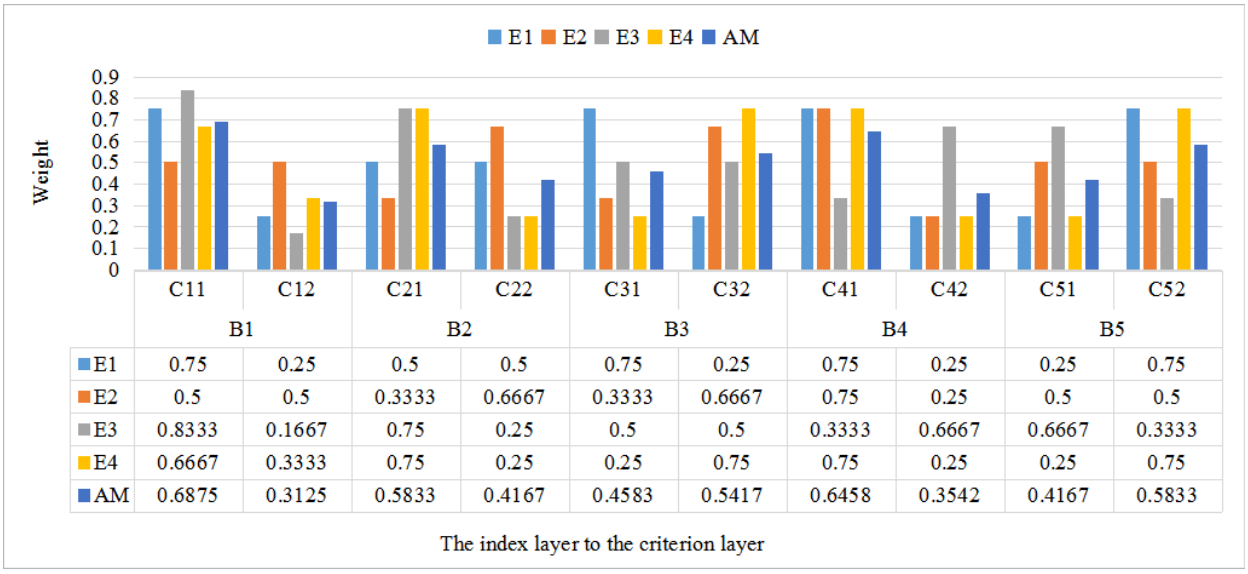


	B1	B2	B3	B4	B5
E1	0.3119	0.201	0.1438	0.1252	0.218
E2	0.2954	0.3204	0.1362	0.1528	0.0952
E3	0.3655	0.1554	0.1936	0.2051	0.0804
E4	0.1585	0.2268	0.1461	0.3641	0.1046
AM	0.2828	0.2259	0.1549	0.2118	0.1246

The criterion layer to the target layer

Figure 2: The weights of criterion layer to that of the target layer

There is also a big difference in the weights of index layer index to that of criterion layer (Figure 3).



	C11	C12	C21	C22	C31	C32	C41	C42	C51	C52
	B1		B2		B3		B4		B5	
E1	0.75	0.25	0.5	0.5	0.75	0.25	0.75	0.25	0.25	0.75
E2	0.5	0.5	0.3333	0.6667	0.3333	0.6667	0.75	0.25	0.5	0.5
E3	0.8333	0.1667	0.75	0.25	0.5	0.5	0.3333	0.6667	0.6667	0.3333
E4	0.6667	0.3333	0.75	0.25	0.25	0.75	0.75	0.25	0.25	0.75
AM	0.6875	0.3125	0.5833	0.4167	0.4583	0.5417	0.6458	0.3542	0.4167	0.5833

The index layer to the criterion layer

Figure 3: The weights of index layer index to that of criterion layer

The weights of the index layer to the target layer, that is, in the total order of the level (Figure 4): the weight of C11, C41, C21 is higher, followed by C22, C12, C32, and the weights of other indicators are lower. Description: Penetration and absorption, wisdom facilities as well as decontamination should be put in the first place in the construction of Rainwater-friendly Community. Utilization rate, collection and storage, along with management cost should also be given priority to in the construction of Rainwater-friendly Community.

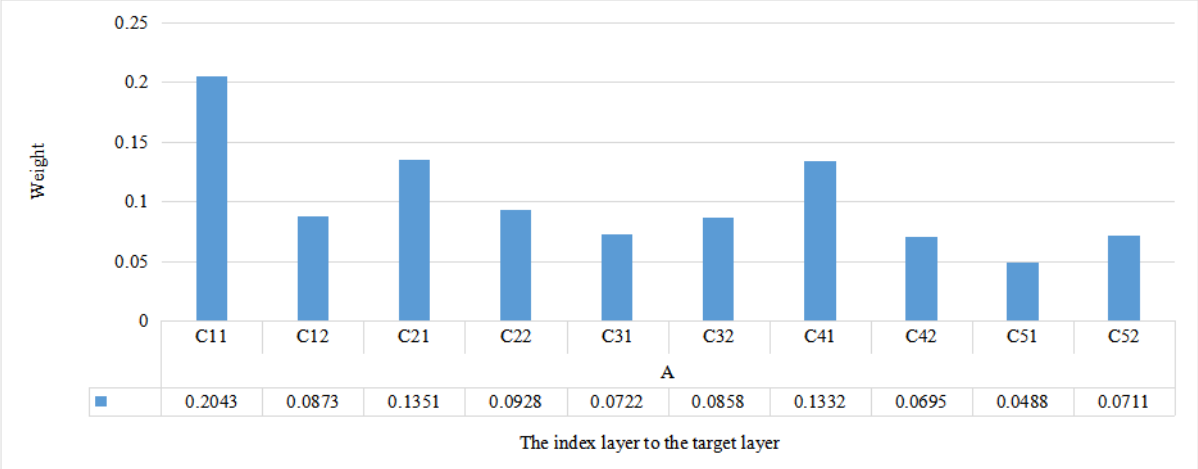


Figure 4: The weights of the index layer to the target layer

CONCLUSIONS

GAHP is a mathematical method based on the idea of pairwise comparison to solve the scheduling problem. It resolves the decision problem into different hierarchical structures, so that we can deal with the complex system problems more accurately. Rainwater-friendly Community is an important component of the spongy city. By utilizing GAHP method, we can consider various factors that affecting the construction of Rainwater-friendly Community comprehensively and the priority of these factors, which will provide basis for the final optimization decision.

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REFERENCES

1. Congying Li: “Ecohydrology and Good Urban Design for Urban Storm Water-logging in Beijing, China”. *Ecohydrology & Hydrobiology*, 2012, 12(4) pp 287-300.
2. Biao Zhang, Gao-di Xie, Na Li, Shuo Wang: “Effect of Urban Green Space Changes on the Role of Rainwater Runoff Reduction in Beijing, China”. *Landscape and Urban Planning*, 2015, 140, pp 8-16.

3. "Water Quality and Public Health Risks Associated with Roof Rainwater Harvesting Systems for Potable Supply: Review and perspectives". *Sustainability of Water Quality and Ecology*, 2015, (6) pp107-118.

4. Chelsea J. Martin-Mikle, Kirsten M. de Beurs, Jason P. Julian, Paul M. Mayer: " Identifying Priority Sites for Low Impact Development (LID) in a Mixed-use Watershed". *Landscape and Urban Planning*, 2014, 140, pp 29-41.

5. Lillian Hayden, Mary L. Cadenasso, Darren Haver, Lorence R. Oki: "Residential Landscape Aesthetics and Water Conservation Best Management Practices: Homeowner Perceptions and Preferences". *Landscape and Urban Planning*, 2015, 144, pp 1-9.

6. Guichao Fan, Denghua Zhong, Fugen Yan, Pan Yue: "A Hybrid Fuzzy Evaluation Method for Curtain Grouting Efficiency Assessment based on an AHP Method Extended by D Numbers", *Expert Systems with Applications*, 2016, 44 pp 289-303.

7. Nouri, Yousef, A. Janalizadeh Choobbasti, Ali Kaveh: "Soil Profile Prediction Using Artificial Neural Networks", *Electronic Journal of Geotechnical Engineering*, 2014, 9(E) pp 9799-9807. Available at ejge.com.

8. Khadija Gdoura, Makram Anane, Salah Jellali: "Geospatial and AHP-multicriteria Analyses to Locate and Rank Suitable Sites for Groundwater Recharge with Reclaimed Water", *Resources, Conservation and Recycling*, 2015, 104, Part A, pp 19-30.

9. Guillaume Tixier, Michel Lafont, Lee Grapentine, Quintin Rochfort, Jiri Marsalek: "Ecological Risk Assessment of Urban Stormwater Ponds: Literature Review and Proposal of a New Conceptual Approach Providing Ecological Quality Goals and the Associated Bioassessment Tools", *Ecological Indicators*, 2011, 11, pp 1497-1506.

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