Evaluating the Effectiveness of Urban Ecological Pond Management in Taipei Metropolitan Area, Taiwan

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Abstract: This study aims to promote environmental education for urban residents by integrated three ponds planning (referred as ITPP) to provide visitors realizing the effects on environment by sightseeing process. In this research we first reviewed literatures and then interviewed with experts by questionnaire using AHP method. Results show that there are four themes and associated benchmarks in ITPP: (1) resource recycling and wetland purification: water resource reuse, urban wetland dispose wastewater, water quality purification; (2) infiltration and hydrological circulation: infiltration and mitigation of storm rain, hydrological circulation; (3) biodiversity, urban microclimate, and environmental education: urban biodiversity and associated microclimate; and (4) aesthetic feeling of landscape: landscape beauty. These four themes expressed by AHP questionnaire data in the Song-Shan Cigarette Factory of Taipei city can be ranked and weighted collectively for 36.75%, 23.04%, 27.88% and 11.59 %, respectively. In addition, the limiting factors in designing ecological pond include: (1) urban residents lacking of knowledge and consciousness in water cycling; (2) very few ecological ponds in urban area; and (3) no actively encouragement by local government. The method may be helpful to landscape architect, environmental education experts and decision-maker in government for sustainable water environment planning.

Keywords: AHP questionnaire, Ecological pond, Environmental education, Constructed wetland; Storm rain.

1. Introduction

The rapid urbanization process of Taipei, like in many other Asian countries, has been going on for a long time and at present around 80% of the Taipei population lives in urban areas. This creates a high pressure on the remaining nature areas in urban regions. Under current trend, by 2020 60% of the world's population will be living in urban, making the improvement of urban water infrastructure a particularly pressing issue [14]. Moreover, a severe drought threat happened lately in Taiwan; many efforts, such as WRA [15], Shiau [12], were made to establish drought contingency plans for municipal water supply systems. Potentially increasing risk comes from water shortage, and the impact from global change [4] and local urban heat island seriousness [8-9, 11] that both make mitigate the waste water an important issues in Taipei. Furthermore, for achieving a sustainable development, impacts on urban biodiversity, new infrastructure projects and other land use changes have to be considered on landscape and regional scales [10]. This requires important decisions to be made after a systematic evaluation of environmental impacts.

Nevertheless, urban ponds built with plastic or concreted materials can be found everywhere that not only deteriorate natural and semi-natu1ral water vegetation but also waste the water resource recycling, and water infiltration [5] benefit to hydrological cycle. Both pond types can not offer living conditions for a variety of water species, and are therefore not essential for maintaining biodiversity. It makes these ponds prone to a continuous fragmentation process and loss of habitat quality and its natural beauty. Therefore an assessment of ecological pond management strategy in urban areas is very urgent and important. To approach this assessment we focused on developing methods and on integrating biodiversity issues in planning and strategic environmental evaluation in urban environment, landscape and related levels. For assessing ecological pond management strategy in urban areas we adopted the analytic hierarchy process (referred as AHP) that were applied in diverse fields by these authors [13, 16] using questionnaire survey to obtain important management levels.

In urban, as a result of population growth and degradation of resources, freshwater supply suffers increasing pressure. Farina [2] pointed out landscape ecology should be more inclusive than the ecosystem level, as it is a collection of ecosystems. Again, the integration of water resource recycling by purifying waste water and by promoting biodiversity issues requires an effectively planning assessment, as the AHP, to help residents and local government in considering these interdisciplinary complicated problems. Thus suitable and accessible urban landscape area was planned in ITPP by linking habitat networks with core areas sufficient for species' persistence, integrated sewage disposer and the landscape beauty all together [3]. In addition, Lin, et al. [7] showed that AHP and factor analysis were used to assist in identifying the most crucial factors and attributes affecting the construction industry safety management system (SMS).

Regarding to wetland system construction, Laber [6] redesigned an eleven-year old storm water treatment at Stammesdorf near Vienna to obtain required parameters for the new design. Online measurements at the inlet of the system of water flow and some physical parameters were undertaken as well as sampling and analysis of the inlet water. Zhang, et al. [17] measured and evaluated the interactions among various variables in the complex urban ecosystem (CUE). They adopted two potential ways to purify the metabolites produced by the CUE: (1) reclamation of wastes, and (2) making wastes harmless for the natural ecosystem. In this study three kinds pond of main material included concreted, plastic and natural were planned and evaluated. The foundation of concrete construction pond must be solid and reinforced to prevent cracking. The plastic material is also called flexible liners and is the most popular way of creating a garden pond. Flexible Liners come with two types - PVC and rubber [1]. The two kinds of ponds are popular in Taiwan.

To promote environmental education for urban residents by ITPP planning by providing visitors in realizing the effects on environment on sightseeing process, this study is focused on: (1) reviewing literatures and then interviewing with experts by questionnaire using AHP method; (2) integrating a landscape ecological pond assessment (LEA) strategy; and (3) demonstrating the application of a LEA in Taipei metropolitan area.

2. Site and method

We received 14 expert questionnaires from 15 issues, thus the recovery rate is 93.33%. There were total 13 valid questionnaires after CR value consistency test that used for AHP analysis. There are 35 variables (Table1) were chosen by experts, using Delphi method, for the assessment of ecological pond. The eight middle level benchmarks were acquired from 108 questionnaires by factor analysis. Cultural Park of Song-Shan Cigarette Factory located at Eastern District of Taipei (Fig.1). Three kinds of ponds with different materials were planned, in this study, from the viewpoint of environmental education. The system includes a pond with cement material covering its bottom and surrounding wall, the second is a pond laid with plastic material on its bottom to prevent polluted water infiltrated into groundwater aquifer, and the third is an ecological pond with natural material and full of aquatic plantations.

The ecological pond designed in constructed wetland can provide a function for water quality purification and serve as a good example for environmental education. Through the processes of physical filter, biological purification, natural settlement, natural aeration etc., the ecological pond can not only purify the waste water from buildings of Cultural Park and water landscape, but also help visitors learn how to purify the water quality by aquatic plantation as well as by water recycling in urban area.

3. Weight value of low level hierarchy

The low level dimensions of this study were derived from the secondary benchmarks coming from the combination of the four upper level dimensions with the eight middle level benchmarks. In other words, the ecological pool benchmark system is a "base level benchmark" which implies it is important for the base level dimensions. In this paper we analyzed the levels of the basic benchmarks that not only are similar to the upper level and middle level benchmarks, in terms of hierarchy, quality with finer quantitative degrees but are linked to a certain degree. For benchmarks in the same level, the effects of the different dimensions are minimal while the combination and complexity of the upper and middle levels are more complicated. Due to the large number of the benchmarks, the study investigated the corresponding dimensional weights and absolute weight dimensions of the low level benchmarks. At the same time, we paid attention on a basic and overall analysis of the four upper level dimensions.

The related analytical dimensions included: (1) three urban wastewater resource reuse dimensions of the low level benchmark (Fig. 2); (2) two infiltration and hydrological circulation dimensions of the low level benchmark; and (3) two biodiversity and environmental education dimensions of the low level benchmark; and (d) the single aesthetic feeling of landscape dimension of the low level benchmark. Fig. 2 shows four upper level dimensions toward an ecological pond in Taipei city. It includes (a) urban wastewater resource reuse dimensions; (b) infiltration and hydrological circulation dimensions; (c) biodiversity and environmental education; and (4) aesthetic feeling of landscape. Table 2 expresses relative weight of concerted pond and plastic pond. This demonstrates both are less benefit to environment. Fig. 3 demonstrates the weight of 35 ecological pond variables using AHP method in Taipei city, Taiwan. Fig. 4 shows the comparison for plastic and concreted ponds in "not purifying water quality", "not mitigating storm rain", and "not benefit to hydrological circulation" in ecological pond convey in Taipei city, Taiwan. The left column of Fig. 4 shows absolute weights of the 6 benchmarks in these two ponds. Shown in Fig. 5 is the opinion of 13 experts about the ecological pond that has not yet been popularized in Taipei. Nine items were listed in the questionnaire. The "lacking of ecological knowledge" is the highest numbers of supporters with 12 votes. Two followed items are "being much influenced by local climate" and "scarce of ecological pond built". It suggests the ecological pond promotion as considering tropical climate in Taipei is highly significant.

3.1 Low level benchmark in urban water resource reuse

3.1.1 Water resource reuse dimension

Nine variables in this dimension were ranked and weighted collectively for 24.2%, 10.46%, 10.14%, 9.96%, 9.85%, 9.38%, 9.23%, 8.59%, and 7.32%, respectively. Three most high weighted variables were discussed. The corresponding ratio of weight of "water resource reuse in ecological pond" is 24.20%, ranking as number one. Two followed variables are "not recharging to underground water in plastic pond" and "separating other biological communities in concreted pond" respectively. It means non-ecological pond design including plastic or concreted pond is not benefit to underground and biological community. The non-ecological pond water isolated by the material of plastic or concreted can not infiltrate and interact with surrounding soil.

3.1.2 Urban wetland dispose wastewater dimension

Ten variables in this dimension were ranked and weighted collectively for 12.67%, 11.80%, 11.72%, 11.06%, 9.62%, 9.02%, 8.79%, 8.78%, 8.31%, and 8.00 %, respectively. Three most high weighted variables were discussed. The corresponding ratio of weight for "remediate water environment in ecological pond" is 12.67%, ranking number is the first. Two followed variables are "benefit to biodiversity in ecological pond" and "circulating reuse water in ecological pond". It means that circulating reuse water can remediate water and is also good for biodiversity.

3.1.3 Water quality purification dimension

Four variables in this dimension were ranked and weighted collectively for 32.27%, 26.82%, 22.60%, and 18.31 %, respectively. Three most high weighted variables were discussed. The corresponding ratio of weight for "effectively enhancing biodiversity in ecological pond" is 32.27%, ranking order is the first. Followed variable is "cultivating water plantation can promote water ecology". It means that in ecological pond both biodiversity and cultivating water plantation circulating can effectively help water quality purification.

3.2 Low level benchmark in infiltration and hydrological circulation

3.2.1. Infiltration and mitigating storm rain dimension

Two variables in this dimension were ranked and weighted collectively for 55.40%, and 44.60 %, respectively. The corresponding ratio of weight for "not mitigating storm rain by infiltration in concreted pond" is 55.40%, ranking order is the first. Followed variable is "not mitigating storm rain by infiltration in concreted pond". It means that non-ecological pond can not effectively mitigate storm rain by infiltration.

3.2.2 Hydrological circulation dimension

There are two variables in this dimension were ranked and weighted collectively for 52.00%, and 48.00 %, respectively. The corresponding ratio of weight of "not benefit to hydrological circulation in concreted pond" is 52.00%, ranking number is first. Followed variable is "not benefit to hydrological circulation in plastic pond". It means that in non-ecological pond is "not benefit to hydrological circulation.

3.3 Low level benchmark in biodiversity, and environmental education

3.3.1. Biodiversity and urban microclimate dimension

Four variables in this dimension were ranked and weighted collectively for 52.24%, 47.76%, 26.82% and 20.30%, respectively. The corresponding ratio of weight for "not purifying water quality in concreted pond" is 52.24%, ranking order is the first. Followed variable is "not purifying water quality in plastic pond". It means non- ecological pond can not purify water quality.

3.3.2. Promoting environmental education dimension

Two variables in this dimension were ranked and weighted collectively for 26.90%, and 26.00 %, respectively. The corresponding ratio of weight for "enhance environmental education for public" is 26.90%, ranking order is the first. Followed variable is "help environmental education for public". It means that ecological pond can effectively promote environmental education involved ecological concept for local residents.

3.4 Low level benchmark in aesthetic feeling of landscape

3.4.1 Landscape beauty dimension

Two variables in this dimension were ranked and weighted collectively for 66.28%, and 34.86 %, respectively. The corresponding ratio of weight for "having nature beauty found in ecological pond" is 66.28%, ranking order is the first. Followed variable is "concerning in landscape beauty in ecological pond". It means that ecological pond exists as nature beauty.

4. Conclusion

AHP provides a systematic procedure that encourages the exploration of data and priority settings and aims to quantitatively address three types of ecological pond levels of waste water reuse issues in Taipei area. Results show that there are four dimensions and associated benchmarks in ITPP: (1) resource reuse and wetland purification: water resource reuse, urban wetland dispose wastewater, water quality purification; (2) infiltration and hydrological circulation: infiltration and mitigation storm rain, hydrological circulation; (3) biodiversity, urban microclimate, and environmental education: biodiversity and urban microclimate; and (4) aesthetic feeling of landscape: landscape beauty. These four dimensions expressed by AHP questionnaire data in Taipei city can be ranked and weighted collectively for 36.75%, 23.04%, 27.88% and 11.59 %, respectively. Overall, the method integrating AHP and ecology landscape design by the viewpoint of environmental education is a novel idea. It may be helpful to further urban environment for sustainable planning. In order to be able to make reliable planning it is important to further survey opinions in this ITPP by questionnaire from local residents who are representatives on environmental education.

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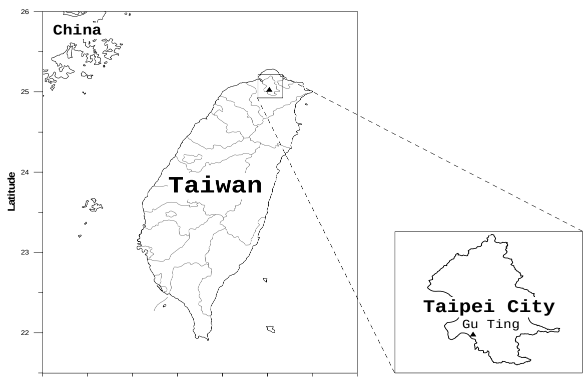

Fig. 1. Location of ecological ponds in Taipei city of Taiwan.

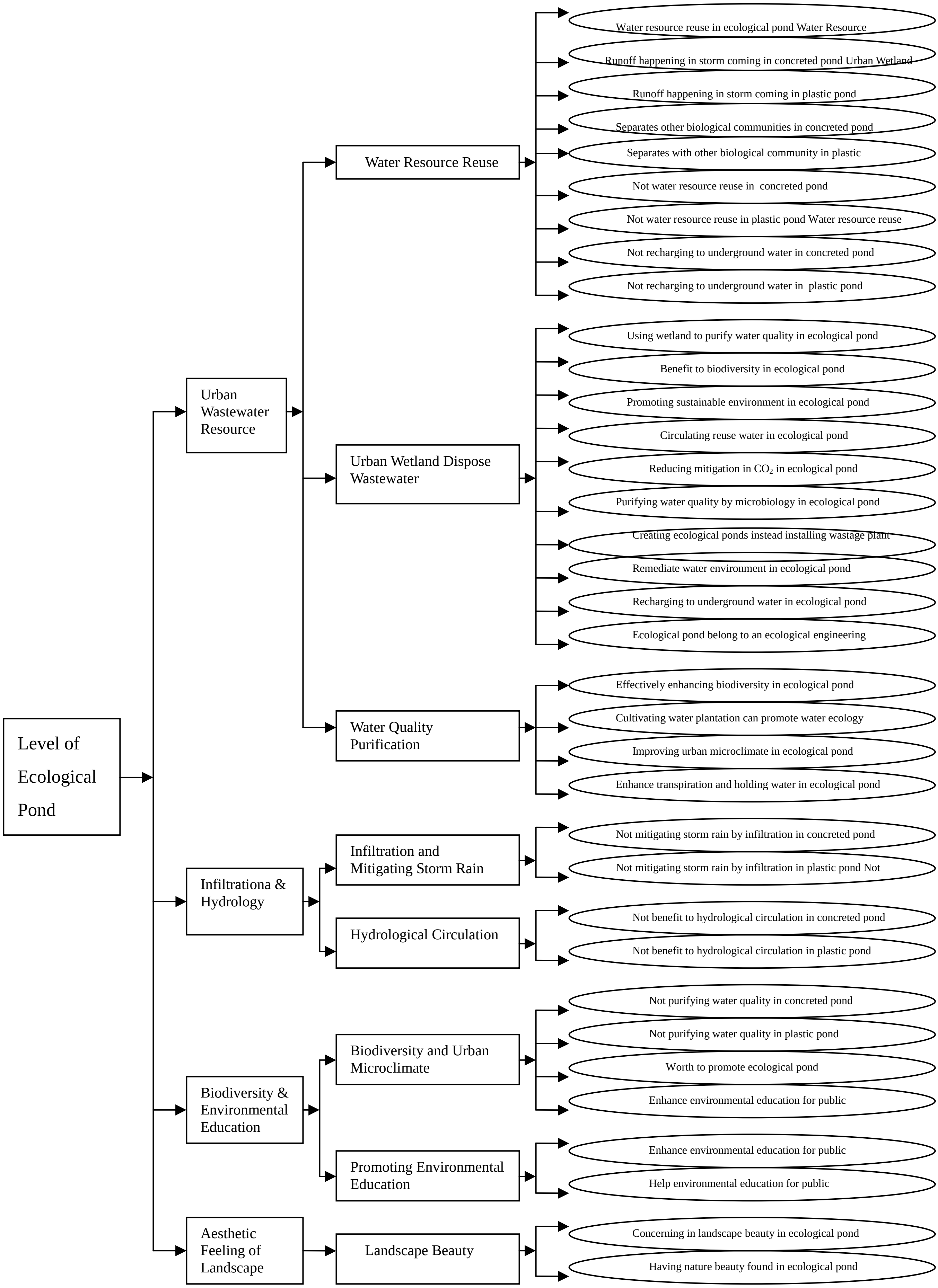

Fig. 2. Levels of an ecological pond design study using FAHB method in Taipei city of Taiwan.

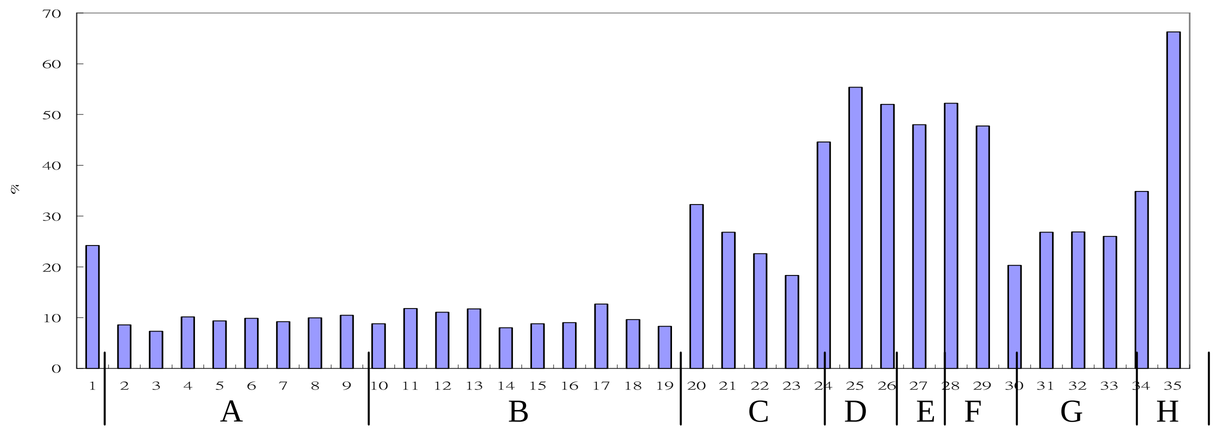

Fig. 3. Levels of ecological pond in Taipei city, Taiwan, left column shows relative weight of the 35 benchmarks. Arabic number in the bottom of this figure presents the number of benchmark same as listed in the first column of Table 1. Characters A~H indicates eight middle level as Fig. 2.

Table2 Relative weights of considered concerted pond and plastic pond.

Related benchmark	Concreted pond	Plastic pond
Runoff happening in storm	54.00	46.00
Separates other biological communities	51.95	48.05
Not water resource reuse	51.90	48.10
Not mitigating storm rain by infiltration	55.40	44.60
Not benefit to hydrological circulation	52.00	48.00
Not purifying water quality	52.24	47.76
Average of relative weight	51.12	48.89
Standard deviation	3.290	3.290

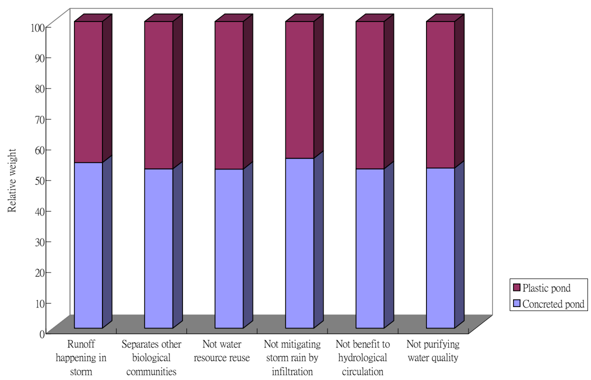

Fig. 4. The comparison between plastic pond and concreted pond in "not purifying water quality", "not mitigating storm rain", and "not benefit to hydrological circulation" in this study. Left column shows relative weight of six related benchmarks as table 2 in two ponds.

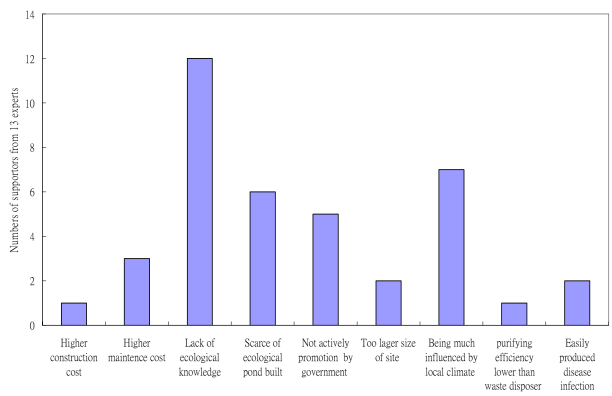

Fig. 5. The opinion of 13 experts about the ecological pond indicates it has not yet been popularized in Taipei. Nine items were listed as questionnaire. It suggests the ecological pond promotion considering tropical climate in Taipei is highly significant.