Application of GDAHP on Quality Evaluation of Urban Lake Landscape

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Abstract

The quality evaluation of urban lake landscape (QEULL) is extremely important for the healthy development of lake landscape. In this research, the evaluation model was established with the group decision analytic hierarchy process (GDAHP) method, which consisted of four layers including the target layer, the factor layer, the index layer and the criterion layer, thus forming a model tree based on their subordinate relationships. The GDAHP method was employed to determine the weights of constituting factors of each layer in the evaluation model, and the fuzzy method was used to establish the factors remark sets of the criterion layer, thus the single-layer evaluation and comprehensive evaluation of urban lake landscape quality was carried out. Quality evaluation model of urban lake landscape established based on the GDAHP method can provide grounds for planning, design, and renewal of urban lake landscape. This model has been used to evaluate and analyze the artificial lake in People’s Park of Xinxiang City, Henan Province. The results proved that the overall landscape quality of the artificial lake of Peoples Park in Xinxiang city was good.

Keywords: Quality Evaluation, Urban Lake Landscape, GDAHP

1. Introduction

The urban lake is an important type of wetland, playing a crucial role in maintaining eco-balance, protecting biodiversity, preserving fresh water resources, regulating and storing flood waters, adjusting the climate, replenishing underground water, degrading pollutants, and providing important resources for our life, production and social development [1]. In addition, it also has social functions including relaxation [2], entertainment and economic ones such as tourism development [3]. Modern urban residents show a keen interest in water landscapes, especially lakes [4]. In order to satisfy such needs, a large number of lakes have been constructed in many cities. In spite of the achievements, there have existed many problems in lake landscape construction [5,6], in some, eco-protection was overemphasized while the public needs of traveling and relaxation were ignored; in others, the development was totally centered on relaxation and entertainment while the construction requests of the ecological environment have been neglected. Such problems have seriously undermined the healthy development of lake landscapes. Therefore, how to accurately evaluate the quality of lake landscape to provide grounds for planning and design as well as renewal and construction of such landscape has become a project deserving research. Zhang Fengling and others thereby have established the appraisal standards for urban river and lake ecological health [7].

The quantifiable methods have the features of accuracy and easy for comparison, therefore it will be a wide prospect applying it in the QEULL.

The AHP was first introduced by Saaty in 1971 to solve the scarce resources allocation and planning needs for the military [8]. Since its introduction, the AHP has become one of the most widely used multiple-criteria decision-making methods, and has already been applied in many field such as political, economic, social, management sciences, industrial controlling, engineering, medicine and mining industry etc.

For some complicated decision problems, in order to avoid the mistakes and to improve the accuracy, it is needed to rely on the wisdom of a group of experts to make a decision.

2. Methods

In this research, a model was established with the GDAHP method. Details steps are as follows.

Step 1: To establish the pairwise matrix $A$:
where \( w_i \) is the relative importance of the \( i \)th index of the index layer, as shown in Table 1.

Step 2: To calculate the product of each line \( M_i \):

\[
M_i = \sum_{j=1}^{n} a_{ij} \quad (i = 1, 2, \ldots, n) \quad (2)
\]

Step 3: To calculate the \( n \)th roots \( \bar{W}_i \) of \( M_i \):

\[
\bar{W}_i = \sqrt[n]{M_i} \quad (i = 1, 2, \ldots, n) \quad (3)
\]

Step 4: To obtain the weight of the \( i \)th evaluation index \( W_i \) by standardizing the \( \bar{W}_i \):

\[
W_i = \frac{\bar{W}_i}{\sum_{i=1}^{n} \bar{W}_i} \quad (4)
\]

Step 5: Consistency check:
The maximum eigen value \( \lambda_{\text{max}} \) is:

\[
\lambda_{\text{max}} = \frac{1}{n} \sum_{i=1}^{n} (AW_i) = \frac{1}{n} \sum_{i=1}^{n} a_{ii} W_i \quad (5)
\]

The consistency index (CI) is:

\[
CI = \frac{\lambda_{\text{max}} - n}{n} \quad (6)
\]

The consistency ratio (CR) is:

\[
CR = \frac{CI}{RI} \quad (7)
\]

where \( RI \) is the random index (Table 2). If \( CR \leq 0.1 \), it means that evaluations tend to be consistent. For multiple levels, \( CRH < 0.1 \) should be satisfied, and

\[
CRH = \frac{CIH}{RIH} \quad (8)
\]

where \( CIH \) is the consistency index of the hierarchy, \( RIH \) is the random index of the hierarchy, and \( CRH \) is the consistency ratio of the hierarchy.

According to Step 1 to Step 4, the local weights (LW) of each layer and the global weights (GW) are obtained, and the consistency check is tenable based on Step 5.

Step 6: Synthesize the fuzzy comprehensive evaluation result-vector \( B \). Synthesize \( A \) and \( R \) of each evaluated object with the appropriate operator, and obtain the fuzzy comprehensive evaluation result-vector of each evaluated object:

\[
B = A \circ R = (b_1, b_2, \ldots, b_m) \quad (9)
\]

Step 7: Calculate the value \( S \), determine the quality ratings of lake landscape, and thus conduct its analysis.

\[
S = B \cdot Med. \, V \quad (10)
\]

### 3. Establish the Evaluation Model—With the Artificial Lake of People’s Park in Xinxiang City

#### 3.1. Establish the Evaluation Factor Set

There are many factors influencing the QEULL. The indices which can reflect essentially the sustainable development of urban lake landscape should be selected and the tree of the QEULL was established (Table 3).

| Rank | 1   | 2   | 3   | 4   | 5   |
|------|-----|-----|-----|-----|-----|
| R. I.| 0   | 0   | 0.52| 0.89| 1.12|
| Rank | 6   | 7   | 8   | 9   | 10  |
| R. I.| 1.26| 1.36| 1.41| 1.46| 1.49|

### Table 1. The relative importance scales of AHP.

| Relative importance | Scaled value |
|---------------------|-------------|
| Extremely important | 9           |
| Especially important| 7           |
| Obviously important | 5           |
| Fairly important    | 3           |
| Equally important   | 1           |
| Fairly not important| 1/3         |
| Not important       | 1/5         |
| Less important      | 1/7         |
| Minimally important | 1/9         |

### Table 2. Values of random consistency index RI.

| Rank | 1   | 2   | 3   | 4   | 5   |
|------|-----|-----|-----|-----|-----|
| R. I.| 0   | 0   | 0.52| 0.89| 1.12|
| Rank | 6   | 7   | 8   | 9   | 10  |
| R. I.| 1.26| 1.36| 1.41| 1.46| 1.49|

#### 3.2. Establish the Fuzzy Remark Set

Establish the fuzzy remark set \( V = \{v_1, v_2, v_3, v_4, v_5\} = \{\text{Excellent, Good, Mediocre, Bad, Very bad}\} \), and
respectively assign the value \( V_{ij} = \{80 \leq v_{ij} < 100, 60 \leq v_{ij} < 80, 40 \leq v_{ij} < 60, 20 \leq v_{ij} < 40, 0 \leq v_{ij} < 20\} \). Med.\( v_{ij} = \{90, 70, 50, 30, 10\} \). Evaluation standards of criterion layer see Table 4.

3.3. Questionnaire

10 sheets of questionnaire were handed out to the experts of landscape planning from Henan Agriculture University, Henan Institute of Science & Technology and Zhengzhou University, etc, to determine the relative importance of each criterion. These experts between 40-60 years old have rich experience because they were engaged in the teaching, research and practice about lake landscape planning and design for a long time, all of them have managed the large-scale lake landscape planning and design directly.

3.4. Weight and the Expert Evaluation

The artificial lake of the People’s Park in Xinxiang City has an area of 7.3 hectares, accounting for 15% of the whole area of the park, and playing the important roles of purifying water quality, regulating partial climate and providing entertainment and sightseeing, etc.

The weights of indices of each layer and the expert ratings are shown in Table 5.

4. Evaluation Results

4.1. Single Evaluation Results

The results (Table 6) were obtained in accordance with

| Table 4. Evaluation standards of criterion layer. |
|-----------------------------------------------|
| criterion layer (21 indices) | Evaluation standard |
| Shoreline | Winding and zigzagging; bending; straight-line form |
| Embankment | Close-to-natural grass slope embankment; stone embankment; concrete embankment |
| Community | Close-to-natural community with a combination of trees, shrubs and grasses and abundant facades; community |
| Plant species | More than 150; between 70 and 150; less than 70 |
| Water content | Enough water; moderate; not enough |
| Water quality | Clear and tasteless; a little turbid and odorous; serious pollution |
| Aquatic biology | Rich variety; moderate; lacking |
| Width of vegetation zone | More than 50 m; between 20 m and 50 m; less than 20 m |
| Coverage of vegetation zone | More than 70%; more than 40%; less than 40% |
| Space | Reasonable spatial organization; moderate; disorderly |
| Facilities | Enough facilities; moderate; lacking |
| Illumination | Meets safety and landscape requirements; only meets safety requirements; not safe |
| Hydrophilicity | Experiences sufficient hydrophilicity; moderate; lacking |
| Safety | No hidden danger; a little hidden danger; unsafe |
| Activities | Abundant; moderate; poor |
| Sense of beauty | Very beautiful; moderate; unbeautiful |
| Culture | Sufficient cultural features; moderate; none |
| Accessibility | Connection with urban trunk road; connection with urban branch road; without connection |
| Public traffic | Very convenient; moderate; not convenient |
| Connection | No disconnection; occasional disconnection; frequent disconnection |
| Comfort level | Fine; general; bad |
Table 5. Comprehensive evaluation results and Specialist comments.

| Comprehensive evaluation results | Specialist comments |
|----------------------------------|---------------------|
| U | U_i | LW | U_j | LW | GW | v_1 | v_2 | v_3 | v_4 | v_5 |
|---|-----|----|-----|----|----|-----|-----|-----|-----|-----|
| SH | 0.225 | 0.0121 | 3/10 | 2/10 | 4/10 | 1/10 | 0/10 |
| EM | 0.775 | 0.0419 | 5/10 | 3/10 | 2/10 | 0/10 | 0/10 |
| CO | 0.829 | 0.2372 | 3/10 | 4/10 | 1/10 | 2/10 | 0/10 |
| SP | 0.171 | 0.0484 | 2/10 | 3/10 | 3/10 | 2/10 | 0/10 |
| WC | 0.237 | 0.0883 | 7/10 | 2/10 | 1/10 | 0/10 | 0/10 |
| W | 0.163 | 0.2586 | 9/10 | 1/10 | 0/10 | 0/10 | 0/10 |
| N | 0.332 | | | | | | | | |
| V | 0.838 | | | | | | | | |
| AE | 0.866 | | | | | | | | |
| E | 0.432 | | | | | | | | |
| TE | 0.134 | | | | | | | | |
| L | 0.179 | | | | | | | | |
| FU | 0.854 | | | | | | | | |
| PF | 0.146 | | | | | | | | |
| IT | 0.583 | | | | | | | | |
| T | 0.057 | | | | | | | | |
| ET | 0.417 | | | | | | | | |

It can be concluded from the above single evaluation results (Table 6) that among the landscape quality of the artificial lake of People’s Park in Xinxiang, the ecological factor was excellent, and the ecological, landscape and communication factors were good.

4.2. Comprehensive Evaluation Results

\[ S(B_j) = 90 \times 0.2829 + 70 \times 0.3829 + 50 \times 0.1342 + 30 \times 0.2 + 10 \times 0 = 65 \]

\[ B_i = (0.163, 0.838)^T \begin{bmatrix} 0.455 & 0.2775 & 0.245 & 0.0225 & 0 \\ 0.2829 & 0.3829 & 0.1342 & 0.2 & 0 \end{bmatrix} = (0.3112, 0.3661, 0.1524, 0.1713, 0) \]

\[ \sum(B_i) = 90 \times 0.3112 + 70 \times 0.3661 + 50 \times 0.1524 + 30 \times 0.1713 + 10 \times 0 = 66.4 \]

Table 6. Index weight value of modification.

| B_i | S | B_i | S |
|-----|---|-----|---|
| 0.3112, 0.3661, 0.1524, 0.1713, 0 | 66.4 | 0.455, 0.2775, 0.245, 0.0225, 0 | 73.3 |
| 0.7281, 0.1409, 0.0974, 0.0159, 0.0179 | 80.9 | 0.2829, 0.3829, 0.1342, 0.2, 0 | 65.0 |
| 0.4002, 0.2643, 0.1644, 0.1635, 0.0085 | 67.7 | 0.1817, 0.2, 0.4183, 0.1183, 0.0817 | 55.6 |
| 0.3833, 0.3430, 0.1627, 0.0659, 0.0452 | 69.1 | 0.2677, 0.1979, 0.5028, 0.0163, 0.0163 | 63.7 |
| 0.3833, 0.3430, 0.1627, 0.0659, 0.0452 | 69.1 | 0.2675, 0.4775, 0.0775, 0.1, 0.0775 | 65.2 |
| 0.3833, 0.3430, 0.1627, 0.0659, 0.0452 | 69.1 | 0.5451, 0.1549, 0.2817, 0.0183, 0 | 74.5 |

The results proved that the overall landscape quality of the artificial lake of Peoples Park in Xinxiang city was good.
5. Conclusions

1) In this research, the evaluation model is established with the GDAHP method, which consists of four layers including the target, the factor, the index and the criterion, thus forming a model tree based on their subordinate relationships. The GDAHP method is employed to determine the weights of constituting factors of each layer in the evaluation model, and the Fuzzy method to establish the remark sets of factors of the criterion layer, thus the single-layer evaluation and comprehensive evaluation of urban lake landscape quality is carried out.

2) Application of quantitative methods in the quality evaluation of urban lake landscape in this research has remedied the disadvantages of subjective evaluation, improving efficiency and accuracy. This model can be employed to compare the landscape quality of different lakes as well as for the optimal selection of different plans for the same lake landscape.

3) This model has been used to evaluate the landscape quality of a lake in Xinxiang city, Henan province and analyze the quality of indexes of each layer as well as the overall quality, thus providing grounds for landscape renewal and reconstruction.

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