Evaluation and Optimization of Children’s Recreational Center in Urban Green Public Space Based on AHP-TOPSIS

Yichuan Zhang and Lei Feng

1School of Horticulture and Landscape Architecture, Henan Institute of Science and Technology, Xinxiang, Henan Province, 453003, People’s Republic of China
2Department of Architecture, Henan Technical College of Construction, Zhengzhou, Henan Province, 450064, People’s Republic of China

Abstract: Good educational environment and recreational site are essential to children’s healthy growth. Taking scientific approaches to evaluate and optimize will promote the construction of children’s recreational center. This study constructed an AHP (Analytic Hierarchy Process)-TOPSIS ( Technique for Order Preference by Similarity to Ideal Solution) optimization model which consisted of the following seven influential factors: site safety (x1), amenities (x2), physical space (x3), activity representation (x4), ecological environment (x5), quality of night scene (x6) and consideration given to supervisor (x7). The AHP method was used to determine the weights of each factor and then the values were assigned to the sample cases in accordance with the evaluation criteria. After that, the TOPSIS was employed to sequence and optimize 28 design proposals of children’s recreational centers. The result showed that the decreasing order of the weight of each influential factor of the quality of children’s recreational centers was x1>x2>x3>x4>x5>x6>x7. Moreover, the sequencing of 28 design proposals had a high differentiating ability. The excellent design proposals that had been screened out were featured by a good balance between the core functions of the recreational center and other auxiliary functions. The AHP-TOPSIS combination model can provide scientific basis for optimizing the design proposal of children’s recreational center and for standardizing the construction of children’s recreational center.

Key words: Evaluation, optimization, AHP-TOPSIS, recreational center

INTRODUCTION

A good educational environment and recreational center are guaranteed to children’s healthy growth (Phar et al., 2010). Children’s recreational centers play a pivotal role in children’s healthy growth (Davidson et al., 2010). According to the research, children’s recreational centers can reduce the possibility of children’s obesity and depression (Trost et al., 2011). Outdoor activities can promote confidence, social skills, competition and collaboration in children by creating more opportunities for children to interact with others (Humbert et al., 2006). Urban green public spaces are important places for children to play and have contact with natural environments (Lachowycz et al., 2012). In recent years, the development of children’s recreational centers has drawn increasing attention from the government. Many recreational centers have been for children in urban green public space, which promotes children’s healthy development. However, there are still many children who do not enjoy enough chances to do outdoor activities. Generally, there are problems on children’s recreational sites: (1) The quantity is small, and many urban green public spaces do not reserve special sites for children’s recreation; (2) low safety degree indicates the presence of potential dangers. Accordingly, many parents would rather their children to stay at home; (3) the recreational sites are poorly designed, without fully taking into account of children’s physical and psychological characteristics thus are not attractive to children. Children have distinctive physical and psychological characteristics from adults, which should be used as the basis for the design of children’s recreational sites.

Normally, the design proposals of children’s recreational sites embody designer’s subject perception of the site conditions. Difference in the understandings of designers will result in a diversity of design proposals. Children have preferences to different recreational sites in urban green public spaces than adults do (Lin et al., 2012). In real life, however, many recreational sites cannot satisfy children’s needs very well because of the designer’s negligence. There is design method, but there
is no fixed design format. Although, children's recreation cannot be specified in a concrete form, the intrinsic requirements with regard to children's recreational sites can be obtained based on public survey, so as to promote the standardization of the designs of children's recreational sites. Thus, it is very important to employ appropriate methods to evaluate children's recreational sites in urban green public spaces. Up to now, most existing evaluations on children's recreational sites are case studies or qualitative studies. If there are multiple influential factors involved, it will be very hard to make a choice among proposals. This is why a scientific evaluation approach is important. The AHP-TOPSIS model is a combination of qualitative and quantitative evaluations, providing basis for optimizing design proposals of children's recreational sites.

**RESEARCH CASES AND METHODS**

**Research cases:** A curriculum design competition involving 28 senior undergraduates majoring in landscape design was hosted. The task was to design a 2000-square-meter children's recreational site in Yulongwan community, Xinxiang city, Henan province. The students were allowed to choose any location they prefer within the community. The students were required to carefully analyze the characteristics of children's recreational sites and submit detailed design proposals within deadline.

**Research method and procedures:** The AHP-TOPSIS was used to evaluate and sequence the 28 design proposals of children's recreational sites. AHP (Bao et al., 2012) which is a combination of qualitative and quantitative method, is used to measure the weight of each influential factor. TOPSIS, or technique for order preference by similarity to ideal solution, is a method which sequences the targets by its similarity to ideal solution to evaluate the target.

The set of design proposals of children's recreational sites A and the set of influential factors X were built. The calculating procedures are as follows:

\[ A = \{A_1, A_2, A_3, \ldots, A_n\} \quad (1) \]

\[ X = \{x_1, x_2, x_3, \ldots, x_n\} \quad (2) \]

**Step 1:** Creation of an evaluation matrix. By comparing n influential factors pair wise on the scale from 1 to 9, a relative importance matrix B is created:

\[
B = b_{ij} = \begin{bmatrix}
 b_{11} & b_{12} & \cdots & b_{1n} \\
 b_{21} & b_{22} & \cdots & b_{2n} \\
 \vdots & \vdots & \ddots & \vdots \\
 b_{n1} & b_{n2} & \cdots & b_{nn}
\end{bmatrix}
\]

\[ (i = 1, 2, 3, \ldots; j = 1, 2, 3, \ldots, n) \quad (3) \]

Matrix B has the following properties:

\[ a_{ii} > 0; b_{ij} = \frac{1}{a_{ii}}; b_{jj} = 1 \]

**Step 2:** Determination of the weight of each influential factor. The method of summation is used to calculate the weights of influential factors. First, matrix B is normalized column by column (making the sum of each column equal 1).

\[ e_i = \frac{b_{ij}}{\sum b_{ij}} \quad (4) \]

Then the sum of each row is calculated:

\[ w_i = \sum e_i \quad (5) \]

Finally, the sum is normalized, and then the weight vector \( w_i \) of each factor is obtained:

\[ w_i = \frac{w_i}{\sum w_i} \quad (6) \]

**Step 3 Consistency check:** Consistency check on matrix B is performed. First, the maximum characteristic root \( \lambda_{\text{max}} \) of matrix B is calculated:

\[ \lambda_{\text{max}} = \frac{\sum (e_i w_i)}{w_i} \]

\[ \text{Then C.I. (Consistency Index) is calculated:} \]

\[ \text{C.I} = \frac{\lambda_{\text{max}} - n}{n-1} \]

Finally, C.R. (Consistency Ratio) is calculated:

\[ \text{C.R} = \frac{\text{C.I.}}{R.I.} \quad (9) \]

where, the average random index R.I. can be obtained by checking Table 1. When C.R.<0.1, the consistency check is passed. Otherwise, the experts need to modify the relative importance of the factor.
Table 1: Average random index

<table>
<thead>
<tr>
<th>Dimension</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.I.</td>
<td>0.0</td>
<td>0.0</td>
<td>0.52</td>
<td>0.89</td>
<td>1.12</td>
<td>1.26</td>
<td>1.36</td>
<td>1.41</td>
<td>1.46</td>
<td>1.49</td>
<td>1.52</td>
<td>1.54</td>
<td>1.56</td>
</tr>
</tbody>
</table>

**Step 4:** Creation of weighted matrix first, the scores given by experts are transformed into matrix $A$.

$$
A = \begin{bmatrix}
    x_{11} & \ldots & x_{1j} & \ldots & x_{1n} \\
    \vdots & \ddots & \vdots & \ddots & \vdots \\
    x_{i1} & \ldots & x_{ij} & \ldots & x_{in} \\
    \vdots & \ddots & \vdots & \ddots & \vdots \\
    x_{m1} & \ldots & x_{mj} & \ldots & x_{mn}
\end{bmatrix}
$$

(10)

Then, the matrix is normalized:

$$
Z_q = W_i \times a_q
$$

(11)

$$
a_q = \frac{x_{iq}}{\sqrt{\sum_{j=1}^{n} x_{ij}^2}} (i=1,2,3,\ldots,m; j=1,2,3,\ldots,n)
$$

(12)

**Step 5:** Determination of the ideal solution and negative ideal solution:

$$
Z^+ = (\max_{i} z_{ij} | j \in J_1), (\max_{i} z_{ij} | j \in J_2) | i = 1,2,3,\ldots,m = z_{1^*}, z_{2^*}, \ldots, z_{m^*}
$$

(13)

$$
Z^- = (\max_{i} z_{ij} | j \in J_1), (\max_{i} z_{ij} | j \in J_2) | i = 1,2,3,\ldots,m = z_{1^-}, z_{2^-}, \ldots, z_{m^-}
$$

(14)

where, $J_1$ is a set of benefit indices, which represent the optimal value of the $j$th index. $J_2$ is a set of loss indices, which represent the worst value of the $j$th index. The larger the benefit index, the more favorable the evaluation result would be and the smaller the loss index, the more favorable the evaluation result would be. Otherwise, the more unfavorable the estimation result would be.

**Step 6:** Calculation of the Euclidean distances from the target sample to ideal solution $S^*$ and to negative ideal solution $S^-$, respectively.

$$
S^* = \sqrt{\sum_{j=1}^{n} (z_{ij} - z_{j*})^2}
$$

(15)

$$
S^- = \sqrt{\sum_{j=1}^{n} (z_{ij} - z_{j^-})^2}
$$

(16)

$$
c_i = \frac{S^-}{S^* + S^-} (i = 1,2,3,\ldots,m)
$$

(17)

**Step 7:** Calculation of the relative similarity of each target plan to the ideal solution.

**Step 8:** Sequencing of the target plans in a decreasing order of relative similarity.

**SELECTION AND VALUE ASSIGNMENT OF INFLUENTIAL FACTORS**

**Selection of influential factors:** There are many factors affecting the design proposal of children's recreational sites. Their impacts can be huge or small, some of them are vital, while others only affect the details. Thus, the selected influential factors should reflect the basic characteristics of the site. By selecting the key factors, the complexity of evaluation can be reduced and a more scientific and feasible evaluation result will be achieved. First, the influential factors which have caught public attention and the factors emerging frequently in literature retrieval were sorted out. Then the experts determined the final factors included. By doing these, the influential factors which fully reflect the essential requirements concerning children's recreational site would be clarified. Finally, the following seven influential factors: site safety ($x_1$), amenities ($x_2$), physical space ($x_3$), activity representation ($x_4$), ecological environment ($x_5$), quality of night scene ($x_6$) and consideration to supervisor ($x_7$) were selected.

**Method and criteria to assign values to influential factors:** The key influential factors in optimizing children's recreational sites are qualitative, so interval value assignment was used to ensure accurability and validity (Table 2). Each influential factor was evaluated on a 0-10 scale (0<very poor = 2, 2<poor = 4, 4<fair = 6, 6<good = 8, 8<excellent = 10). The final score was the average of all scores.

**Data acquisition:** Four experts form Henan Agricultural University, Henan University of Science and Technology, Henan Institute of Science and Technology and Xinxiang Gardening Bureau scored 28 design proposals for children's recreational site. Each proposal's final score was the average of the four scores. (Table 3) These factors were all high priority indices, which meant that the higher the score, the better the quality of the design proposal would be. The Yaahp 6.0 software was used to calculate weights and DPS 7.5 was used to do the TOPSIS sequencing.
Table 2: The influential factors and criteria of optimizing design proposals for children's recreational site

<table>
<thead>
<tr>
<th>No.</th>
<th>Influential factor</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>x₁</td>
<td>Site safety</td>
<td>The site should ensure children's safety (Carver et al., 2008) and prevent children from being harmed, which includes protecting children from cars. Safety conditions consist of firm, stable and child-height amenities, depth control of water program, safety of electrical amenities, flexibility of floor materials, environmental cleanliness.</td>
</tr>
<tr>
<td>x₂</td>
<td>Amenities</td>
<td>Amenities should be diverse in types, to satisfy different recreational needs of children of different age and gender and disabled children.</td>
</tr>
<tr>
<td>x₃</td>
<td>Physical space</td>
<td>It should be tailor-made for children and attractive to children. It should also have good artistic quality and be beneficial to children's mental and physical health.</td>
</tr>
<tr>
<td>x₄</td>
<td>Ecological environment</td>
<td>The ecological environment should be good, to ensure that children can enjoy enough sunshine, overshad and fresh air.</td>
</tr>
<tr>
<td>x₅</td>
<td>Quality of night scene</td>
<td>The night scene should enable children to have activities during the night.</td>
</tr>
<tr>
<td>x₆</td>
<td>Consideration given to supervisor</td>
<td>Parents' needs should be fully considered by providing amenities to cater to their needs.</td>
</tr>
</tbody>
</table>

Table 3: Design samples if children's recreational site and values assigned to the influential factors

<table>
<thead>
<tr>
<th>Proposal</th>
<th>x₁</th>
<th>x₂</th>
<th>x₃</th>
<th>x₄</th>
<th>x₅</th>
<th>x₆</th>
<th>x₇</th>
<th>x₈</th>
<th>x₉</th>
<th>x₁₀</th>
<th>x₁₁</th>
<th>x₁₂</th>
<th>x₁₃</th>
<th>x₁₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.6</td>
<td>8.0</td>
<td>9.0</td>
<td>8.2</td>
<td>8.7</td>
<td>9.3</td>
<td>9.2</td>
<td>15</td>
<td>8.4</td>
<td>8.9</td>
<td>7.5</td>
<td>8.8</td>
<td>8.4</td>
<td>9.0</td>
</tr>
<tr>
<td>2</td>
<td>8.5</td>
<td>8.6</td>
<td>8.4</td>
<td>7.5</td>
<td>9.2</td>
<td>8.5</td>
<td>7.6</td>
<td>16</td>
<td>8.7</td>
<td>9.2</td>
<td>9.6</td>
<td>7.5</td>
<td>9.2</td>
<td>7.0</td>
</tr>
<tr>
<td>3</td>
<td>9.2</td>
<td>9.4</td>
<td>6.2</td>
<td>9.0</td>
<td>7.5</td>
<td>9.0</td>
<td>8.6</td>
<td>17</td>
<td>7.5</td>
<td>7.6</td>
<td>9.0</td>
<td>6.7</td>
<td>7.4</td>
<td>8.3</td>
</tr>
<tr>
<td>4</td>
<td>9.1</td>
<td>7.2</td>
<td>7.5</td>
<td>6.3</td>
<td>6.8</td>
<td>7.6</td>
<td>9.1</td>
<td>18</td>
<td>9.5</td>
<td>7.9</td>
<td>5.7</td>
<td>7.4</td>
<td>8.3</td>
<td>9.0</td>
</tr>
<tr>
<td>5</td>
<td>6.1</td>
<td>8.0</td>
<td>9.1</td>
<td>8.1</td>
<td>6.9</td>
<td>8.2</td>
<td>8.8</td>
<td>19</td>
<td>8.4</td>
<td>6.7</td>
<td>8.2</td>
<td>9.0</td>
<td>6.5</td>
<td>7.5</td>
</tr>
<tr>
<td>6</td>
<td>5.3</td>
<td>6.7</td>
<td>7.6</td>
<td>5.7</td>
<td>8.7</td>
<td>7.8</td>
<td>9.0</td>
<td>20</td>
<td>8.1</td>
<td>9.0</td>
<td>7.4</td>
<td>9.4</td>
<td>7.9</td>
<td>7.6</td>
</tr>
<tr>
<td>7</td>
<td>9.4</td>
<td>8.7</td>
<td>9.2</td>
<td>8.6</td>
<td>6.5</td>
<td>9.0</td>
<td>7.6</td>
<td>21</td>
<td>7.6</td>
<td>8.3</td>
<td>9.1</td>
<td>8.4</td>
<td>9.1</td>
<td>9.0</td>
</tr>
<tr>
<td>8</td>
<td>8.6</td>
<td>6.9</td>
<td>8.5</td>
<td>7.9</td>
<td>7.6</td>
<td>8.4</td>
<td>6.4</td>
<td>22</td>
<td>9.0</td>
<td>9.2</td>
<td>7.8</td>
<td>8.6</td>
<td>8.5</td>
<td>8.0</td>
</tr>
<tr>
<td>9</td>
<td>8.4</td>
<td>7.8</td>
<td>7.1</td>
<td>9.0</td>
<td>9.4</td>
<td>7.6</td>
<td>8.9</td>
<td>23</td>
<td>6.7</td>
<td>6.5</td>
<td>7.3</td>
<td>8.0</td>
<td>7.9</td>
<td>7.5</td>
</tr>
<tr>
<td>10</td>
<td>7.1</td>
<td>9.0</td>
<td>9.5</td>
<td>8.5</td>
<td>7.5</td>
<td>8.8</td>
<td>7.6</td>
<td>24</td>
<td>8.6</td>
<td>8.0</td>
<td>9.2</td>
<td>9.4</td>
<td>8.0</td>
<td>9.2</td>
</tr>
<tr>
<td>11</td>
<td>4.9</td>
<td>6.2</td>
<td>7.3</td>
<td>5.1</td>
<td>8.3</td>
<td>6.5</td>
<td>7.2</td>
<td>25</td>
<td>7.4</td>
<td>9.0</td>
<td>7.0</td>
<td>8.2</td>
<td>9.2</td>
<td>8.7</td>
</tr>
<tr>
<td>12</td>
<td>8.5</td>
<td>8.7</td>
<td>5.9</td>
<td>7.6</td>
<td>6.9</td>
<td>7.9</td>
<td>9.1</td>
<td>26</td>
<td>8.9</td>
<td>7.1</td>
<td>8.4</td>
<td>6.4</td>
<td>7.9</td>
<td>7.6</td>
</tr>
<tr>
<td>13</td>
<td>9.8</td>
<td>7.6</td>
<td>8.4</td>
<td>9.3</td>
<td>9.2</td>
<td>8.0</td>
<td>8.9</td>
<td>27</td>
<td>9.4</td>
<td>8.0</td>
<td>9.1</td>
<td>9.4</td>
<td>8.6</td>
<td>8.4</td>
</tr>
<tr>
<td>14</td>
<td>4.7</td>
<td>7.9</td>
<td>8.6</td>
<td>6.0</td>
<td>9.0</td>
<td>7.8</td>
<td>7.4</td>
<td>28</td>
<td>9.6</td>
<td>9.1</td>
<td>8.2</td>
<td>7.5</td>
<td>7.8</td>
<td>9.5</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

Weights of influential factors: According to step 1-3, four experts compared 7 influential factors pairwise on a 1-9 scale to calculate the weights (Table 4). The consistency check showed 0.0915=0.1, which conformed to the requirements.

It can be obtained from Table 4 that the decreasing order of the weight of each influential factor is \( x₁ > x₂ > x₃ > x₄ > x₅ > x₆ > x₇ \). During the construction of children's recreational sites, site safety and amenities are priorities. Only when the parents are assured that the amenities are safe enough will they allow their children to use the recreational center, thereby increasing its utilization. The recreational sites near roads or streets are not recommended because of safety and crime problems, which will make parents worried and children teased (Mulvihill et al., 2000). Amenities are the key content of the design (Giles-Corti and Donovan, 2002). The site will be more attractive just because of these amenities. Boys and girls have different preferences in regard to outdoor activities and the preferences change dynamically as they get older. Thus, children's recreational site should provide high-quality amenities for children of different age and gender. The benefits of ecological environment are embodied in plants. Trees and flowers are especially attractive to children. Since children's fear of the dark can result in their reduced willingness to have night activities, good night scene is also very important. It is also crucial to make a variety of activities available. The research informs us that children coming from areas with few recreational sites are less willing to participate in group activities than those coming from areas with a great variety of recreational sites. It is necessary to have their parents on the side of children during their outdoor activities. However, some sites have not yet reserved space for adults to rest or recreate, which will result in shortened duration of children's activities. Moreover, if adults and children can participate in the activities together, it will improve the parent-children relationships.

It should be pointed out that the weight of one influential factor represents the relative importance of the factor; it does not mean that a low weighted factor is unimportant. An excellent design proposal of children's recreational site should have outstanding focuses, implemented with other auxiliary function. Only by achieving these goals can the designed center satisfy children's recreational needs.

Optimizing design proposals: According to Step 4-5, the ideal solution and negative ideal solution are obtained. Ideal solution (\( z^* \)) is the optimal environmental quality of
children's recreational site, with all influential factors reaching the optimal. And negative ideal solution \((Z^-)\) is the worst environmental quality of children's recreational site, with all influential factors reaching the worst.

According to Step 6-7, calculate the distances from each design proposal to the ideal solution \(Z^+\) and negative ideal solution \(S^*\), respectively, which are \(z^-\) and \(s^-\). \(S^*\) is the similarity between the evaluated target to the ideal solution. The smaller \(S^*\), the closer between the proposal and the ideal solution, and hence the optimal the proposal would be. Calculate the similarity \(C_i\) to the ideal solution. When \(C_i = 0, S_i = Z^-\), which means the target plan is the worst. When \(C_i = 1, S_i = Z^+\), which means the target plan is the optimal. During the actual quality evaluations of children's recreational sites, the possibilities of either optimal or worst design proposals are small. Sequencing is to compare each proposal's quality to the ideal and worst solutions, respectively and then sequence the target plan in an increasing order of \(C_i\). If there is a design proposal which is closest to the ideal solution and furthest from the worst solution, then its quality is the best among all design proposals.

According to Step 8, the final sequencing result is shown (Table 5). \(C_i\) was used to classify the design proposals for children's recreational site into different quality grades. It can be obtained from Table 4 that proposal 27, proposal 7, proposal 13 and proposal 22 rank 1 to 4, possessing higher comprehensive quality. The sequencing can act as the basis for decision making and optimization. This evaluation involved 7 key influential factors, making the model simple and feasible. But some other indices may also affect the design quality of children's recreational site. The interval value assignment has certain fuzziness, though resulting in larger errors. Accordingly, it is proposed in the study to add other evaluation indices and scoring experts to address the above problems and thus to lower the errors.

### CONCLUSION

By adopting a combination of AHP and TOPSIS, this study selected seven influential factors: site safety, amenities physical space, activity representation, ecological environment, quality of night scene, consideration given to supervisor, to construct a model to evaluate and optimize the design proposals of children's recreational site.

AHP-TOPSIS model could differentiate among different design proposals and perform a comprehensive, reasonable and accurate evaluation of children's recreational sites in urban green public spaces. It is an easy and effective evaluation method.

This method can also be used to evaluate and classify other kinds of activity sites. But it should be noted that different activity sites may have totally different key influential indicators.

### REFERENCES


