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

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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 (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 given to supervisor (x_7). 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 center. The result showed that the decreasing order of the weight of each influential factor of the quality of children's recreational center was $x_1>x_4>x_2>x_3>x_6>x_7>x_5$. 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 guarantee to children's healthy growth (Pluhar *et al*., 2010). Children's recreational center plays a pivotal role in children's healthy growth (Davidson *et al*., 2010). According to the research, children's recreational center 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 center 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

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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 majored 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:

$$A=\{A_1,\ A_2,\ A_3,\ \ldots,\ A_m\} \tag{1}$$

$$X=\{X_1,\ X_2,\ X_3,\ \ldots,\ X_n\} \tag{2}$$

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:

$$B=b_{ij}=\begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ b_{m1} & b_{m2} & \cdots & b_{mn} \end{bmatrix},(i=1,2,3\ldots,m;\ j=1,2,3,\ldots,n) \tag{3}$$

Matrix B has the following properties:

$$b_{ij}>0; b_{ij}=\frac{1}{a_{ji}}; b_{ii}=1$$

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):

$$c_{ij}=\frac{b_{ij}}{\sum_{j=1}^{n} b_{ij}} \tag{4}$$

Then the sum of each row is calculated:

$$\overline{W}=\sum_{j=1}^{n} c_{ij} \tag{5}$$

Finally, the sum is normalized, and then the weight vector W_j of each factor is obtained:

$$W_j=\frac{\overline{W}}{\sum_{j=1}^{n}\overline{W}} \tag{6}$$

Step 3 Consistency check: Consistency check on matrix B is performed. First, the maximum characteristic root λ_{max} of matrix B is calculated:

$$\lambda_{max}=\sum_{j=1}^{n}\frac{(BW)_j}{nW_j} \tag{7}$$

Then C.I. (Consistency Index) is calculated:

$$C.I.=\frac{\lambda max-n}{n-1}(\text{n is the demension of the matrix}) \tag{8}$$

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

$$C.R.=\frac{C.I}{R.I} \tag{9}$$

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

Dimension	1	2	3	4	5	6	7	8	9	10	11	12	13
R.I.	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54	1.56

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

$$A=\begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1jn} \\ \cdots & & \cdots & & \cdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \cdots & & \cdots & & \cdots \\ x_{ml} & \cdots & x_{mj} & \cdots & x_{mm} \end{bmatrix}(i=1,2,3,\ldots,m;j=1,2,3,\ldots,n) \quad (10)$$

Then, the matrix is normalized:

$$Z_{ij}=W_j\times a_{ij} \quad (11)$$

$$a_{ij}=\frac{x_{ij}}{\sqrt{\sum_{i=1}^{m}x_{ij}^2}},(i=1,2,3,\ldots m;j=1,2,3,\ldots,n) \quad (12)$$

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

$$Z^*=\left(\max_i z_{ij}\left|j\in J_1\right.\right),\left(\max_i z_{ij}\left|j\in J_2\right.\right),\left|i=1,2,3,\ldots,m\right.=z_1^*,z_2^*,\ldots,z_j^*,\ldots,z_n^* \quad (13)$$

$$Z^-=\left(\max_i z_{ij}\left|j\in J_1\right.\right),\left(\max_i z_{ij}\left|j\in J_2\right.\right),\left|i=1,2,3,\ldots,m\right.=z_1^-,z_2^-,\ldots,z_j^-,\ldots,z_n^- \quad (14)$$

where, J_1 is a set of benefit indices, which represent the optimal value of the jth index. J_2 is a set of loss indices, which represent the worst value of the jth 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.

$$S^*=\sqrt{\sum_{j=1}^{n}\left(Z_{ij}-z_j^*\right)^2} \quad (15)$$

$$S^-=\sqrt{\sum_{j=1}^{n}\left(Z_{ij}-z_j^-\right)^2} \quad (16)$$

$$C_i=\frac{S_i^-}{S_i^*+S_i^-},(i=1,2,3,\ldots,m) \quad (17)$$

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 acquirability 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

No.	Influential factor	Criteria
x_1	Site safety	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 cleanness.
x_2	Amenities	Amenities should be diverse in types, to satisfy different recreational needs of children of different age and gender and disabled children.
x_3	Physical space	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.
x_4		collaboration with others.
x_5	Ecological environment	The ecological environment should be good, to ensure that children can enjoy enough sunshine, overshadow and fresh air.
x_6	Quality of night scene	The night scene should enable children to have activities during the night.
x_7	Consideration given to supervisor	Parents' needs should be fully considered by providing amenities to cater to their needs.

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

Proposal	x_1	x_2	x_3	x_4	x_5	x_6	x_7	Proposal	x_1	x_2	x_3	x_4	x_5	x_6	x_7
1	7.6	8.0	9.0	8.2	8.7	9.3	9.2	15	8.4	8.9	7.5	8.8	8.4	9.0	9.7
2	8.5	8.6	8.4	7.5	9.2	8.5	7.6	16	8.7	9.2	9.6	7.5	9.2	7.0	8.9
3	9.2	9.4	6.2	9.0	7.5	9.0	8.6	17	7.5	7.6	9.0	6.7	7.4	8.3	7.6
4	9.1	7.2	7.5	6.3	6.8	7.6	9.1	18	9.5	7.9	5.7	7.4	8.3	9.0	9.5
5	6.1	8.0	9.1	8.1	6.9	8.2	8.8	19	8.4	6.7	8.2	9.0	6.5	7.5	9.1
6	5.3	6.7	7.6	5.7	8.7	7.8	9.0	20	8.1	9.0	7.4	9.4	7.9	7.6	6.2
7	9.4	8.7	9.2	8.6	6.5	9.0	7.6	21	7.6	8.3	9.1	8.4	9.1	9.0	7.9
8	8.6	6.9	8.5	7.9	7.6	8.4	6.4	22	9.0	9.2	7.8	8.6	8.5	8.0	9.4
9	8.4	7.8	7.1	9.0	9.4	7.6	8.9	23	6.7	6.5	7.3	8.0	7.9	7.5	8.5
10	7.1	9.0	9.5	8.5	7.5	8.8	7.6	24	8.6	8.0	9.2	9.4	8.0	9.2	7.8
11	4.9	6.2	7.3	5.1	8.3	6.5	7.2	25	7.4	9.0	7.0	8.2	9.2	8.7	9.0
12	8.5	8.7	5.9	7.6	6.9	7.9	9.1	26	8.9	7.1	8.4	6.4	7.9	7.6	6.8
13	9.8	7.6	8.4	9.3	9.2	8.0	8.9	27	9.4	8.0	9.1	9.4	8.6	8.4	9.4
14	4.7	7.9	8.6	6.0	9.0	7.8	7.4	28	9.6	9.1	8.2	7.5	7.8	9.5	9.1

RESULTS AND DISCUSSION

Weights of influential factors: According to step 1-3, four experts compared 7 influential factors pair wise 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 $x_1>x_4>x_2>x_3>x_6>x_7>x_5$. 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 tensed (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

Table 4: The weights of influential factors

Influential factors	x_1	x_2	x_3	x_4	x_5	x_6	x_7
Weight	0.2998	0.1696	0.1059	0.2190	0.0529	0.0975	0.0552

Table 5: Euclidean distance C_i and sequence

Proposal	S*	S^-	C_i	Rank	Proposal	S*	S^-	C_i	Rank
1	0.0175	0.0290	0.6234	18	15	0.0117	0.0349	0.7483	8
2	0.0145	0.0319	0.6885	13	16	0.0137	0.0344	0.7151	9
3	0.0100	0.0399	0.7993	5	17	0.0229	0.0238	0.5093	23
4	0.0203	0.0321	0.6123	19	18	0.0156	0.0368	0.7028	12
5	0.0275	0.0219	0.4435	25	19	0.0161	0.0336	0.6764	14
6	0.0387	0.0090	0.1881	27	20	0.0145	0.0347	0.7046	11
7	0.0074	0.0400	0.8446	2	21	0.0170	0.0297	0.6367	17
8	0.0162	0.0319	0.6633	15	22	0.0090	0.0377	0.8075	4
9	0.0140	0.0339	0.7079	10	23	0.0266	0.0212	0.4443	24
10	0.0198	0.0288	0.5928	22	24	0.0105	0.0374	0.7808	7
11	0.0436	0.0049	0.1006	28	25	0.0191	0.0281	0.5955	21
12	0.0168	0.0314	0.6517	16	26	0.0202	0.0310	0.6064	20
13	0.0085	0.0429	0.8348	3	27	0.0069	0.0415	0.8582	1
14	0.0404	0.0117	0.2253	26	28	0.0108	0.0393	0.7846	6

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 of each design proposal to the ideal solution Z* and to 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 serve 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.

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