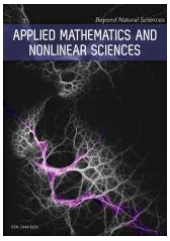
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The practice of multi-criteria decision analysis modeling in decision support for landscape planning

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Abstract

In this paper, after constructing the index system of garden landscape planning, the entropy weight method and hierarchical analysis method are used to combine and assign weights to each index. Using a multi-criterion decision analysis model to establish the decision matrix of landscape planning alternatives, the weighted normative value of each indicator is obtained to obtain the weighted normalization matrix for landscape planning. According to the matrix analysis to get the positive and negative ideal solution of each index, calculate the utility function value between each alternative and the perfect solution, and get the optimal decision-making scheme of landscape planning. The analysis of the three options for landscape planning found that Scheme S2 has the largest utility function value of 0.642, which is considered the optimal scheme. The analysis of the application effect of this scheme found that the proportion of garden green space in the Xinghua garden landscape area increased by 16.23 % compared with 2010, and the proportion of enterprise and institutional land decreased by 5.04 %. The analysis results of this paper show that the multi-criteria decision analysis model plays a highly supportive role in the decision-making of landscape planning, and lays a foundation for the decision-making of the optimal scheme in future landscape planning.

Keywords: Multi-criteria decision analysis; Indicator weights; Entropy weighting method; Hierarchical analysis; Landscape planning.
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1 Introduction

Landscape planning and design refers to the creation of landscape space with aesthetic and ornamental value in the natural environment by artificial means [1-2]. The principle of aesthetics refers to a methodology of using various laws and principles of beauty in design to achieve artistic effects [3]. Aesthetic principles focus on the nature of beauty, laws, and the mechanism of beauty generation, which is an indispensable and important part of landscape planning and design [4-5]. Initially, landscape design is to meet the needs of people to get close to nature and the embodiment of personal aesthetics. With the development of the contemporary economy, people need to satisfy the spiritual life in addition to the material life, so the principle of aesthetics plays an important role in landscape planning and design [6-7]. It can not only guide designers to make reasonable choices in spatial layout, formal expression, color application, and other aspects [8]. It can also combine the sustainable landscape, focus on the integration of energy saving and emission reduction advanced technology, integrate cultural elements, and strengthen garden planning in the context of regional culture [9].

Currently, society is in the process of sustained and rapid development. People-oriented is to ensure the foundation of the steady progress of civilization. In the process of social development, people-oriented concepts began to be integrated into a variety of different levels [10-11]. Therefore, no matter under what circumstances the urban landscape planning needs to be incorporated into the people-oriented development concept, in this development mode, urban landscape planning work is no exception [12-13]. Landscape planning and design as a new period of urban construction as well as social development of important projects for the beautification of the urban environment, the construction of ecological city, to create a harmonious development of human and nature living space has a very strong role in promoting the study of the development of urban landscaping, landscape garden humanized design into the landscape planning work [14-15]. Through the analysis of humanized design problems and points put forward to promote the humanized design of landscape gardens' specific content so as to promote the steady development of society to provide reference [16].

Landscape garden design occupies an important position in urban landscape planning, with the continuous integration of humanized design concepts, so as to establish a harmonious relationship between the city and the people, adding charm to the construction of the town, but also to further enhance the utilization rate of the city's landscape gardens [17-18]. Good landscape garden design can give urban residents a better living environment but also can promote the development of urban residents in the construction of spiritual civilization. Landscape garden not only has the function of leisure and entertainment, but also can play the role of beautifying the urban landscape [19-20]. As an important indicator of urban modernization, attention to urban landscape garden design should be strengthened, and its in-depth development should be continuously promoted [21-22]. In the environment of increasing buildings, an urban landscape can not only effectively coordinate the urban environment but also provide people with a more comfortable living, working, and learning environment, and its importance is increasing [23-24]. In order to give full play to its role and value, the concept of sustainable development should always be followed to ensure that people's living needs are fully satisfied at the same time, to provide a high-quality living environment for future generations [25-26]. Taking sustainable development as the goal-oriented, comprehensive thinking for the planning and design of urban landscaping, in order to ensure that urban landscaping improves the quality of life of residents, optimizes the living environment of the city to give full play to the role of laying a solid foundation [27].

This paper establishes the indicator system of landscape planning, normalizes the indicators in the indicator system through the combination of the entropy weighting method and hierarchical analysis

method, and obtains the indicator weights of landscape planning by linear weighting according to the assignment results of the two methods. Using a multi-criteria decision analysis model to calculate the index attribute value under each alternative scheme of landscape planning, as well as the index weights and decision attribute value calculation to get the weighted normative value of each index and construct the weighted normalization matrix of landscape planning. Using the Euclidean distance calculation method to analyze the utility function value of the alternative programs according to the positive and negative ideal solution of each indicator, the program with a higher utility function value is determined as the optimal landscape planning program. On this basis, the three alternatives for landscape planning decision analysis and the optimal program for practical application explore the application of the effect in order to reflect the effectiveness of this paper's multi-criteria decision analysis model in landscape planning decision support.

2 Method

2.1 Establishment of Landscape Planning Indicator System

In this paper, the evaluation indexes of landscape planning are divided into three levels: the target layer, the criterion layer, and the index layer, to establish a hierarchical structure. The index system of landscape planning is shown in Table 1. The goal layer is the purpose of making decisions, and the criterion layer is a set of rules related to the decision-making goal, including feasibility analysis, social analysis, safety analysis, accessibility analysis, and balance analysis. The indicator layer is a set of solutions for the guidelines, and the objectives, procedures, and indicators are numbered to facilitate the establishment of the judgment matrix.

Table 1. Architecture of Landscape Planning Index system

Target layer	Criterion layer	Index layer	Index number
Landscape planning evaluation index(A)	Feasibility analysis(A1)	Feasibility of land planning	A11
		landform	A12
	Social analysis(A2)	Population density distribution	A21
		Residential distribution	A22
		Inflammable and explosive facilities	A23
	Safety analysis(A3)	Secondary industrial land	A31
		Power facility	A32
		Flood area	A33
	Accessibility analysis(A4)	Resident accessibility	A41
		Perimeter distance	A42
	Equilibrium analysis(A5)	Square land	A51
		school	A52
		gymnasium	A53

2.2 Calculation of Landscape Planning Indicator Weights

In order to better reflect the relative importance of the indicators in landscape planning, to more effectively avoid the inherent shortcomings of a separate assignment method, and to more accurately carry out weight assignment, this paper uses AHP and entropy weight method to determine the subjective and objective weights of the indicators. It establishes a combination of assignment methods,

and the specific flow of the combination of assignment methods is shown in Fig. 1, which makes the final coupling of the weights not only clarify the experts' preferences but also take into account the intrinsic factors of the indicators. The preferences and inherent characteristics of the indicators are taken into account.

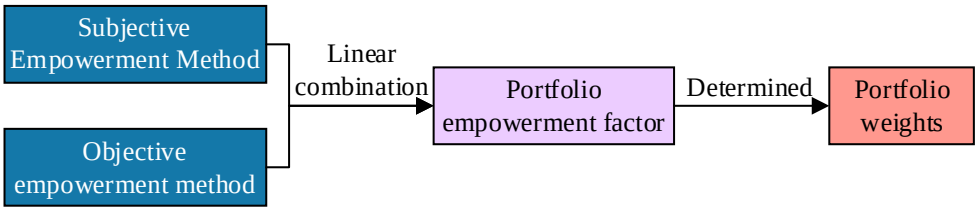


Figure 1. The process of combining the empowerment method

In this paper, the two kinds of assignment results of the AHP and entropy weighting method are linearly weighted. A multi-criteria decision analysis model based on combined assignment is established to process the results of landscape planning, and then the model is solved with the following formulas:

$$W_j = \alpha * W_{j\ \text{Subjective}} + (1-\alpha) * W_{j\ \text{Objective}} \tag{1}$$

Where, W_j is the jnd indicator weight after the combination of the two assignment methods, is the combination of AHP weight $W_{j\ \text{Subjective}}$ and entropy weight $W_{j\ \text{Objective}}$ $(j=1,2,\ldots n)$, α, $(1-\alpha)$ for the main objective weight accounted for the proportion of the combination weight, take $\alpha = 0.5$.

2.2.1 Objective empowerment based on the entropy power method

1) Data normalization.

For larger and better type indicators:

$$v_{ij} = \frac{v_{ij} - \min\left(x_j\right)}{\max\left(x_j\right) - \min\left(x_j\right)} \tag{2}$$

For smaller and better type indicators:

$$v_{ij} = \frac{\max\left(x_j\right) - v_{ij}}{\max\left(x_j\right) - \min\left(x_j\right)} \tag{3}$$

Where x_{ij} is normalized to v_{ij}. $\max\left(x_j\right)$ and $\min\left(x_j\right)$ are the maximum and minimum values of the jth indicator, respectively.

The normalization matrix V can be derived:

$$V = \{v_{ij}\}_{m\times n} = \begin{pmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{pmatrix} \tag{4}$$

2) The proportion of the i nd sample value under the j st landscaping planning indicator to that indicator p_{ij}:

$$p_{ij} = \frac{v_{ij}}{\sum_{i=1}^{m} v_{ij}} \left(0 \le p_{ij} \le 1\right) \tag{5}$$

3) Calculate the entropy value of each indicator in landscape planning Hj:

$$H_j = -\frac{1}{\ln m} \sum_{i=1}^{m} p_{ij} \ln p_{ij} \left(0 \le H_j \le 1\right) \tag{6}$$

4) Calculate the coefficient of variation d_j:

$$d_j = 1 - H_j (j = 1, 2, \ldots n) \tag{7}$$

For the j st landscaping planning indicator, the greater the degree of variability of the calculated indicator a_{ij}, the smaller the entropy value H_j of the indicator, then d_j becomes larger, indicating that the indicator is also more important.

5) Calculate the entropy weight coefficient ω_j of each indicator:

$$\omega_j = \frac{d_j}{\sum_{j=1}^{n} d_j} (j = 1, 2, \ldots n) \tag{8}$$

In this study p_{ij} will encounter $\ln 0$, so the value of 0 is approximated as 0.00001.

2.2.2 AHP-based subjective empowerment

1) First of all, according to the research objectives of landscape planning and the interconnection between the factors in the system, the hierarchical analysis structure model is constructed, and the specific hierarchical analysis structure is shown in Figure 2. The target layer is the evaluation goal to be studied, and in this paper, it is the optimal landscape planning program. To achieve the goal, the criterion layer is the intermediate link, and the index layer is the specific index for evaluating the goal.

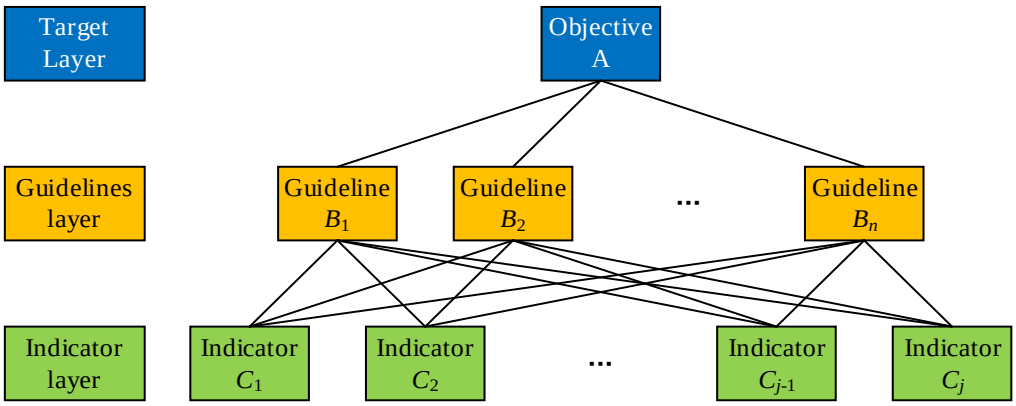


Figure 2. Hierarchical analysis structure schematic

2) Create a judgment matrix. Comparison judgment matrices are established for two comparisons at the criterion level or sub-criterion level, and judgment matrices are established for two comparisons of each program under each criterion $R=\left(r_{ik}\right)_{n\times n}$.

3) Consistency test. First of all, according to the comparison judgment matrix established in step 2, to establish the judgment matrix $\bar{R}$, and then the consistency test of the comparison judgment matrix, this paper adopts the consistency test formula, such as formula (9):

$$d(\bar{R},R)=\frac{1}{2(n-1)(n-2)}\sum_{i=1}^{n}\sum_{k=1}^{n}\left(\left|\bar{\mu}_{ik}-\mu_{ik}\right|+\left|\bar{v}_{ik}-v_{ik}\right|+\left|\bar{\pi}_{ik}-\pi_{ik}\right|\right) \tag{9}$$

Where when $d(R,\bar{R})<0.1$, the judgment matrix satisfies the consistency requirement. Otherwise, it does not satisfy the consistency requirement. When the consistency requirements are not met, proceed to step 4, and when the consistency requirements are met, proceed directly to step 5.

4) Adjust the consistency of the judgment matrix. Adjust and then judge whether $d(\bar{R},\vec{R})<0.1$ is satisfied. If not, repeat step 3 and step 4 to adjust, if the consistency is satisfied, then go to step 5.

5) Calculate the weight vector of the judgment matrix according to formula (10):

$$\omega_i=\left(\frac{\sum_{k=1}^{n}\mu_{ik}}{\sum_{i=1}^{n}\sum_{k=1}^{n}\left(1-v_{ik}\right)},1-\frac{\sum_{k=1}^{n}\left(1-v_{ik}\right)}{\sum_{i=1}^{n}\sum_{k=1}^{n}\mu_{ik}}\right) \tag{10}$$

6) Aggregate the weights of all the indicators in the landscape planning, using Equation (11) to aggregate the weights from the bottom to the top level of the hierarchical model expressed as a number of intervals:

$$\rho(\alpha)=0.5\left(1+\pi_{\alpha}\right)\left(1-\mu_{\alpha}\right) \tag{11}$$

2.2.3 Combined Empowerment Results

The results of analyzing the weights of indicators in the index system of landscape planning in this paper are shown in Table 2. From the results of the weight calculation of the constructed evaluation system, it can be seen that the balance criterion has the highest weight (0.333) in the guideline level affecting landscape planning, followed by the feasibility criterion and the safety criterion (0.203), indicating that safety and accessibility have almost the same degree of influence on the target level landscape planning. The lowest layer in the guideline is accessibility.

Table 2. Landscape planning decision index weight

Criterion layer	Index weight	Index layer	Index number	Index weight
Feasibility analysis(A1)	0.203	Feasibility of land planning	A11	0.061
		landform	A12	0.142
Social analysis(A2)	0.161	Population density distribution	A21	0.032
		Residential distribution	A22	0.039
		Inflammable and explosive facilities	A23	0.09
Safety analysis(A3)	0.203	Secondary industrial land	A31	0.079
		Power facility	A32	0.105
		Flood area	A33	0.019
Accessibility analysis(A4)	0.1	Resident accessibility	A41	0.054
		Perimeter distance	A42	0.046
Equilibrium analysis(A5)	0.333	Square land	A51	0.126
		school	A52	0.103
		gymnasium	A53	0.104

2.3 Multi-criteria decision analysis modeling

A multi-criteria decision analysis model can evaluate alternatives from multiple attribute perspectives and other advantages. Its basic principle is to rank the evaluation object by calculating the relative distance between the ideal program and the negative ideal program, and the best program is as close as possible to the perfect program and as far as possible from the negative ideal program. The index value of the perfect program is the best value among the evaluation indexes, and the negative value of the perfect program is the worst value among the evaluation indexes.

Let alternative $A=\{A_1, A_2, \cdots A_n\}$ of the multi-attribute decision problem for landscape planning, the vector of attributes for evaluating the alternatives be $X=\{X_1, X_2, \cdots X_m\}$, and the decision matrix in assessing each attribute of each alternative by the experts be $F=(f_{ij})_{n\times m}$, where f_{ij} is the value of the attribute of the i th alternative under the j th attribute. Each scenario $A_i(i=1,2,\cdots n)$ in the set of scenarios $A=\{A_1, A_2, \cdots A_n\}$ of the landscaping plan can be denoted as $A_i=\{f_{i1}, f_{i2}, \cdots f_{im}\}$ and specified as $f_{ij}\geq 0$. The weight vector of each attribute in the landscaping plan is then denoted as $\omega=(\omega_1, \omega_2, \cdots, \omega_m)^T$ and satisfies $\sum_{j=1}^{m}\omega_j=1,\ \omega_j\in[0,1](j=1,2,\cdots m)$.

1) Use the vector normalization method to find the normative decision matrix of the garden landscape planning index system. Assuming that the decision matrix derived from the evaluation is $F=\left(f_{ij}\right)_{n\times m}$, the normative matrix obtained by vector normalization method is as follows:

$$f_{ij}'=f_{ij}\Big/\sqrt{\sum_{i=1}^{n}f_{ij}^{2}},i=1,2,\cdots,n,\quad j=1,2,\cdots m \tag{12}$$

2) Calculate the weighted normalization matrix for each metric of landscape planning $Z=\left(z_{ij}\right)_{n\times m}$. Where the weighted normative values $z_{ij}=w_j f_{ij}'$, $i=1,2,\cdots,n, j=1,2,\cdots,m$. where w_j is the weight of the jth attribute or criterion and $\sum_{j=1}^{m}\omega_j=1$ is satisfied.

3) Determine the positive and negative ideal solutions:

$$f(k_i^{+})=\left\{z_1^{*},z_2^{*},\cdots,z_m^{*}\right\}=\left\{\left(\max_j z_{ij}\mid i\in I\right),\left(\min_j z_{ij}\mid i\in I\right)\right\} \tag{13}$$

$$f(k_i^{-})=\left\{z_1^{-},z_2^{-},\cdots,z_m^{-}\right\}=\left\{\left(\min_j z_{ij}\mid i\in I'\right),\left(\max_j z_{ij}\mid i\in I'\right)\right\} \tag{14}$$

Where I represents the beneficial or efficiency-based criterion and I' represents the unfavorable or consumption-based criterion.

4) The n-dimensional Euclidean distance calculation method is used to calculate the distance condition. The distance of each landscaping plan alternative from the best ideal solution is calculated as follows:

$$d_i^{+}=\sqrt{\sum_{j=1}^{m}\left(z_{ij}-z_j^{+}\right)^2},i=1,2,\cdots n \tag{15}$$

$$d_i^{-}=\sqrt{\sum_{j=1}^{m}\left(z_{ij}-z_j^{-}\right)^2},i=1,2,\cdots n \tag{16}$$

Where d_i^{+} represents the distance from alternative A_i to the ideal solution and d_i^{-} represents the distance from alternative A_i to the negative ideal solution.

5) Calculate the value of the utility function to the ideal solution. The utility function value of the alternative solutions for landscape planning is defined as follows:

$$f(k_i)=d_i^{-}/d_i^{-}+d_i^{+},j=1,2,\cdots m \tag{17}$$

6) Sort the programs from largest to smallest according to $f(k_i)$ and select the optimal program.

The construction of the optimal scheme process of landscape planning based on a multi-criteria decision analysis model is carried out through the above research process, and the specific decision-making steps are shown in Figure 3. The evaluation index system of landscape planning suitability is established by combining the principles of landscape planning and related research information. The evaluation indicators' weights are determined using the hierarchical analysis method and entropy weight method. Together with the weights of the indicators obtained from the operation, each indicator factor should be weighted and superimposed to get the optimal plan for landscape planning.

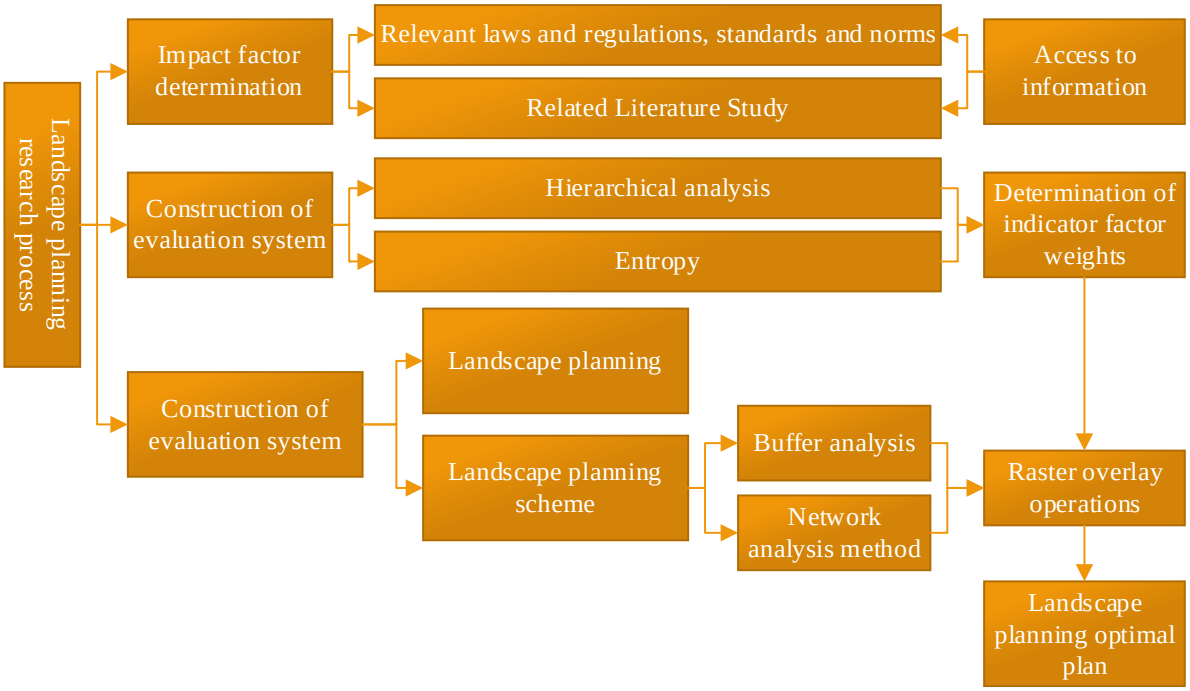


Figure 3. Landscape planning process based on multi-criterion decision model

3 Results and discussion

3.1 Decision Support Analysis for Landscape Planning

This paper uses the planning scheme of the Xinghua garden landscape area as an example to analyze the role and effects of the multi-criteria decision analysis model in garden landscape planning. Xinghua Garden landscape area is located in the southwestern part of the city, the northeast corner of the intersection of Xinghua Road and Gaomei Road, south to Xinghua Road, west to Gaomei Road, north to 295 meters north of Xinghua Road, east to 295 meters east of Gaomei Road, which connects to the main city of Shijiazhuang via Century Avenue west, is an important node of the new avenue. The status quo of the land for the store, more enterprises, the nature of the land for construction and road land, the government will fund the project before the implementation of the project unit is responsible for land acquisition, demolition, and relocation, land acquisition after the nature of the project's construction land will be green land.

3.1.1 Planning Decision Matrix Establishment Analysis

The linguistic scale rules are used to process and quantify the landscape planning indicators in this section to obtain the final decision matrix. The quantitative values 1-5 represent the linguistic scales "very poor," "poor," "fair," "good," and "very good." The results of the index processing of land

planning feasibility, for example, are shown in Table 3. Program S1 is very poor in land planning feasibility, which is very unfavorable to the planning of the garden scenic spot, so it is given the linguistic value of "poor," corresponding to the quantitative value of 2. Program S2 has a better land planning feasibility, which is beneficial to the planning of the garden scenic spot, so it is given the linguistic value of "good," corresponding to the quantitative value of 1. "The land planning feasibility attribute of S3 is in between, so it is given the linguistic value of "general," and the quantitative value is 3. This treatment makes the specific values reflect the attributes of the landscape planning scheme. It ensures that the attributes are characterized by their characteristics, which is not only a good way to improve the landscape planning but also a good way to improve the landscape planning. This method of processing assigns specific values to the attributes of the landscape planning scheme, which ensures the characteristics of the attributes and simplifies the decision-making process at the same time.

Table 3. Quantitative value of each alternative scheme

Scheme	Index attribute	Language scale	Quantitative value
S1	The feasibility of land planning is worse	Difference	2
S2	The feasibility of land planning is better	Good	4
S3	Feasibility of land planning	General	3

Based on this, the decision matrix of landscape planning alternative data is shown in Figure 4. In terms of topography and geomorphology indicators, scheme S1 has poor topography and geomorphology, with a quantized value of 1, and S2 has very good topography and geomorphology, with a quantized value of 5. In the decision-making of power facility indicators, schemes S1 and S2 are the lack of power facilities and the abundance of power facilities, with the corresponding quantized values of 2 and 4, respectively.

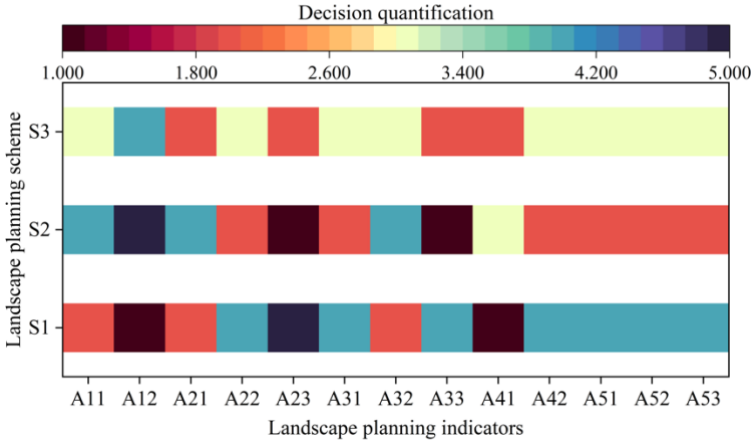


Figure 4. The decision matrix of landscape planning scheme

3.1.2 Decision Analysis for Landscape Planning

In this paper's multi-criteria decision analysis model, first of all, we need to determine the positive ideal solution and negative ideal solution of each indicator in the landscape planning to form an extended decision matrix, specific indicators of extended decision analysis results shown in Table 4. Then, the matrix is normalized to eliminate the adverse effects caused by the odd sample data and facilitate the comparative analysis of decision-making results. The final normalization results are shown in Table 5. In terms of determining the positive and negative ideal solutions, the negative perfect solution for indicators that have a positive impact on landscape planning is the minimum value

of the program, and the positive ideal solution is the maximum value. For example, in terms of land planning feasibility, S2 has the optimal decision value of 4 for all scenarios, so this value is defined as a positive ideal solution. In contrast, S1 has the worst decision value of 2, which is defined as a negative perfect solution. It can be seen that determining the positive and negative ideal solutions before normalization allows both solutions to retain the basic characteristics and magnitudes of the original scheme attributes.

Table 4. Landscape planning extension decision matrix

Index layer	S1	S2	S3	Negative solution	Positive solution
Feasibility of land planning	2	4	3	2	4
Landform	1	5	4	1	5
Population density distribution	2	4	2	2	4
Residential distribution	4	2	3	2	4
Inflammable and explosive facilities	5	1	2	1	5
Secondary industrial land	4	2	3	2	4
Power facility	2	4	3	2	4
Flood area	4	1	2	1	4
Resident accessibility	1	3	2	1	3
Perimeter distance	4	2	3	2	4
Square land	4	2	3	2	4
School	4	2	3	2	4
Gymnasium	4	2	3	2	4

Table 5. Landscape planning index normalization decision matrix

Index layer	S1	S2	S3	Negative solution	Positive solution
Feasibility of land planning	0.5	1	0.75	0.5	1
Landform	0.25	1.25	1	0.25	1.25
Population density distribution	0.5	1	0.5	0.5	1
Residential distribution	1	0.5	0.75	0.5	1
Inflammable and explosive facilities	1.25	0.25	0.5	0.25	1.25
Secondary industrial land	1	0.5	0.75	0.5	1
Power facility	0.5	1	0.75	0.5	1
Flood area	1	0.25	0.5	0.25	1
Resident accessibility	0.25	0.75	0.5	0.25	0.75
Perimeter distance	1	0.5	0.75	0.5	1
Square land	1	0.5	0.75	0.5	1
School	1	0.5	0.75	0.5	1
Gymnasium	1	0.5	0.75	0.5	1

The normalized matrix is multiplied by the corresponding indicator weights to form a weighted decision matrix, and the results of the analysis of the weighted decision matrix of each indicator are shown in Table 6. From the analysis of the residents' accessibility index, its positive and negative

ideal solutions are 0.0405 and 0.0135, respectively, and the positive and negative ideal solutions of the residential distribution index are 0.039 and 0.0195 respectively.

Table 6. Landscape planning index weighted decision matrix

Index layer	S1	S2	S3	Negative solution	Positive solution
Feasibility of land planning	0.0305	0.061	0.04575	0.0305	0.061
Landform	0.0355	0.1775	0.142	0.0355	0.1775
Population density distribution	0.016	0.032	0.016	0.016	0.032
Residential distribution	0.039	0.0195	0.02925	0.0195	0.039
Inflammable and explosive facilities	0.1125	0.0225	0.045	0.0225	0.1125
Secondary industrial land	0.079	0.0395	0.05925	0.0395	0.079
Power facility	0.0525	0.105	0.07875	0.0525	0.105
Flood area	0.019	0.00475	0.0095	0.00475	0.019
Resident accessibility	0.0135	0.0405	0.027	0.0135	0.0405
Perimeter distance	0.046	0.023	0.0345	0.023	0.046
Square land	0.126	0.063	0.0945	0.063	0.126
School	0.103	0.0515	0.07725	0.0515	0.103
Gymnasium	0.104	0.052	0.078	0.052	0.104

The multi-criteria decision analysis model constructed in this paper first defines the utility function $f(k_i^+)$ of the positive and negative ideal solutions, which further strengthens the connection between these two solutions and makes the decision-making results more stable. Further calculation of the final decision ranking index $f(k_i)$ can be obtained based on the multi-criteria decision analysis model decision-making results. Specific landscape planning decision-making results are shown in Figure 5. The value of the utility function $f(k_i^-)$ of scheme S2 corresponding to the negative ideal solution is 0.394, and the value of the utility function $f(k_i^+)$ corresponding to the positive ideal solution is 0.674, both of which are the highest values among all the schemes, which indicates that the decision maker has the highest degree of satisfaction with scheme S2. The final utility function value of scheme S2 is 0.642, which verifies the advantages of S2 in planning landscaping. Therefore, it is considered the highest-ranked scheme by the decision maker in this instance. The value of S3 is 0.572, which is recognized as the lowest-ranked scheme. Comprehensively comparing the results of the three scenarios, the final ranking of the landscape planning scenarios in the multi-criteria decision analysis model of this paper can be obtained as S2 (0.642) > S1 (0.594) > (0.572).

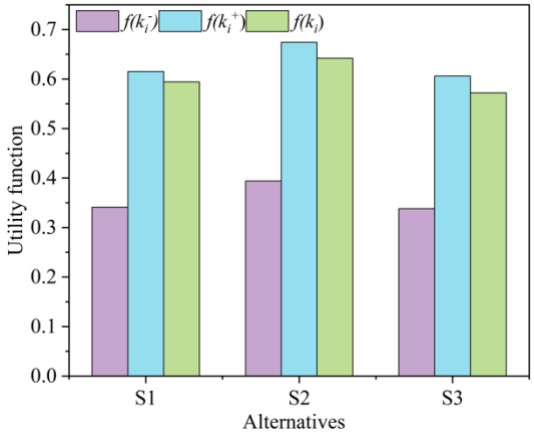


Figure 5. Analysis of the utility function of all parties

Combining the above analysis, it is found that the multi-criteria decision analysis model in this paper forms the utility function between two solutions in landscape planning by defining the utility degree of positive and negative ideal solutions, which makes the model ensure the stability of the results at the same time to give the decision maker more space for choice. The decision maker can choose the best solution according to the utility function.

3.2 Landscape planning effect analysis

In this section, the optimal landscape planning scheme obtained using the multi-criteria decision analysis model is implemented in the Xinghua Landscape Area. Comparative analysis of the landscape structure of Xinghua landscape area after planning and 2010, to explore the application of this paper based on the multi-criteria decision analysis model design of landscape planning program, the results of the comparative analysis of the landscape structure as shown in Table 7. In 2010, the three main types of landscape elements in the landscape area were broadleaf forest, mixed forest, and coniferous forest, which accounted for 49.91%, 10.9%, and 12.91% of the total operating area of the landscape area, respectively. Compared with the broad-leaved forest, the proportion of coniferous forests is low. When the broad-leaved trees lose their leaves in winter, the garden landscape area presents a scene of all the trees being killed, resulting in the beauty of the garden landscape area being greatly reduced. The area of garden green space only accounts for 8.39%, which indicates that the proportion of garden green space is low, and it is difficult to satisfy the growing demand of the public for recreation and fitness.

On the other hand, the proportion of land for enterprises and management organizations and land for tourism service facilities is on the high side, accounting for 7.30% and 8.21% of the operating area of landscaped areas, respectively. The high proportion of land for enterprises and management organizations and land for tourism service facilities can easily cause more serious water and air pollution in the core area of the garden landscape area while reducing the proportion of garden green space. Compared to 2010, the optimization scheme of garden landscape planning proposed in this paper, based on the multi-criteria decision analysis model, has led to a significant change in the resource structure of the garden landscape area. In the optimized planning scheme, the four main landscape element types were broadleaf forest, garden green space, coniferous forest, and mixed forest, which accounted for 30.36 %, 29.14 %, 16.82 %, and 14.90 % of the total area of the landscape operation, respectively. Among them, the proportion of coniferous forests, garden green space, and mixed forests increased by 8.43 %, 16.23 %, and 4.00 %, respectively, thus improving the beauty of the winter scenery in the landscape forests, providing more recreational and fitness venues for the general public, and providing richer and more diversified habitats and breeding places for rare wild animals in the landscape. Along with the expansion of the area of coniferous forests, garden green space, and mixed forests, the area of broad-leaved forests has decreased from 1,120.45 hm^2 to 742.35 hm^2. Compared with 2010, the proportion of land used for enterprises, institutions, and tourism service facilities has decreased by 5.04 % and 4.35 %, respectively, and the reduced area is mainly used for the construction of recreational parks for the public.

Table 7. The optimization scheme is compared with the initial landscape structure

Landscape element type	The 2010 view structure		Optimization plan		Landscape change	
	Area (hm^2)	Proportion (%)	Area (hm^2)	Proportion (%)	Area (hm^2)	Proportion (%)
Organ use	178.52	7.30	85.65	2.26	-123.28	-5.04
Waters	58.32	2.39	65.24	2.67	6.92	0.28
Mixed forest	296.47	10.90	364.25	14.90	97.78	4.00
Garden green	205.64	8.39	712.53	29.14	396.89	16.23
Service facilities	200.65	8.21	94.21	3.85	-106.44	-4.35
Coniferous forest	215.64	12.91	411.27	16.82	206.23	8.43
Broad-leaved forest	1120.45	49.91	742.35	30.36	-478.1	-19.55

4 Conclusion

In this paper, after constructing the guideline index system of landscape planning, the optimal scheme in landscape planning is analyzed by using the multi-criteria decision analysis model, and its practical application effect is explored and the results show that:

1) Among the levels of criteria affecting landscape planning, the equilibrium criterion has the highest weight (0.333), followed by the feasibility criterion and the safety criterion (0.203). In the indicator of land planning feasibility, S2 has the optimal decision value for all scenarios.4 In the weighted decision matrix, the positive and negative ideal solutions for the indicator of residents' accessibility are 0.0405 and 0.0135, respectively, and the positive and negative ideal solutions for the indicator of distribution of residential areas are 0.039 and 0.0195, respectively.

2) In the landscape planning alternatives S1, S2, and S3, the value of the utility function $f(k_i^-)$ of program S2 corresponding to the negative ideal solution is 0.394, the value of the utility function $f(k_i^+)$ corresponding to the positive ideal solution is 0.674, and the value of the final utility function is 0.642, which are all the highest values among all the programs, so program S2 is the optimal program in landscape planning.

3) Applying the optimal plan of landscape planning to the Xinghua landscape area, it is found that after the implementation of the optimal strategy, the proportions of coniferous forests, garden green space, and mixed forests in the landscape area have increased by 8.43%, 16.23%, and 4.00% respectively. Compared with 2010, the proportion of land for enterprises, institutions, and tourism service facilities decreased by 5.04 % and 4.35 %, respectively, and the reduced area was mainly used to build recreational parks for citizens.

In summary, the multi-criteria decision analysis model is highly effective in supporting landscape planning decision-making and is able to select the optimal solution for landscape planning decision-making.

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