Hindawi
Health & Social Care in the Community
Volume 2024, Article ID 5056891, 17 pages
https://doi.org/10.1155/2024/5056891

Research Article

Assessment of Urban Blue-Green Space Landscape Ecological Health Based on the GST-AHP-TOPSIS Composite Model

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Received 30 October 2023; Revised 10 March 2024; Accepted 19 March 2024; Published 1 April 2024

Academic Editor: Mucahit Aydin

The urban blue-green space landscape ecology is an important component that supports the urban landscape ecosystem. In this study, a combination model of the grey system theory (GST), analytic hierarchy process (AHP), and technique for order of preference by similarity to ideal solution (TOPSIS) was used to construct criteria layers from the following four aspects: green space vegetation coverage, ecosystem diversity, air and water quality, social participation, and health. The GST method was employed to screen evaluation indicators, the AHP method was used to calculate the weight of each indicator, and finally, TOPSIS was applied for weighted ranking to verify the scientific and rationality of the evaluation system. The results indicated the following: (1) out of 36 indicator factors, 10 were not selected through the GST method; (2) the weight ranking of the criteria layer was as follows, from highest to lowest: D_2 ecosystem diversity 0.4816 > D_1 green space vegetation coverage 0.2608 > D_3 air and water quality 0.1864 > D_4 social participation and health 0.0713; and (3) the relative closeness and ranking of different regions in Jinan city were as follows: Da Ming Hu area > Shan Da Lu area > Gu Cheng area > Shang Bu area. This study can help avoid decision-making errors caused by subjective factors and provide new approaches for the assessment of the ecological health of urban blue-green space landscapes.

1. Introduction

Landscape ecological health (LEH) is an interdisciplinary field that combines landscape ecology and ecosystem health studies. LEH primarily focuses on the issues of landscape ecosystem health that have suffered severe pollution and degradation under the intense human activities [1]. Urban blue-green spaces are composite ecosystems composed of water bodies and green areas [2], shaping the overall landscape structure of urban areas. Simultaneously, they are among the most severely impacted ecosystems by human societal and economic activities [3, 4]. Therefore, the assessment of urban LEH quality holds significant importance.

Urban blue-green spaces are based on blue-green corridors and patches, composed of urban green areas, water bodies, and more, forming an urban ecological spatial network that constitutes the overall ecological framework of the city. It is a complex ecological entity [5]. In China, urban green spaces are often referred to as "urban green areas" and encompass forests, urban green spaces, parks, scenic areas, residential area green spaces, and more [6]. They play a critical role as essential components of urban ecosystems and green infrastructure, fulfilling important ecosystem services (ESC) functions. Urban blue spaces typically refer to water bodies in urban environments, whether natural or artificial, including rivers, lakes, wetlands, waterfalls, and fountains. [7–9].

In recent years, scholars have increasingly explored urban blue-green space landscapes, with research focuses varying between domestic and international contexts. Internationally, the primary emphasis is on the study of the impact of urban blue-green spaces on residents' health, socioeconomic factors, environmental justice, and more [7, 10, 11]. In contrast, domestic research primarily centers on the positive effects of urban blue-green spaces in areas such as society, economy, culture, riverbanks, green areas, as well as their effects on urban grids, urban heat islands, sponge cities, spatial scales, river wetlands, and their role as natural barriers [8, 9, 12–17]. Currently, there is limited research on the landscape ecological health (LEH) of urban blue-green spaces, and scholars have proposed various indicators such as "landscape accessibility," "green three-dimensional quantity," and "even distribution of various ecological facilities" [18–20]. These indicators primarily evaluate the effects of green spaces on cities, and the study of blue spaces lags behind that of green spaces, with relatively limited metrics for assessing blue spaces. Therefore, the key to assessing urban blue-green space LEH lies in the scientific selection of evaluation methods. These methods mainly include the analytic hierarchy process (AHP), fuzzy comprehensive evaluation (FCED), grey statistical theory (GST), principal component analysis (PCA), cluster analysis (CA), and TOPSIS-weighted ranking [21]. While these evaluation methods can effectively assess the quality of targets, they often lack a comprehensive understanding of the nature and mechanisms of urban blue-green space LEH. In addition, the selected evaluation indicator factors are often too simplistic, and the ability to select among these factors is lacking, resulting in an evaluation system that lacks accuracy and scientific rigor. Urban spatial layout planning, urban heat environment patterns, and the quality of living environments and physical health all depend on the construction of urban blue-green spaces. It is imperative to establish a scientific, rational, and accurate evaluation system for urban blue-green space landscape LEH under the concept of sustainable development. The objectives of this study are as follows: (1) quantifying the proportions of LEH indicator factors in urban blue-green spaces, (2) analyzing landscape indices using a combination model of GST-AHP-TOPSIS, (3) optimizing blue-green space LEH based on the best evaluation indicator factors, and (4) developing strategies for creating blue-green space landscape LEH under the concept of green development. The results of this research will provide a scientifically sound theoretical guide for urban blue-green space landscape planning, quality healthcare services, and ecosystem development. Figure 1 illustrates the framework of the article.

2. Research Object and Research Methods

2.1. Overview of the Research Area. Jinan is located in the central-western part of Shandong Province, with the Yellow River to the north and Mount Tai to the south. It is situated between approximately 36°01′ to 37°32′ north latitude and 116°13′ to 117°44′ east longitude [22]. The city falls within a warm temperate climate zone, experiencing distinct four seasons and abundant sunshine, with an average annual temperature of 13.6°C and an average annual precipitation of 614 mm [23]. The research area in this study corresponds to the administrative boundaries of Jinan city after the 2019 administrative division adjustment, and its total area has increased to 10,244 square kilometers. In 2022, Jinan had a permanent population of 9.415 million, with a per capita GDP of 128,829 yuan/person and a total regional GDP of 1,202.746 billion yuan [24]. The specific area of focus in this research is a typical central district within the old city of Jinan, including the Shangbu area, the Gucheng area, the Shanda Road area, and the Daming Lake area, constituting the basic control planning units. The total area of this study region is 30.33 square kilometers, extending east to Erhuan East Road, west to Weier Road, south to Jingshi Road, and north to Beiyuan Overpass. This area is considered the urban core of Jinan and encompasses 14 communities within a 15-minute living circle [25]. The choice of this area for the study is based on several considerations: The region is part of the old city, with relatively well-developed urban infrastructure and a substantial amount of blue and green spaces, making it suitable for the analysis of sanitary and ecological elements. It contains significant blue and green space forms such as Daming Lake Park, Baotu Spring Park, Wulongtan Park, and Qianfoshan scenic area. In addition, it boasts well-established green infrastructure and a variety of spatial types. There is existing quantitative research data available for this typical area, making it a good foundation for this study. Figure 2 illustrates the classification of blue-green spaces in Jinan City.

2.2. Research Methods

2.2.1. Grey System Theory (GST). Grey system theory (GST) is a statistical method that applies whitening functions for mathematical operations and statistics, suitable for dealing with model frameworks involving a significant number of unknown values. Whitening function analysis generates whitening statistics for given values, which describe the level of certainty about the research object. When the greyness is 1, the set's whiteness is 0, indicating a lack of knowledge about the research object. When the greyness is 0, the whiteness is 1, signifying a complete determination of the object under study. Traditional mathematics discusses sets with a greyness of 0 and whiteness of 1, indicating a known object. Grey sets describe populations containing both known and unknown quantities, meaning a portion is known and a portion is unknown. When evaluating the landscape quality (LEH) of urban blue-green landscapes, there are numerous indicators to consider. To obtain scientifically and reasonably selected indicators, it is necessary to use the grey statistical theory (GST) to select a set of relatively high-importance indicators, thereby obtaining a more comprehensive and authoritative set of indicators. Figure 2 illustrates the classification of blue-green spaces in Jinan city.

2.2.2. Analytic Hierarchy Process (AHP). The analytic hierarchy process (AHP) is a multicriteria decision-making method developed by American operations researcher Thomas L. Saaty at the University of Pittsburgh [26] aimed at assisting decision-makers in making rational decisions when faced with complex choices. This method breaks down complex problems into several relatively simple hierarchies. It quantifies subjective qualitative analyses through pairwise

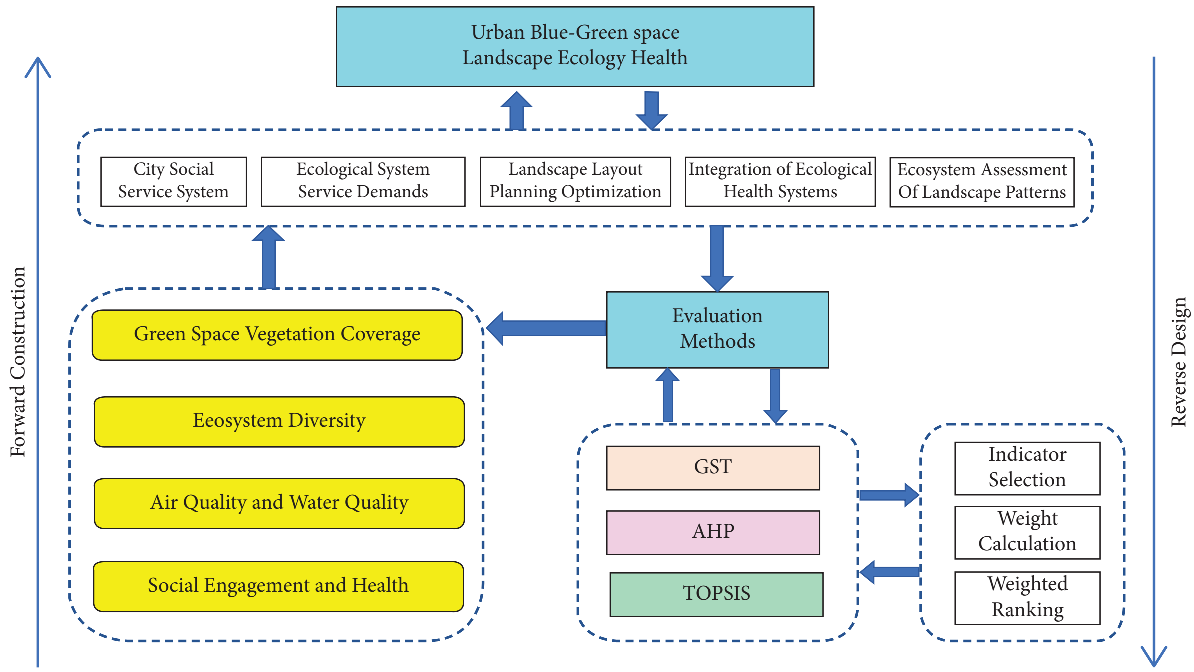

Figure 1: Framework structure diagram.

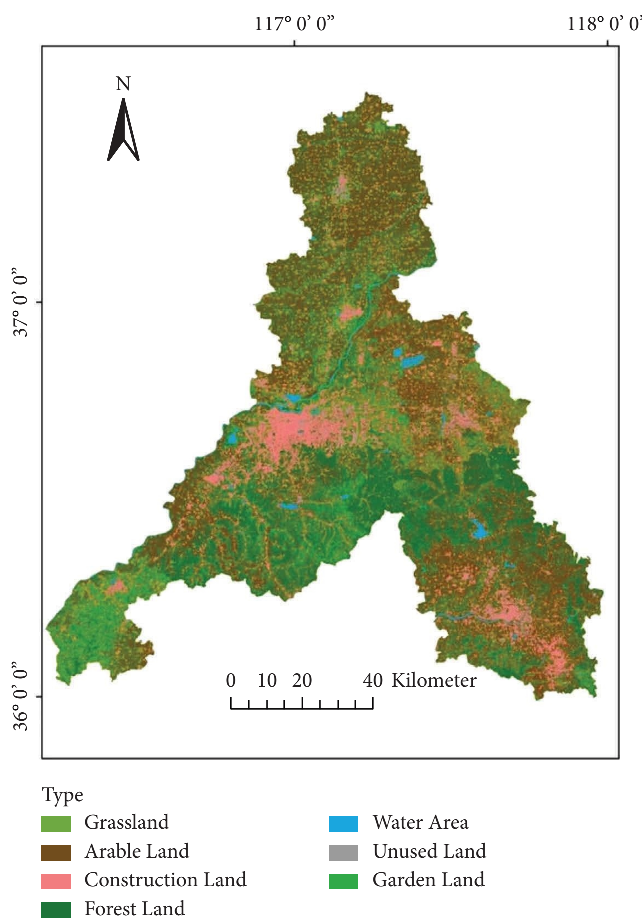

Figure 2: Classification results of blue-green spaces in Jinan city.

comparisons, quantification, and ranking, creating a multilayered analytical model. Compared to other methods, AHP provides a clear mathematical logic and a well-defined hierarchy. It combines decision-makers' subjective preferences with mathematical logic, making problem-solving systematic, concise, and not limited by mathematical background. AHP effectively transforms multicriteria problems into multilevel single-objective problems. During this process, AHP uses mathematical calculations based on the quantity relationships between elements at the same hierarchy level, avoiding the arbitrariness of a single subjective evaluation [27]. The basic steps of the AHP method include constructing judgment matrices, calculating the maximum eigenvalue and eigenvector, conducting consistency checks, and ranking hierarchical indicators. Due to the numerous factors influencing landscape ecological health (LEH) in urban blue-green spaces and the presence of fuzziness and uncertainty, the AHP method can accurately and effectively determine indicators at various levels, including criteria, objectives, and attributes, leading to a comprehensive analysis of the landscape quality indicators for urban blue-green spaces LEH.

2.2.3. Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). TOPSIS is a ranking method initially proposed by Hwang and Yoon to approximate the ideal solution. The basic steps of the TOPSIS method are as follows: establishing an initial decision matrix, normalizing the initial matrix, determining the positive and negative ideal solutions, calculating distances, and ranking. By comparing the landscape's positive ideal solution and negative ideal solution for various areas in Jinan, if a particular area's total score is close to the positive ideal solution and far from the negative ideal solution, it is considered the best solution, indicating the highest quality in terms of landscape ecological health (LEH) for blue-green spaces.

3. Construction of the Landscape Ecological Health (LEH) Evaluation Index System for Urban Blue-Green Spaces

3.1. Selection of LEH Evaluation Indicators Using the Grey System Theory (GST). The grey system theory (GST) [28] can be applied to the abstraction of LEH evaluation indicators for urban blue-green spaces, considering their multicriteria characteristics. This method involves comparing, quantifying, and extracting important indicator factors. The specific steps are as follows.

3.1.1. Preliminary Selection of LEH Evaluation Indicators for Urban Blue-Green Spaces. Through a review of the literature [29–38] and consultation with experts, four criterion layers were identified, including visual psychology, ecological function, aesthetic function, and service effect, encompassing a total of 36 indicators as the preliminary selection of LEH evaluation indicators for urban blue-green spaces.

3.1.2. Calculation of Grey Whitening Functions

① Questionnaire Survey

A questionnaire survey was distributed to 30 experts in the fields of landscape, geography, and the environment, using the Likert scale method with seven levels to rate the importance of the selected indicator elements. The scale ranged from 1 (very unimportant) to 7 (very important), with 2–6 indicating varying levels of importance. This process generated original data on the importance levels of the 36 selected indicators.

② Data Processing

Grey whitening functions were used to process the original data concerning the importance levels of the 36 selected indicators, as obtained from the expert survey. In grey system theory, whitening functions are a mathematical method for dealing with incomplete and uncertain information. The preliminary LEH indicator set for urban blue-green spaces was categorized into three groups (high, medium, and low) based on grey classes. In accordance with the definition of grey correlation functions, high-, medium-, and low-level grey whitening functions were defined for $f_k(ab)$ [39] based on the grey system methods.

When $k = 1$, the whitening function calculation formula for "high degree of importance" is as follows:

$$f_1(ab) = \begin{cases} 1, & h_{ab} \geq 7, \\ \dfrac{h_{ab} - 4}{7 - 4}, & 4 < h_{ab} < 7, \\ 0, & h_{ab} \leq 4. \end{cases} \quad (1)$$

When $k = 2$, the whitening function calculation formula for "medium degree of importance" is as follows:

$$f_2(ab) = \begin{cases} 0, & h_{ab} \geq 7, \\ \dfrac{7 - h_{ab}}{7 - 4}, & 4 < h_{ab} < 7, \\ 1, & h_{ab} = 4, \\ \dfrac{h_{ab} - 1}{4 - 1}, & 1 < h_{ab} < 4, \\ 0, & h_{ab} \leq 1. \end{cases} \quad (2)$$

When $k = 3$, the whitening function calculation formula for "low degree of importance" is as follows:

$$f_3(ab) = \begin{cases} 0, & h_{ab} \geq 4, \\ \dfrac{4 - h_{ab}}{4 - 1}, & 1 < h_{ab} < 4, \\ 1, & h_{ab} \leq 1, \end{cases} \quad (3)$$

where a represents the degree of importance, $a = 1, 2, \cdots, 7$, b represents the index number, $b = 1, 2, \cdots, 30$, $f_k(ab)$ represents the whitening function value of the b-th index with an importance level of a, and h_{ab} represents the assigned value corresponding to the importance level of the b-th index as a. Using formulas (1)–(3), the whitening function values for each index can be calculated according to the following three levels of importance: high, medium, and low.

3.1.3. Calculation of Grey Decision Coefficients and Grey Decision Vectors. Grey decision coefficients are used to measure the impact of various factors on decision outcomes. The definition of grey decision coefficient $\eta_k(b)$ for the b-th indicator in the k-th grey class is as follows: $L(ab)$ represents the number of experts who assigns an importance value a to the b-th indicator and $f_k(ab)$ represents the whitening function value for the b-th indicator when its importance is a. Therefore, $\eta_k(b)$ is defined as follows:

$$\eta_k(b) = \sum_{a=1}^{7} L(ab) \times f_k(ab). \quad (4)$$

For each evaluation indicator, the corresponding three-level grey decision coefficients (high, medium, and low) can be calculated using equation (4) as follows:

$$\begin{aligned} &\eta_1(b), \\ &\eta_2(b), \\ &\eta_3(b). \end{aligned} \quad (5)$$

These three coefficients together form a grey decision vector as follows:

$$\{\eta_1(b), \eta_2(b), \eta_3(b)\}. \quad (6)$$

By comparing the grey decision vectors of various evaluation indicators, important indicators with a high level of importance can be selected, completing the process of indicator selection.

3.2. Construction of LEH Evaluation Indicators for Blue-Green Spaces Using the Analytic Hierarchy Process (AHP). The evaluation indicators selected through the grey system theory (GST) are ranked using the analytic hierarchy process (AHP). The specific steps are as follows.

3.2.1. Construction of the Judgment Matrix. Usually, in the minds of different decision-makers, the importance of different elements varies. Therefore, the analytic hierarchy process often uses pairwise comparisons of decision factors to create pairwise comparison matrices. Commonly, numerical scales are used to quantitatively process the judgments of decision-makers, resulting in a judgment matrix. The scale meanings are shown in Table 1, and these values are determined based on the intuition and judgment of decision-makers during qualitative analysis.

3.2.2. Eigenvalue Method to Obtain Maximum Eigenvalue and Eigenvector (Weight Vector)

① Calculate the eigenvalue and corresponding eigenvector for each judgment matrix:

$$\begin{aligned} \lambda &= (\lambda_1, \lambda_2, \cdots \lambda_n), \\ \omega_i &= (\omega_{i1}, \omega_{i2}, \cdots, \omega_{in}), \quad i = 1, 2, \cdots n. \end{aligned} \quad (7)$$

② Normalize the eigenvectors as follows:

$$\omega_i^0 = \frac{1}{\sum_{j=1}^{n} \omega_{ij}} (\omega_{i1}, \omega_{i2}, \cdots, \omega_{in}), \quad i = 1, 2, \cdots n. \quad (8)$$

③ Calculate the maximum eigenvalue as follows:

$$\lambda_{\max} = \max\{\lambda_1, \lambda_2, \cdots \lambda_n\}. \quad (9)$$

3.2.3. Consistency Test of the Judgment Matrix

① Calculate the consistency index (CI) as follows:

$$\mathbf{CI} = \frac{\lambda_{\max} - n}{n - 1}. \quad (10)$$

② Determine the corresponding average random consistency index (RI) from the table.

The values of the average random consistency index (RI) are shown in Table 2.

Based on the order of the judgment matrix, the corresponding average random consistency index RI can be obtained from Table 2.

③ Calculate the consistency ratio CR and make a judgment as follows:

$$\mathbf{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}, \quad (11)$$

When $\mathbf{CR} = 0$, it is considered that the judgment matrix is completely consistent; when $\mathbf{CR} < 0.1$, it is considered that the consistency of the judgment matrix is acceptable; when $\mathbf{CR} > 0.1$, it is considered that the judgment matrix does not meet the consistency requirement, and it needs to be reconstructed and revised until it meets the consistency requirement.

Table 1: Scale meaning comparison table.

Quantitative value	Meaning
1	Equally important in comparison between two factors
3	Slightly more important in comparison between two factors, with the former being more important than the latter
5	Significantly more important in comparison between two factors, with the former being much more important than the latter
7	Strongly more important in comparison between two factors, with the former being significantly stronger in importance than the latter
9	Extremely more important in comparison between two factors, with the former being of utmost importance compared to the latter
2, 4, 6, 8	The intermediate value between the adjacent judgments described above
Reciprocal	If the ratio of the importance of factor i to factor j is a_{ij}, then the ratio of the importance of factor j to factor i is $a_{ji} = 1/a_{ij}$

Table 2: Average random consistency index RI.

Matrix order	1	2	3	4	5	6	7	8	9
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46

3.2.4. Hierarchy Index Ranking

① Individual ranking of hierarchy indices: the ranking of hierarchy indices is determined by the calculated weight vectors.

② Overall ranking of hierarchy indices: the overall ranking of hierarchy indices is calculated by combining the weight vectors.

3.3. Ranking of LEH Evaluation for Blue-Green Spaces in Different Areas Using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The TOPSIS method is a multiobjective decision-making technique that involves ranking based on the distance between objects and the ideal solution [40]. When combined with the AHP method, it allows for the scientific ranking of various evaluation objects through the construction of a weighted matrix. The specific steps are as follows.

Suppose there are m evaluation objects, each with n evaluation indicators.

(1) Construct the judgment matrix as follows:

$$X = \left(x_{ij}\right)_{m\times n}, \quad i = 1, 2, \cdots, m; \; j = 1, 2, \cdots, n, \tag{12}$$

where x_{ij} represents the evaluation value of the i-th evaluation object for the j-th indicator. It is specified that $x_{ij} > 0$. The evaluation values of the i-th evaluation object for various indicators are denoted as follows:

$$M_i = \left(x_{i1}, x_{i2}, \cdots, x_{in}\right), \quad i = 1, 2, \cdots, m. \tag{13}$$

The evaluation values of all evaluation objects for various evaluation indicators are represented as the weight vector of that evaluation indicator as follows:

$$\omega = \left(\omega_1, \omega_2, \cdots, \omega_n\right), \quad i = 1, 2, \cdots, m. \tag{14}$$

Satisfying $\sum_{j=1}^{n} \omega_j = 1, \omega_j \geq 0, \quad j = 1, 2, \cdots, n.$

(2) Standardize the judgment matrix as follows:

$$Y = \left(y_{ij}\right)_{m\times n}, \quad i = 1, 2, \cdots, m; \; j = 1, 2, \cdots, n, \tag{15}$$

where $y_{ij} = x_{ij} - \min\{x_{i1}, x_{i2}, \cdots x_{in}\}/\max\{x_{i1}, x_{i2}, \cdots x_{in}\} - \min\{x_{i1}, x_{i2}, \cdots x_{in}\}$, $i = 1, 2, \cdots, m; \; j = 1, 2, \cdots, n$.

(3) Construct a weighted normalized judgment matrix as follows:

$$Z = \left(z_{ij}\right)_{m\times n}, \quad i = 1, 2, \cdots, m; \; j = 1, 2, \cdots, n, \tag{16}$$

where $z_{ij} = \omega_j y_{ij}, \quad i = 1, 2, \cdots, m; \; j = 1, 2, \cdots, n$

(4) Determine the best vector and worst vector.

Define the positive ideal solution M^+ and the negative ideal solution M^- using the maximum and minimum values of each indicator, respectively, as follows:

$$\begin{aligned} M^+ &= \{z_1{}^+, z_2{}^+, \cdots, z_n{}^+\}, \\ z_j{}^+ &= \max_i z_{ij}, \quad j = 1, 2, \cdots, n, \\ M^- &= \{z_1{}^-, z_2{}^-, \cdots, z_n{}^-\}, \\ z_j{}^- &= \min_i z_{ij}, \quad j = 1, 2, \cdots, n. \end{aligned} \tag{17}$$

So, M^+ is the best vector, and M^- is the worst vector.

(5) Calculate the Euclidean distance between each evaluation object and the best vector, resulting in $d_i{}^+$, and between each evaluation object and the worst vector, resulting in $d_i{}^-$:

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

$$d_i^- = \|z_i - M^-\| = \sqrt{\sum_{j=1}^{n}\left(z_{ij} - z_j^-\right)^2}, \quad i = 1, 2, \cdots, m, \tag{18}$$

where $z_i = (z_{i1}, z_{i2}, \cdots, z_{im})$ is the i-th row of the weighted normalized decision matrix $Z = (z_{ij})_{m\times n}$.

(6) Calculate the relative closeness of each evaluation object to the best vector, denoted as C_i^+, as follows:

$$C_i^+ = \frac{d_i^-}{d_i^+ + d_i^-}, \quad i = 1, 2, \cdots, m. \tag{19}$$

If $z_i = M^+$, then $C_i^+ = 1$; if $z_i = M^-$, then $C_i^+ = 0$; C_i^+ with the condition $0 \le C_i^+ \le 1$. Therefore, the closer C_i^+ is to 1, the closer the evaluation object M_i is to the best vector M^+.

(7) Rank the evaluation objects: arrange the evaluation objects in descending order based on the calculated values of relative closeness C_i^+, yielding the ranking results of the evaluation objects.

4. Calculation Result Analysis

4.1. Analysis of GST Indicator Selection Results. By comparing the grey decision vectors of various evaluation indicators, important indicators with a high level of importance are selected, completing the process of indicator selection. The importance levels of landscape ecological health (LEH) evaluation indicators for urban blue-green spaces, as determined through grey statistical analysis, are presented in Table 3.

4.1.1. Analysis of Green Space Vegetation Coverage. High forest coverage, green space coverage, urban greening rate, and the distribution of green space areas effectively mitigate the impact of urban climate change, improve the quality of life for urban residents, and promote urban sustainability. The temperature regulation capacity, air humidity regulation, and CO_2 absorption capacity help alleviate the urban heat island effect and contribute to improving the city's climate, residents' quality of life, and urban sustainability.

Three indicators of green space vegetation coverage were not selected. While floral diversity, garden coverage, and lawn coverage contribute to beautifying the urban environment and have a positive impact on the psychological well-being of urban residents, their ecological service functions are limited to a small local area and do not have a significant ecological impact. The evaluation index system for LEH green space vegetation coverage is analyzed as shown in Figure 3.

4.1.2. Analysis of Ecosystem Diversity. The level of wetland conservation helps protect urban wetland ecosystems. The degree of biodiversity and species richness is instrumental in establishing robust ecosystems. The integrity of natural landscapes contributes to urban greening, air quality improvement, and environmental beautification. Maintaining water quality health supports safe drinking water supply, aquatic ecosystems, and recreational opportunities. Ecosystem services can provide various services to the city, promoting the physical and mental well-being of residents and the city's sustainability.

Two indicators of ecosystem diversity were not selected. The conservation of endangered species and habitat area, due to factors such as data availability, priority, methodology, resource constraints, require accurate data for comprehensive assessment and were, therefore, not included. The analysis of the LEH green and blue space ecosystem diversity evaluation index system is shown in Figure 4.

4.1.3. Air Quality and Water Quality. Air Quality Index, Water Quality Index, pollutant adsorption, wastewater treatment efficiency, water accessibility, and river and lake health directly impact the environmental quality and quality of life for city residents. They also reflect the overall environmental health of the city. Good air and water quality have a significant impact on the lives and health of urban residents.

Two indicators for air quality and water quality were not selected. While waste management efficiency and flood risk are crucial urban environmental issues, their selection was influenced by factors such as prioritization, resources, and policy directions. They are not as urgent as other indicators, which is why they were not included. The analysis of the LEH green and blue space air quality and water quality evaluation index system is shown in Figure 5.

4.1.4. Social Engagement and Health. The Community Health Index is a key factor reflecting the quality of life for community residents. Facility maintenance, timeliness of services, and ecological corridor connectivity contribute to providing city residents with safer, more reliable, and timely services, promoting the ecological sustainability of the city. Improving psychological health, public engagement, and environmental protection provide psychological health services, democratic decision-making, protect various city resources, and enhance the quality of the urban environment.

Three indicators for social engagement and health were not selected. Although environmental education opportunities, public recreational spaces, and information disclosure contribute to raising awareness of environmental issues and providing recreational spaces, these indicators are not highly correlated with urban blue-green spaces and were, therefore, not included. The analysis of the LEH green and blue space social participation and health evaluation index system is shown in Figure 6.

Table 3: Grey statistical analysis results of the importance levels of landscape ecological health indicators for urban blue-green spaces.

Landscape ecological health (LEH) evaluation criteria for urban blue-green spaces	Preliminary evaluation indicators	Grey decision vector			Importance	Select
		η_{high}	η_{medium}	η_{low}		
Green space vegetation coverage B_1	C_1: Forest coverage rate	15.00	11.67	3.33	High	Yes
	C_2: Green space coverage	16.33	11.33	2.33	High	Yes
	C_3: Temperature regulation capability	14.33	12.33	3.33	High	Yes
	C_4: Air humidity regulation	15.00	12.33	2.67	High	Yes
	C_5: CO_2 absorption capability	17.00	11.33	1.67	High	Yes
	C_6: Green space area distribution	19.00	10.33	0.67	High	Yes
	C_7: Urban greening rate	19.67	9.33	1.00	High	Yes
	C_8: Floral diversity	1.67	13.00	15.33	Low	No
	C_9: Garden coverage	7.00	17.67	5.33	Medium	No
	C_{10}: Lawn coverage	6.67	19.00	4.33	Medium	No
Ecosystem diversity B_2	C_{11}: Wetland conservation level	14.00	12.67	3.33	High	Yes
	C_{12}: Diversity index	14.67	13.00	2.33	High	Yes
	C_{13}: Natural landscape integrity	17.00	11.33	1.67	High	Yes
	C_{14}: Water quality health	16.00	13.33	0.67	High	Yes
	C_{15}: Habitat area	3.00	11.33	15.67	Low	No
	C_{16}: Endangered species conservation	3.00	8.33	18.67	Low	No
	C_{17}: Ecosystem services	15.33	12.67	2.00	High	Yes
	C_{18}: Species richness	16.00	12.67	1.33	High	Yes
Air quality and water quality B_3	C_{19}: River and lake health	14.33	11.67	4.00	High	Yes
	C_{20}: Water accessibility	13.67	12.00	4.33	High	Yes
	C_{21}: Pollutant adsorption	15.67	12.33	2.00	High	Yes
	C_{22}: Flood risk	4.33	11.33	14.33	Low	No
	C_{23}: Waste management efficiency	5.67	16.00	8.33	Medium	No
	C_{24}: Wastewater treatment efficiency	14.67	12.00	3.33	High	Yes
	C_{25}: Water Quality Index	16.33	11.67	2.00	High	Yes
	C_{26}: Air Quality Index	15.67	13.33	1.00	High	Yes
Social engagement and health B_4	C_{27}: Community Health Index	15.00	12.00	3.00	High	Yes
	C_{28}: Environmental education opportunities	4.33	14.00	11.67	Medium	No
	C_{29}: Facility maintenance	16.33	11.33	2.33	High	Yes
	C_{30}: Timeliness of services	13.67	11.67	4.67	High	Yes
	C_{31}: Public recreational spaces	3.33	16.33	10.33	Medium	No
	C_{32}: Psychological health improvement	14.67	12.00	3.33	High	Yes
	C_{33}: Ecological corridor connectivity	17.33	12.00	0.67	High	Yes
	C_{34}: Public engagement	14.00	11.67	4.33	High	Yes
	C_{35}: Information disclosure	1.33	12.33	16.33	Low	No
	C_{36}: Environmental protection	16.67	11.33	2.00	High	Yes

4.2. Analysis of AHP Indicator Weight Results. Based on the evaluation index system, we conducted a questionnaire survey from June 14th to 22nd, 2023, inviting 30 experts from universities and companies such as Shandong University, Jinan University, Shandong University of Art and Design, Shandong Jianzhu University, and Shandong Tongyuan Design Co., Ltd. All experts reside within the research area of this paper. The survey questionnaire consisted of background questions and main questions. The background questions included respondents' personal basic information and their usage of the research area, such as gender, age, education level, and recreational activities in the area. The main questions asked respondents to quantitatively rate the landscape ecological health of the research area based on their subjective perceptions. The questionnaire was self-administered and consisted of four pages of A4 paper, including four background questions and ratings for 26 evaluation index factors. It could be completed within 5 minutes, and respondents were instructed to select appropriate options and fill in appropriate scores based on their own circumstances.

A total of 30 questionnaires were distributed, all of which were returned, resulting in 30 valid questionnaires, with an effective rate of 100%. The respondents covered the following three age groups: youth (18–40 years old), middle aged (40–65 years old), and elderly (over 65 years old), accounting for 36.16%, 50.44%, and 13.04%, respectively. There were 22 males and 8 females; educational backgrounds ranged from undergraduate to doctoral degrees, with a majority holding master's degrees, accounting for 27.21%, 40.07%, and 20.12%, respectively. Regarding the frequency of recreational activities in the area, 1 person visited for the first time, accounting for approximately 1.8% of the total respondents, 5 people visited for the second time,

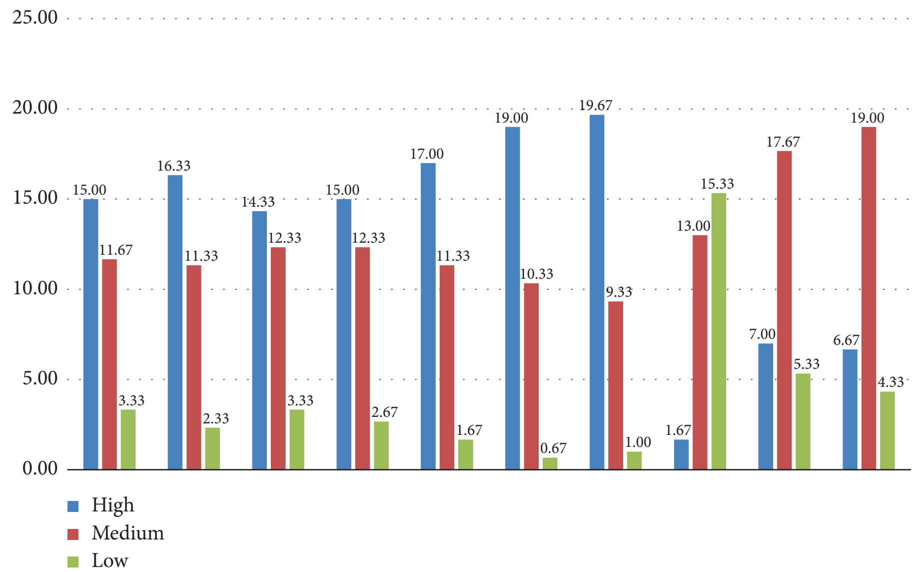

FIGURE 3: Analysis of the green space vegetation coverage evaluation indicator system for blue-green space LEH.

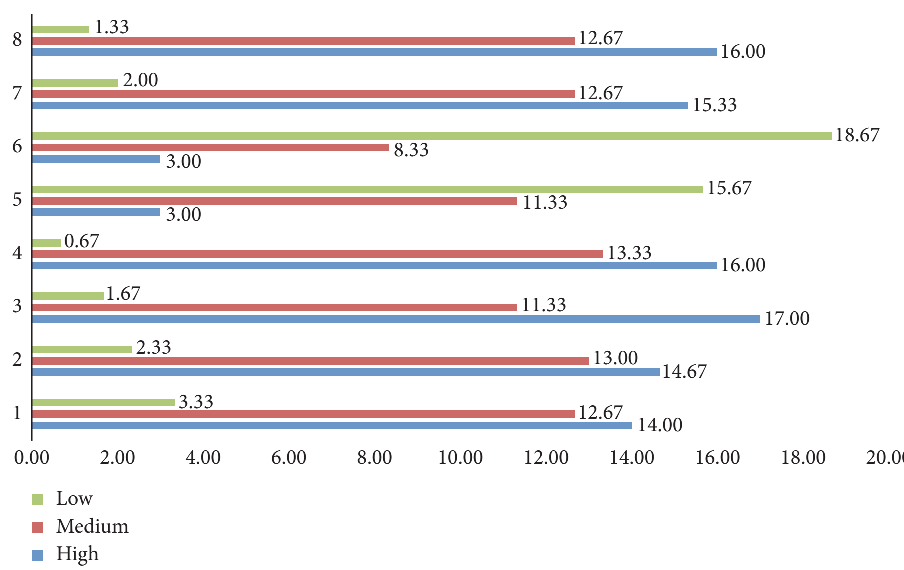

FIGURE 4: Analysis of the ecosystem diversity evaluation indicator system for blue-green space LEH.

accounting for about 19.6%, and the remaining 24 people visited three times or more, accounting for approximately 78.6%. The 30 experts conducted pairwise comparisons of the 26 different evaluation indicators based on their relative importance and determined the results of the 30 judgments through weighted averaging, upon which five judgment matrices were constructed A—D, D_1—P, D_2—P, D_3—P, and D_4—P. Using the eigenvalue method to calculate the eigenvectors, which represent the weight values of urban blue-green space LEH evaluation indicators (Table 4), and conducting a consistency check, the calculation results indicate that the CR values for the judgment matrices A—D, D_1—P, D_2—P, D_3—P, and D_4—P are 0.0518, 0.0448, 0.0548, 0.0329, and 0.0261, respectively. All CR values are less than 0.1, passing the consistency test.

4.2.1. Analysis of Evaluation Indicator Weight Calculation Results. Through the analytic hierarchy process, a comprehensive evaluation analysis of the LEH effectiveness of hygienic city blue-green spaces was conducted, and the weight ranking results for the criterion layer are as follows: D_2 ecosystem diversity $0.4816 > D_1$ green area vegetation coverage $0.2608 > D_3$ air and water quality $0.1864 > D_4$ social engagement and health 0.0713. As hygienic city blue-green spaces primarily aim to provide a healthy and livable environment for urban residents, they receive the highest weighting. Green area vegetation coverage in urban blue-green spaces has a higher weight than air and water quality, and its impact is also greater than ecosystem diversity, so it receives a higher weight than social engagement and health.

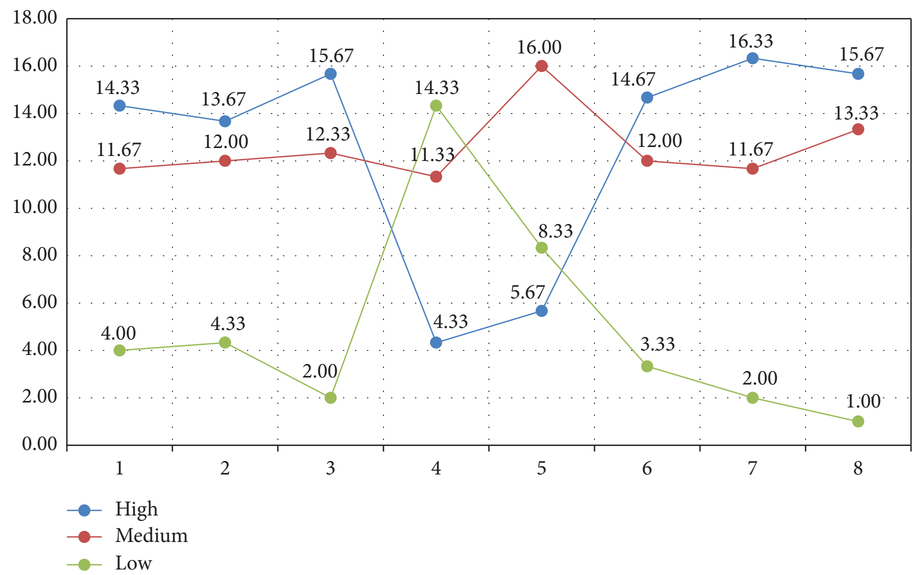

Figure 5: Analysis of the air quality and water quality evaluation indicator system for blue-green space LEH.

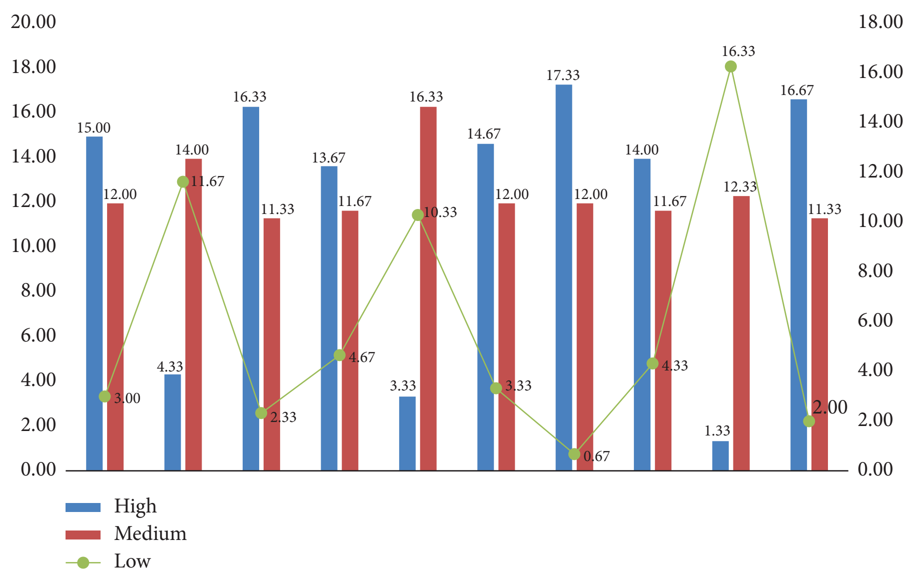

Figure 6: Analysis of the social engagement and health evaluation indicator system for blue-green space LEH.

In the total weight ranking of the 26 indicator levels, the following conclusions were drawn: ecosystem services (P_{25}) has the highest weight, followed by natural landscape integrity (P_{23}). These two indicators have a significant impact on the comprehensive evaluation of hygienic city blue-green space LEH. The data also show that forest coverage (P_{11}), diversity index (P_{22}), and air quality index (P_{36}) are similarly crucial for hygienic city blue-green space LEH. The weights of other indicators are as follows, in descending order: green area coverage rate (P_{12}) > species richness (P_{26}) > Water Quality Index (P_{35}) > temperature regulation capability (P_{13}) > wetland conservation level (P_{21}) > air humidity regulation (P_{14}) > river and lake health (P_{31}) > Community Health Index (P_{41}) > wastewater treatment efficiency (P_{34}) > CO_2 absorption capacity (P_{15}) > water quality health (P_{24}) > psychological health improvement (P_{44}) > distribution of green areas (P_{16}) > pollutant adsorption (P_{33}) > public participation (P_{46}) > urban greening rate (P_{17}) > water accessibility (P_{32}) > environmental protection (P_{47}) > timeliness of services (P_{43}) > ecological corridor connectivity (P_{45}) > facility maintenance and upkeep (P_{42}).

4.3. *TOPSIS Indicator Weight Analysis*

4.3.1. Questionnaire Survey. Satisfaction surveys were conducted based on 36 indicators within four major categories that revolve around factors influencing the usage of hygienic city blue-green spaces, as shown in Table 5. The Likert five-point scale was employed, with a total of 25 questions. Respondents were required to provide a satisfaction rating for each question, ranging from "very dissatisfied," "dissatisfied," "neutral," "satisfied," to "very

TABLE 4: Weights of various factors in the comprehensive evaluation indicator system for urban blue-green space LEH effectiveness.

Target layer A	Criterion layer D	Weight	Indicator layer P	Weight	Total weight ranking
Comprehensive evaluation of the landscape ecological health of a healthy urban blue-green space	D_1: Green space vegetation coverage	0.2608	P_{11}: Forest coverage rate	0.3237	0.0844
			P_{12}: Green area coverage rate	0.2257	0.0589
			P_{13}: temperature regulation capability	0.1661	0.0433
			P_{14}: Air humidity regulation	0.1160	0.0303
			P_{15}: CO_2 absorption capacity	0.0706	0.0184
			P_{16}: Distribution of green areas	0.0591	0.0154
			P_{17}: Urban greening rate	0.0388	0.0101
	D_2: Ecosystem diversity	0.4816	P_{21}: Wetland conservation level	0.0631	0.0304
			P_{22}: Diversity index	0.1454	0.0700
			P_{23}: Natural landscape integrity	0.2248	0.1083
			P_{24}: Water quality health	0.0374	0.0180
			P_{25}: Ecosystem services	0.4187	0.2016
			P_{26}: Species richness	0.1106	0.0533
	D_3: Air quality and water quality	0.1864	P_{31}: River and lake health	0.1484	0.0277
			P_{32}: Water accessibility	0.0405	0.0075
			P_{33}: Pollutant adsorption	0.0624	0.0116
			P_{34}: Wastewater treatment efficiency	0.1045	0.0195
			P_{35}: Water Quality Index	0.2686	0.0501
			P_{36}: Air Quality Index	0.3755	0.0700
	D_4: Social engagement and health	0.0713	P_{41}: Community Health Index	0.3548	0.0253
			P_{42}: Facility maintenance and upkeep	0.0324	0.0023
			P_{43}: Timeliness of services	0.0680	0.0048
			P_{44}: Psychological health improvement	0.2362	0.0168
			P_{45}: Ecological corridor connectivity	0.0450	0.0032
			P_{46}: Public participation	0.1594	0.0114
			P_{47}: Environmental protection	0.1042	0.0074

Table 5: Percentage of LEH usage satisfaction evaluation for urban blue-green spaces.

Evaluation indicators	Scoring criteria (proportion)				
	Very dissatisfied 1 point (%)	Dissatisfied 2 point (%)	Neutral 3 point (%)	Satisfied 4 point (%)	Very satisfied 5 point (%)
P_{11}: Forest coverage rate	3.0	25.0	36.5	24.8	10.7
P_{12}: Green area coverage rate	3.3	30.0	44.0	16.3	6.4
P_{13}: Temperature regulation capability	0.5	3.5	45.8	23.0	27.2
P_{14}: Air humidity regulation	1.0	3.3	40.0	43.0	12.7
P_{15}: CO_2 absorption capacity	1.6	18.5	22.0	49.8	8.1
P_{16}: Distribution of green areas	5.5	3.8	39.8	37.5	13.4
P_{17}: Species richness	0.0	12.5	46.0	31.8	9.7
P_{21}: Wetland conservation level	0.0	7.0	52.5	33.5	7.0
P_{22}: Diversity index	6.0	13.0	42.8	37.5	0.7
P_{23}: Natural landscape integrity	0.2	19.0	29.5	34.0	17.3
P_{24}: Water quality health	5.5	18.5	37.5	30.0	8.5
P_{25}: Ecosystem services	1.3	7.0	39.4	47.8	4.5
P_{26}: Species richness	0.3	7.2	46.0	45.3	1.2
P_{31}: River and lake health	0.3	14.0	48.3	29.8	7.6
P_{32}: Water accessibility	2.0	7.2	43.5	36.8	10.5
P_{33}: Pollutant adsorption	9.5	14.5	36.5	33.8	5.7
P_{34}: Wastewater treatment efficiency	10.4	36.0	41.5	11.3	0.8
P_{35}: Water Quality Index	1.5	6.5	39.8	40.0	12.2
P_{36}: Air Quality Index	0.5	5.5	41.5	38.5	14
P_{41}: Community Health Index	5.0	10.0	33.3	36.3	15.4
P_{42}: Facility maintenance and upkeep	8.0	24.0	33.0	31.8	3.2
P_{43}: Timeliness of services	6.5	14.5	34.5	38.0	6.5
P_{44}: Psychological health improvement	2.5	5.0	43.8	35.0	13.7
P_{45}: Ecological corridor connectivity	11	15.5	30.0	34.8	8.7
P_{46}: Public participation	0.3	3.8	50.8	33.8	11.3
P_{47}: Environmental protection	4.3	9.0	46.0	35.5	5.2

satisfied," which corresponded to scores of 1, 2, 3, 4, and 5, respectively.

4.3.2. Construction of the Judgment Matrix. The evaluation of the use of urban blue-green space LEH includes four segments to be evaluated, and each segment has 26 evaluation indicators. Therefore, the judgment matrix is as follows:

$$X = \left(x_{ij}\right)_{4\times 26} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{126} \\ x_{21} & x_{22} & \cdots & x_{226} \\ x_{31} & x_{32} & \cdots & x_{326} \\ x_{41} & x_{42} & \cdots & x_{426} \end{bmatrix}. \quad (20)$$

Since all 26 indicators studied in this paper are positive indicators, there is no need for further normalization.

4.3.3. Standardized Judgment Matrix. Using the range standardization method, the original data were subjected to linear transformation to obtain the standardized judgment matrix, which represents the normalized data for the Shangbu District, Gucheng District, Shanda Road District, and Daming Lake District in Jinan, as shown in Table 6.

4.3.4. Construction of the Weighted Normalized Judgment Matrix. The weight values of each factor in the comprehensive evaluation indicator system for the LEH effect of urban blue-green spaces obtained through the AHP method are multiplied by the corresponding values in the standardized judgment matrix to construct the weighted normalized judgment matrix. This matrix represents the weighted values for Shangbu District, Gucheng District, Shanda Road District, and Daming Lake District in Jinan, as shown in Table 7.

4.3.5. Calculating the Relative Closeness of Each District. Based on the magnitude of the relative closeness (C_i^{+}), Jinan's Shangbu District, Gucheng District, Shanda Road District, and Daming Lake District are ranked to provide decision-making criteria. Using the calculated weighted values for each district, we first construct the best vector

Table 6: Normalized values.

Evaluation indicators	Shangbu District	Gucheng District	Shanda Road District	Daming Lake District
P_{11}: Forest coverage rate	0.1759	0.3007	0.3255	0.5419
P_{12}: Green area coverage rate	0.2193	0.4319	0.4478	0.6749
P_{13}: Temperature regulation capability	0.3748	1.0000	0.3129	0.7381
P_{14}: Air humidity regulation	0.2422	0.5325	0.2712	0.9555
P_{15}: CO_2 absorption capacity	0.0000	0.5269	0.3060	0.8453
P_{16}: Distribution of green areas	0.4258	0.1990	0.5549	0.9854
P_{17}: Species richness	0.5125	0.5721	0.6008	0.8125
P_{21}: Wetland conservation level	0.4462	0.5947	0.6078	0.8992
P_{22}: Diversity index	0.3993	0.5608	0.5285	0.7264
P_{23}: Natural landscape integrity	0.1504	0.9209	0.4771	0.7335
P_{24}: Water quality health	0.3085	0.8547	0.4937	0.6883
P_{25}: Ecosystem services	0.2473	0.2725	0.8860	0.4991
P_{26}: Species richness	0.1606	0.1990	0.2921	0.9367
P_{31}: River and lake health	0.2998	0.9120	0.1933	0.6831
P_{32}: Water accessibility	0.6400	0.1521	0.1217	0.9842
P_{33}: Pollutant adsorption	0.3355	0.9559	0.4638	0.7247
P_{34}: Wastewater treatment efficiency	0.4493	0.1029	0.7441	0.3286
P_{35}: Water quality index	0.2672	0.0000	0.9798	0.7317
P_{36}: Air quality index	0.1928	0.5020	0.1551	0.9373
P_{41}: Community health index	1.0000	0.2504	0.4701	0.0820
P_{42}: Facility maintenance and upkeep	0.7547	0.7247	1.0000	0.1289
P_{43}: Timeliness of services	0.6859	0.5155	0.8950	0.0000
P_{44}: Psychological health improvement	0.6186	0.5936	0.8042	0.6233
P_{45}: Ecological corridor connectivity	0.2402	0.2419	0.6022	1.0000
P_{46}: Public participation	0.8987	0.4703	0.0000	0.6139
P_{47}: Environmental protection	0.3595	0.8609	0.3268	0.7516

Table 7: Weighted values of indicators for each district.

Evaluation indicators	Shangbu District	Gucheng District	Shanda Road District	Daming Lake District
P_{11}: Forest coverage rate	0.014852	0.025388	0.027475	0.045747
P_{12}: Green area coverage rate	0.012907	0.025422	0.026361	0.039724
P_{13}: Temperature regulation capability	0.016236	0.043319	0.013556	0.031975
P_{14}: Air humidity regulation	0.007328	0.016110	0.008205	0.028906
P_{15}: CO_2 absorption capacity	0.000000	0.009701	0.005634	0.015565
P_{16}: Distribution of green areas	0.006563	0.003067	0.008553	0.015188
P_{17}: Species richness	0.005186	0.005789	0.006080	0.008222
P_{21}: Wetland conservation level	0.013560	0.018072	0.018470	0.027327
P_{22}: Diversity index	0.027960	0.039268	0.037009	0.050867
P_{23}: Natural landscape integrity	0.016286	0.099696	0.051647	0.079406
P_{24}: Water quality health	0.005557	0.015395	0.008893	0.012398
P_{25}: Ecosystem services	0.049872	0.054943	0.178649	0.100646
P_{26}: Species richness	0.008556	0.010599	0.015557	0.049895
P_{31}: River and lake health	0.008294	0.025229	0.005348	0.018895
P_{32}: Water accessibility	0.004831	0.001148	0.000919	0.007430
P_{33}: Pollutant adsorption	0.003903	0.011119	0.005395	0.008429
P_{34}: Wastewater treatment efficiency	0.008751	0.002004	0.014494	0.006402
P_{35}: Water quality index	0.013378	0.000000	0.049057	0.036634
P_{36}: Air quality index	0.013492	0.035135	0.010854	0.065606
P_{41}: Community health index	0.025297	0.006335	0.011892	0.002075
P_{42}: Facility maintenance and upkeep	0.001743	0.001674	0.002310	0.000298
P_{43}: Timeliness of services	0.003325	0.002500	0.004339	0.000000
P_{44}: Psychological health improvement	0.010417	0.009996	0.013544	0.010497
P_{45}: Ecological corridor connectivity	0.000771	0.000776	0.001932	0.003209
P_{46}: Public participation	0.010214	0.005345	0.000000	0.006978
P_{47}: Environmental protection	0.002671	0.006396	0.002428	0.005584

Table 8: Relative closeness and ranking of each district.

District	Positive ideal solution (M^+)	Negative ideal solution (M^-)	Relative closeness (C_i^+)	Ranking
Shangbu District	0.18345995	0.03052634	0.14265559	4
Gucheng District	0.14823537	0.09830851	0.39874651	3
Shanda Road District	0.09769359	0.14526488	0.59790003	2
Daming Lake District	0.08650754	0.12876075	0.5981408	1

(M^+ positive ideal solution) and the worst vector (M^- negative ideal solution). Then, we calculate the Euclidean distances between each district and the positive and negative ideal solutions, denoted as d_i^+ and d_i^-, respectively. Using the formula for relative closeness C_i^+, a higher value C_i^+ indicates a higher level of satisfaction for that district. Therefore, arranging the relative closeness C_i^+ in the descending order provides the satisfaction ranking results for Shangbu District, Gucheng District, Shanda Road District, and Daming Lake District, as shown in Table 8.

5. Urban Blue-Green Space LEH Landscape Quality Optimization Strategies

5.1. Building a "Blue-Green Integration, City-Water Unity" Blue-Green Space Layout. Under the LEH concept, by implementing "interconnected river systems, integrated green corridor landscapes, and complementary park and square green spaces" [41], it is possible to create a convergence of urban water networks, urban ecological networks, urban landscape networks, and urban public space networks. This fosters a livable, healthy, and sustainable urban environment, helping to maintain urban ecological balance, alleviate the urban heat island effect, improve the quality of life for urban residents, and enhance resource efficiency [42]. Through high-performance core nodes, the optimization of blue-green spaces is expanded from point to area, transforming Jinan into a three-level blue-green space system: "regional blue-green space, community blue-green space, and node blue-green space." This system is anchored by core optimization frameworks, such as Daming Lake, Baotu Spring, and Qianfoshan, and integrates urban blue-green space networks within the city and edge ecological green belts, creating an "urban space structure of mountains, springs, lakes, rivers, and the city" [43].

5.2. Constructing an Ecological Grid Structure to Enhance Urban Space Quality. Focusing on the integration of urban attributes related to "nature-society-economy-culture," rational planning of blue-green spaces within the city's boundaries is undertaken to create an ecological grid system with continuous connectivity and integrity, including mountains, rivers, lakes, and green spaces [44, 45]. To better harness the coupled security effects of blue-green spaces, the main measures include (1) connecting rivers and lakes through new construction, identifying low-power water systems, strengthening linear water body planning, restructuring the urban water grid structure, and preventing water disasters. (2) Building a blue-green space grid in the urban main and subsidiary rivers, large urban green belts, and urban main roads, among other natural and traffic buffer zones, to truly mitigate urban pollution effects and enhance connectivity of urban ecological sectors [46]. (3) Linking natural ecological resources such as mountains, water bodies, wetlands, parks, and green spaces with human-made resources such as farmland and protective forests to interconnect and improve the ecological network, forming an interconnected and urban ecosystem.

5.3. Constructing Human-Centric Blue-Green Spaces to Enhance Public Service Capabilities. The key to constructing the human-made environment in urban blue-green spaces lies in establishing an urban park and green space system that seamlessly integrates with the city. One of the goals of the ecological health of urban blue-green spaces is to create core cultural elements of urban greenery and water. To enhance the service capabilities of urban blue-green spaces, it is necessary to increase service level indicators, including per capita blue space, accessibility, and the water view rate of surrounding residents, to supplement traditional park and green space systems [47, 48]. This involves unearthing historical and cultural elements, including material spatial culture and nonmaterial spiritual cultural activities, integrating point-like cultural spaces within urban blue-green spaces to meet various production and service activities in the city and enhance the city's economic and cultural level [49].

6. Discussion and Conclusion

6.1. Discussion. Integrating the grey system theory (GST), analytic hierarchy process (AHP), and technique for order of preference by similarity to ideal solution (TOPSIS) in assessing the landscape ecological health (LEH) of urban blue-green spaces offers a comprehensive framework for evaluating the intricate relationships among ecological, social, and economic factors. Our analysis revealed several key points as follows: (1) methodological approach: adopting the GST-AHP-TOPSIS combination model enabled systematic evaluation of diverse criteria layers, facilitating the identification of influential factors impacting urban blue-green space LEH. This methodological approach ensured a comprehensive understanding of landscape health and offered a structured framework for decision-making. (2) Indicator selection and weighting: the selection and weighting of evaluation indicators were critical steps in our assessment process. Through expert consultations and surveys, we identified and prioritized key indicators such as ecosystem diversity, green space vegetation coverage, air and water quality, and social participation and health. The AHP method facilitated the calculation of indicator weights, offering insights into the relative importance of each criterion layer. (3) Regional disparities: while areas like Daming Lake District demonstrated higher landscape health levels, others, such as the Shangbu District, encountered more significant challenges. These results highlight the necessity for targeted interventions and policy actions to tackle specific environmental issues and enhance overall landscape quality. (4) Sensitivity analysis: in order to ensure the reliability of our conclusions, we performed a sensitivity analysis to gauge the impact of potential variations in input parameters on our results. This analysis involved altering key parameters, such as the weights assigned to different evaluation indicators and the criteria used for district ranking. Remarkably, the results of the sensitivity analysis indicated that despite fluctuations in these parameters, the overall district ranking remained relatively consistent. This underscores the robustness of our conclusions regarding the relative performance of districts in terms of urban blue-green space LEH, as they are not substantially affected by variations in input parameters. Moving forward, we aim to conduct more extensive sensitivity analyses to investigate the influence of additional factors on our findings. By doing so, we will further enhance the credibility and applicability of our evaluation framework.

6.2. Conclusion. In conclusion, our study highlights the significance of adopting an integrated approach to assess the landscape ecological health (LEH) of urban blue-green spaces. By leveraging the GST-AHP-TOPSIS combination model, we have developed a systematic and scientifically grounded evaluation framework that can inform decision-making processes and guide urban planning initiatives. Our findings emphasize the need for comprehensive strategies aimed at enhancing the quality and resilience of urban landscapes, thereby promoting the well-being of residents and fostering sustainable urban development. Moving forward, continued research in this area is essential to address emerging environmental challenges and ensure the long-term health and vitality of urban blue-green spaces.

This study has several limitations, including data limitations, methodological limitations, regional limitations, and temporal limitations. First, regarding data, the data used in this study primarily came from literature and expert surveys, which may suffer from issues of incompleteness or lack of comprehensiveness, potentially affecting the accuracy and reliability of the research results. Second, concerning methodology, although this study utilized the GST-AHP-TOPSIS combination model for evaluation, different evaluation methods may yield varying results, introducing a certain degree of subjectivity and bias. In addition, in terms of region, this study primarily focused on evaluating the blue-green spaces of specific cities, and the actual situations in different regions may exhibit significant differences, thereby limiting the generalizability and applicability of the research findings due to regional constraints. Lastly, regarding time, the data and information involved in this study are concentrated within specific time periods, and future changes may impact the stability of the research results. Regular updates of data and information are necessary to ensure the timeliness and reliability of the research findings. In future research, efforts can be made to diversify and broaden the sources of data, explore and compare the effectiveness of different evaluation methods, expand the scope of research, and engage in long-term tracking and monitoring of the development and changes in blue-green spaces. These endeavors aim to better understand and address the various limitations inherent in the evaluation of urban blue-green space health, thus advancing the continuous development and progress of this field.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors wish to thank all participants of this study for their selfless participation and dedication. The authors also acknowledge National Social Science Fund Art Project, 2018 (project no.: 18BA009).

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