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Research on Park Environment Evaluation based on Multi-dimensional Perception

-- Taking the Transformation of Xigang Garden Industrial Heritage in Qinhuangdao as an Example

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Abstract

As an important part of urban green infrastructure, urban parks not only have ecological regulation functions, but also bear cultural, leisure and other social values. The environmental quality and user experience of urban parks have attracted great attention. Existing studies have evaluated park environments from multiple dimensions through quantitative evaluation systems, and found that natural elements are easy to evoke emotional resonance, but little attention has been paid to the bidirectional influence of user behavior and environmental design, making it difficult to guide spatial optimization. This study takes the Xigang Garden Industrial Heritage Renovation Project in Qinhuangdao as the empirical object, based on the theory of multisensory perception, integrates questionnaire surveys, spatial syntax analysis and IPA models, and constructs a park environment evaluation system with user experience as the core. The study deeply analyzes the differences in tourist perception from the visual, auditory and tactile perspectives, and systematically identifies tourist preferences by combining behavioral trajectory analysis and demand research. The research conclusions provide a theoretical framework and practical path for the renovation of industrial heritage parks.

Keywords

Industrial Heritage Park; Multi-Dimensional Perception; User Experience; Importance-Performance Analysis.

1. Introduction

As a vital component of urban green infrastructure, the environmental quality and user experience of urban parks have garnered increasing attention from various sectors of society. Parks serve not only as spaces for urban residents to relax and connect with nature, but also as prominent symbols of a city's achievements in ecological civilization construction[1]. Therefore, research on park environmental perception evaluation based on user experience is crucial for improving park service quality and promoting sustainable urban development.

The *Notice of the State Council on Strengthening Urban Greening Construction* emphasizes that urban parks not only fulfill ecological functions such as regulating climate, conserving soil and water, and reducing pollution, but also serve social functions including cultural transmission, science education, and recreational activities[1]. Against this backdrop, evaluating park environments from the perspective of user experience provides a scientific basis for policymakers and offers significant value in optimizing park design and management, enhancing service quality, and increasing public well-being.

Previous studies have developed various quantitative evaluation indicator systems to systematically assess park environmental quality. For instance, the ASEB method divides park experience into four dimensions-activity experience, environmental experience, perception experience, and benefit experience-further refined into 21 specific indicators[2];Factor analysis has been employed to identify key factors affecting urban park satisfaction, resulting in an eight-dimensional evaluation system comprising safety, comfort, social interaction, pleasure, respect, physiological needs, convenience, and self-actualization[3]; Another framework evaluates park quality based on the experiential process, dividing it into perception, cognition, and experience phases. This model underscores the importance of human-environment interaction and offers a new theoretical path for future research[4].

Social media data provide a novel perspective for assessing park environmental perception. Analyzing user-generated content such as reviews and images enables researchers to uncover visitor preferences regarding landscapes and facilities, offering advantages in terms of temporal continuity and spatial coverage[5,8]. For example, a study in Hefei revealed that natural elements evoke stronger emotional responses than artificial structures[6]. Big data technologies allow for dynamic monitoring of visitor behavior, optimizing resource allocation, and revealing emotional impacts across different park types. Moreover, analyzing social media feedback provides abundant real-time insights, aiding managers in promptly responding to public needs[5]. Studies focusing on specific groups-such as the elderly, children, and the visually impaired-highlight differences in perceptual needs. Visually impaired individuals prioritize tactile and auditory features, while older adults emphasize safety and comfort[8,9]. However, existing research rarely explores the bidirectional influence between user behavior (e.g., gathering, strolling) and spatial design, limiting guidance for spatial optimization.

Research on park environmental perception evaluation emphasizes a user-centered approach, focusing on actual experiences and emotional responses. Such methods assist park managers in identifying and resolving issues encountered by residents during use[5]. Current studies show that visual perception is the most influential sensory element in park experiences, followed by tactile and olfactory perceptions[5], Natural elements like vegetation and water bodies significantly influence user behavior and experiences[6,7]. Users engage with parks through sensory inputs-vision, touch, smell-which are critical in perception and evaluation, thus guiding more precise ecological design optimizations. This enhances the park's ecological service functions, supports sustainable urban development, and improves resident satisfaction.

This study collects visitor perception data through questionnaire surveys and field observations, employing descriptive statistics and environmental psychology principles for analysis. First, using the Importance-Performance Analysis (IPA) method and factor analysis with SPSS, a park environmental perception evaluation system is constructed to provide a scientific basis for park management and planning. Secondly, importance-satisfaction difference analysis is conducted across sensory dimensions such as visual, auditory, and olfactory perceptions to explore perceptual differences and visitor preferences. Finally, through behavioral observations and survey-based analyses, visitor emotional experiences and improvement needs are identified, leading to targeted strategies for enhancing park environments.

2. Research Scope and Methodology

2.1 Research Scope

The study focuses on Xigang Garden, which encompasses the areas of the Qinhuangdao Port Grand Wharf, Wharf A, Wharf B, the South Warehouse, Laogang Road, Kaoshan Road, and the section along Qingsong Road, as well as part of the Taiping Bay yard. This area constitutes the first phase of the Hebei Port Group's International Tourism Port pilot zone, covering approximately 1,200 mu (around 80 hectares).

Xigang Garden enjoys excellent transportation accessibility and is a repurposed site developed from an abandoned port. It uniquely combines railway elements, maritime atmosphere, and vast ocean views. This distinctive integration sets it apart in terms of landscape characteristics, enabling a successful transformation into a popular tourist destination and granting it significant research value. Within the park, numerous remnants of obsolete railway equipment, old factory buildings, and freight station facilities have been preserved and repurposed. These historical artifacts have been creatively transformed into unique landscape features, endowing the park with a rich historical and cultural ambiance (see Figure 1).

Figure 1. Site Plan (Image Source: Drawn by the Author)

2.2 Research Methodology

1) Questionnaire Survey

The questionnaire survey serves as the primary method of data collection in this study. A questionnaire comprising multiple-choice and rating questions is designed and distributed via an online platform. The content includes basic user information, usage habits, and satisfaction evaluations. A pilot survey will first be conducted on a small scale to refine the wording of questions based on participant feedback, ensuring clarity and comprehensibility. During the formal distribution phase, random sampling will be employed with a target of collecting over 80 valid responses. This method allows for the rapid acquisition of a large volume of standardized data, making it suitable for statistical analysis.

2) Field Observation and Spatial Analysis

To obtain scientifically quantified primary data, field observations will also be conducted. On-site measurements and photographs will be taken at the target location. Key measurements include pedestrian walkway widths, vehicular lane widths, greenbelt widths, and building setback distances. Additionally, fundamental principles of space syntax will be applied to assess indicators such as spatial accessibility and path permeability, allowing for the calculation of integration, choice, and depth values of park pathways. This method provides the most authentic firsthand data and helps to compensate for potential biases in survey responses.

3) Data Analysis

The collected data will be processed and analyzed using SPSS 26.0 software. Descriptive statistics and reliability-validity tests will be performed to assess the basic quality of the data. Correlation analysis will be used to explore relationships among variables, and factor analysis will be employed to reduce the dimensionality of the evaluation scale. These scientific analysis methods allow for the extraction of valuable patterns and conclusions from the data.

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3. Data Collection and Analysis

3.1 Data Collection

Questionnaire Design.The questionnaire consists of four sections: (1) basic personal information, (2) evaluation of the park's natural ecological environment, (3) evaluation of park facilities and services, and (4) evaluation of the park's social functions. A total of 17 indicator items are included. A five-point Likert scale is used for measurement. For perceived importance, scores range from 1 ("very important") to 5 ("not important at all"); for perceived performance (i.e., satisfaction), scores range from 1 ("very satisfied") to 5 ("very dissatisfied").

Data Collection.The survey targeted residents living near Xigang Garden. A total of 120 preliminary questionnaires were distributed, and 81 valid responses were recovered. After collection, data cleaning was performed to eliminate invalid responses and ensure the authenticity of pedestrians' environmental perception evaluations.

3.2 Indicator System Construction and Variable Statistical Analysis

This study conducts statistical analysis of selected variables based on four dimensions: natural ecology, service facilities, social functions, and management and maintenance (see Table 1). The indicators cover dimensions such as ecology, infrastructure, and function, reflecting the comprehensive nature of environmental perception (including visual, auditory, and tactile aspects). All indicators can be measured on-site or derived from spatial analysis, ensuring scientific validity. Moreover, the framework emphasizes actual user needs-such as comfort, convenience, and safety-rather than focusing solely on aesthetic or ecological value (see Figure 2).

Natural Ecology: The park's greening rate affects visual comfort, air quality, and psychological relaxation[10];The coastline development index measures the accessibility of water bodies, enhancing landscape diversity and recreational experience[11];A rich variety of plant species stimulates the senses-sight, smell, and touch-thereby enriching the natural experience[12].

Rest facilities directly influence users' length of stay and comfort; the adequacy and rational placement of amenities such as benches and pavilions are key to user satisfaction. Cultural and recreational facilities-such as sculptures, stages, and fitness equipment-meet users' entertainment and cultural needs, enhancing the park's vibrancy and appeal[10]:Social interaction facilities, including plazas and interactive installations, encourage interpersonal communication and strengthen the park's social function[13];The convenience and cleanliness of basic amenities like restrooms directly impact user satisfaction[14].

The density of pedestrian paths reflects the development level of the walking network within the park, influencing the ease and enjoyment of exploration. Higher integration of park pathways indicates better spatial accessibility and centrality, making them more likely to attract foot traffic. Choice value represents the likelihood of a space being traversed; spaces with higher choice values are more likely to be passed through by visitors. Depth value indicates the spatial depth of a route-again, a higher value affects navigability and spatial coherence. These space syntax metrics (see Figure 4) quantitatively assess the rationality and accessibility of park path design, influencing users' navigation efficiency and freedom of movement[15];Proper pedestrian walkway width helps prevent crowding and enhances comfort; a balanced width of motor vehicle lanes ensures both safety and convenience. Greenbelt width reduces noise, improves microclimates, and enhances the walking experience[18];The setback distance of roadside buildings influences the sense of openness and the coordination between the park and its surrounding environment[16];Noise monitoring levels are directly related to users' ability to relax and communicate comfortably[17];Wind speed and wind force particularly affect thermal comfort in open areas (Street Design Manual. The City of San Diego. [Accessed: 2024-04-17]).

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Table 1. Statistical Analysis of Park Environmental Variables (Source: Compiled by the Author)

Common Factor	**Indicator Variable**	**Value**	**References**
Natural Ecology	Park Greening Rate	44.5%	[10]
	Park Shoreline Coefficient	5.2 km	[11]
	Number of Plant Species	106 species	[12]
Service Facilities	Rest Facilities	565 benches, 1 pavilion, 6 leisure areas	[10]
	Cultural and Entertainment Facilities	1 exhibition hall, 2 creative shops, 10 restaurants	
	Social Interaction Facilities	1 children's play area, 3 sports fields	[13]
	Toilets	15 locations	[14]
Social Function	Walking Path Density	Total length: 9.8 km, Total area: 40 m²	[15]
	Park Road Integration	Average: 0.646902	
	Park Road Choice Index	Average: 1099.03	
	Park Road Depth Value	Average: 8.73968	
	Pedestrian Path Width	Average: 2.17 meters	Street Design Manual. The City of San Diego. [Accessed: 2024-04-17]
	Motor Vehicle Lane Width	Average: 10.27 meters	
	Greenbelt Width	Average: 10.8 meters	
	Building Setback Distance	Average: 10.93 meters	[16]
	Noise Monitoring	65 dB	[17]
	Wind Speed Monitoring	3.5 m/s, Level 3 wind	[18]

3.3 Descriptive Analysis of Sample Information

By calculating the mean values of importance, performance, and their differences across 17 indicators, the differences in visitors' perception and evaluation of the park environment are revealed (see Table 2). The results show that the mean values of importance for park environmental perception range from 2.56 to 4.32, with an overall average of 3.47. Among them, five indicators-park greening rate (4.32), rest facilities (4.27), toilets (4.26), park road depth value (4.05), and pedestrian path width (4.17)-scored above 4.0, indicating higher expectations from residents. On the other hand, park shoreline coefficient (2.56), park walking path density (2.65), and greenbelt width (2.65) were the three indicators rated as least important.

As for performance perception in pedestrian environments of densely populated urban areas, the mean values range from 2.40 to 3.68, with an overall average of 3.43. Five indicators-park greening rate (4.22), park shoreline coefficient (4.09), rest facilities (4.12), toilets (4.17), and greenbelt width (4.14)-scored above 4.0, indicating relatively high satisfaction among residents. Other items were rated as average in terms of performance.

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Table 2. Differences in Importance and Performance Mean Values of Park Walkability Environment Perception Indicators (Source: Compiled by the Author)

Common Factor	Indicator Variable	Importance Mean	Std. Dev.	Performance Mean	Std. Dev.
Natural Ecology	Park Greening Rate	4.32	0.834	4.22	0.822
	Park Shoreline Coefficient	2.56	1.432	4.09	0.925
	Number of Plant Species	3.46	1.225	3.57	0.894
Service Facilities	Rest Facilities	4.27	0.791	4.12	0.886
	Cultural and Entertainment Facilities	2.86	1.181	2.40	1.281
	Social Interaction Facilities	3.57	0.935	2.86	1.232
	Toilets	4.26	0.877	4.17	0.877
Social Function	Walking Path Density	2.65	1.398	3.70	0.798
	Park Road Integration	3.75	0.888	2.63	1.400
	Park Road Choice Index	3.75	0.799	2.81	1.266
	Park Road Depth Value	4.05	0.865	2.64	1.408
	Pedestrian Path Width	4.17	0.834	3.94	1.004
	Motor Vehicle Lane Width	3.41	1.058	3.99	0.873
	Greenbelt Width	2.65	1.407	4.14	0.818
	Building Setback Distance	2.78	1.369	3.79	0.737
	Noise Monitoring	3.77	0.795	2.74	1.116
	Wind Speed Monitoring	2.78	1.107	2.57	1.274
Overall Mean		3.47		3.43	

4. Construction of Park Environmental Perception Evaluation Model and Analysis of Perception Differences

4.1 Factor Analysis of Park Environmental Perception Evaluation

Using SPSS 26.0 analysis software, the Cronbach's α value was found to be 0.894, the KMO value was 0.765, and the Bartlett's Test of Sphericity yielded a value of 1172.563 with a significance level of $p < 0.001$, indicating that the model is suitable for factor analysis. Further dimensional categorization of the park environmental perception evaluation indicators retained only those indicator items with factor loadings above 0.5 after orthogonal rotation, resulting in the identification of three common factors. These three common factors were named as Park Environmental Quality and Service Capacity Common Factor, Park Ecological Comfort and Transportation Accessibility Common Factor, and Public Health Services Common Factor.

The reliability test results (Cronbach's α) for each common factor were 0.895, 0.822, and 0.569 respectively. The cumulative variance contribution rate was 69.805% (see Table 3).

Table 3. Factor Analysis of Park Walkability Environment Perception Indicators (Source: Compiled by the Author)

Common Factor	Indicator Variable	Factor Loading	Cronbachs'α	Eigenvalue	Variance Contribution (%)
Park Environmental Quality and Service Capacity	Park Shoreline Coefficient	0.836	0.895	6.530	38.409
	Number of Plant Species	0.601			
	Walking Path Density	0.692			
	Park Road Integration	0.692			
	Park Road Choice Index	0.607			
	Motor Vehicle Lane Width	0.542			
	Greenbelt Width	0.821			
	Building Setback Distance	0.779			
	Noise Monitoring	0.651			
	Wind Speed Monitoring	0.773			
Park Ecological Comfort and Transportation Accessibility	Park Greening Rate	0.527	0.822	3.326	19.562
	Rest Facilities	0.695			
	Park Road Depth Value	0.809			
	Pedestrian Path Width	0.743			
Public Health Services	Cultural and Entertainment Facilities	0.801	0.569	2.012	11.834
	Social Interaction Facilities	0.575			
	Toilets	0.630			
Cronbach's α = 0.894 KMO = 0.765 Bartlett's Test of Sphericity = 1172.563 (p = 0.000) Cumulative Variance Contribution (%) = 69.805%					

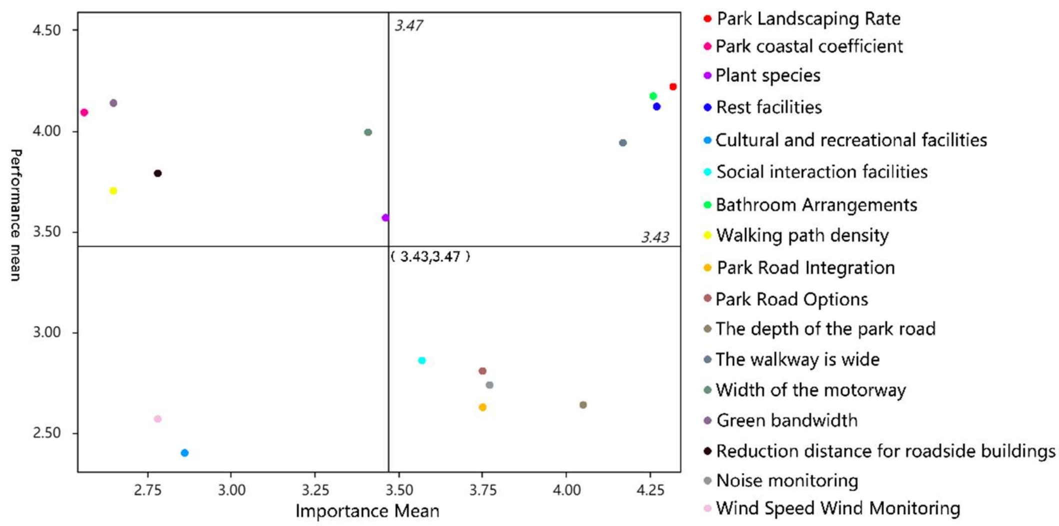
4.2 Analysis of Differences in Park Environmental Perception Evaluation

Based on the pedestrian evaluation scores for various indicators of the park's walking environment, the mean values were calculated and the 17 perception evaluation indicators were coded and visualized using a quadrant chart (Table 4). According to the results of the Importance-Performance Analysis (IPA), four indicators-park greening rate (A1), rest facilities (B1), restroom layout (B4), and pedestrian walkway width (C5)-fall into Quadrant I (high importance–high satisfaction). This indicates that these aspects are both highly valued by residents and performing well, effectively meeting their basic needs.

Six indicators-coastline development index (A2), number of plant species (A3), pedestrian path density (C1), vehicle lane width (C6), greenbelt width (C7), and building setback distance (C8)-are located in Quadrant II (low importance–high satisfaction), suggesting that the current conditions exceed residents' expectations, although they are not considered highly important. This may imply a potential over-allocation of resources and indicates opportunities for more balanced investment.

Two indicators-cultural and recreational facilities (B2) and wind speed/wind force monitoring (C10)-are in Quadrant III (low importance–low satisfaction), reflecting both low attention and low satisfaction from residents, and highlighting the need for targeted follow-up improvements. Five indicators-social interaction facilities (B3), road integration (C2), road choice value (C3), road depth (C4), and noise monitoring (C9)-are situated in Quadrant IV (high importance–low satisfaction). This shows that although these aspects are highly valued by residents, current conditions fail to meet expectations and should be prioritized for improvement and enhancement.

Table 4. IPA Analysis of Park Environmental Perception Evaluation (Table Source: Drawn by the Author)



5. Conclusion and Recommendations

This study explores strategies to improve the walking environment of urban parks based on differences in environmental perception, offering design and construction recommendations for similar parks in Qinhuangdao and across the country. By integrating questionnaire surveys, field observations, Importance-Performance Analysis (IPA), and factor analysis, a user experience-based environmental perception evaluation system was developed. The study analyzed visitors' perceptual differences from a multi-sensory perspective and identified visitor needs through behavioral observation and surveys. Findings indicate that indicators closely related to user experience-such as greening rate, facility and restroom layout, and pathway accessibility-are generally considered important by visitors. However, many of these aspects fall short of expectations, revealing significant room for improvement.

5.1 Enhance the Appeal of Social Interaction Facilities

Visitors reported that while scenic viewing spots are abundant, facilities that promote social interaction are clearly insufficient. It is recommended to add interactive installations, communal chess tables, and outdoor fitness zones in high-traffic areas of the park. These can be complemented by themed events such as markets or concerts to enhance visitor engagement and social experiences. Additionally, spatial syntax should be applied to optimize the layout of such facilities, ensuring that interactive spaces are located at highly accessible nodes to maximize usage.

5.2 Optimize the Design of Park Circulation Routes

Currently, some park pathways suffer from poor planning and an inadequate navigation system, causing visitors to lose their way or walk in circles, which negatively affects their efficiency and experience. To address this, it is suggested to restructure the pathway network by adding looped main roads and connecting side paths, eliminating dead-end routes, and improving overall accessibility. A variety of paths-such as waterfront promenades and shaded trails-should be designed, with landscape landmarks used to enhance wayfinding and cater to different walking preferences.

5.3 Reduce the Disruption Caused by Cruise Horn Noise

Survey responses and on-site interviews identified cruise horn noise as the primary source of noise pollution in the park. While noise undermines the park’s ambiance, cruises remain a key attraction for enjoying coastal scenery. To mitigate this, technical solutions include the use of low-noise engines, eco-friendly materials, optimized hull design, and onboard soundproofing measures (e.g., insulation panels, soundproof windows). From a management perspective, cruise routes should be adjusted to avoid sensitive areas such as bird habitats and quiet scenic zones. Strict noise control standards should be implemented, including negotiated limits on horn use with shipping authorities. Additionally, soundscape design can help mask noise using natural water features, or guide visitors toward quieter, high-quality areas away from main waterways.

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