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A Study on the Public Perception of Sports Spaces Under Urban Overpasses from the Perspective of Age Differences

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Abstract: As China's urban development enters the era of stock optimization, the practice of transforming and utilizing spaces under urban overpasses is rapidly gaining momentum. Converting these underpass spaces into sports areas has emerged as a new form of creating public space. Understanding the perceptions of users from different age groups towards these underpass spaces holds significant guiding value for optimizing the design of such areas and improving the quality of service. Taking the Yanshan Interchange Low-line Park in Jinan as an example, this research applied methods of observation, interviews, questionnaires, and importance–satisfaction analysis (ISA) to investigate the activity preferences and the similarities and differences in the perceptions of spatial environment elements in underpass spaces among four age groups: children, youth, middle-aged adults, and the elderly. The findings indicate that different age groups exhibit varying degrees of sensitivity to spatial information, demand levels, and perceptual perspectives in underline parks, which result in distinct spatiotemporal distributions and spatial perception disparities when using the park. All the groups agree that the underpass sports space requires significant improvements in terms of comfort and safety. Based on this, this study proposes age-friendly urban space renewal strategies for spaces under elevated highways, focusing on addressing areas with lower satisfaction across all age groups. These strategies include optimizing the allocation of time, area, and activity types within activity spaces, enhancing the safety and comfort of activity areas, and enriching the cultural connotation and inclusivity of the space. This research provides a theoretical basis for optimizing and creating age-friendly or age-specific urban sports public spaces under elevated highways.

Keywords: sports space under overpasses; public perception; age differences; age-friendly; inclusive design

Academic Editors: Francesca Moraci, Laura Ricci, Kh Md Nahiduzzaman, Celestina Fazia, Carmela Mariano and Francesca Perrone

Received: 31 December 2024
Revised: 24 January 2025
Accepted: 28 January 2025
Published: 30 January 2025

Citation: Wen, Z.; Luo, X.; Wang, X.; Liu, H. A Study on the Public Perception of Sports Spaces Under Urban Overpasses from the Perspective of Age Differences. *Land* **2025**, *14*, 293. https://doi.org/10.3390/land14020293

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1. Introduction

As a means to alleviate ground-level traffic congestion and improve transportation efficiency, elevated highways have been widely constructed during China's rapid urbanization phase. However, this has led to the creation of underutilized, negative spaces beneath the bridges. Although these under-bridge spaces are a crucial component of urban public areas, they have often been neglected. Most of these spaces are used in an unplanned manner as parking lots, disorganized green areas, informal structures, or even dumping grounds. By 2020, China's overall urbanization rate exceeded 60%, signaling a

transition in China's urban development from an era of growth to an era of optimizing existing urban assets [1]. In 2021, the government released the 14th Five-Year Plan and 2035 Vision for National Economic and Social Development [2], which proposed urban renewal initiatives to optimize urban spatial structures and enhance quality. As part of the focus on existing assets, the potential of under-bridge spaces garnered significant attention, spurring numerous design projects aimed at transforming these areas into recreational and sports spaces for public use. In 2019, the China Planning and Design Commission launched a specialized study on utilizing space under bridges. By analyzing the projected footprint of bridges, it was found that 402 hectares of under-bridge space was available, with approximately 244 hectares already in use and 158 hectares untapped [3]. Given the extensive scale of these spatial resources, cities across China have gradually implemented projects to revitalize and renovate under-bridge spaces. Guidelines and regulations have also been introduced, such as the Beijing Design Guidelines for the Utilization of Space Under Bridges, which was officially issued in January 2023 to promote the structured utilization of these spaces. Jinan, the capital of Shandong Province, boasts an abundance of groundwater resources and relies on its spring water as a primary source for drinking, which has also become a significant cultural emblem of the city. To protect these water resources, Jinan has refrained from developing an extensive subway system to address the growing traffic demand; therefore, elevated highways have become a key element of Jinan's transportation infrastructure. While these highways have accelerated urban development, they have also created large under-bridge spaces that are underutilized. Recognizing the negative impact of these spaces—such as their detrimental effects on the urban environment and community connectivity—the government has begun to transform them into spaces suitable for community activities, enhancing their social, economic, and cultural value and transforming them from negative to positive spaces. In October 2021, Shandong Province's first Lowline Park—the Yanshan Interchange Lowline Park in Jinan—was opened to the public. This park makes full use of the space under the Yanshan interchange, creating a high-quality, multifunctional area under the bridge that integrates cultural, recreational, and fitness functions for city residents. Following its opening, the park received enthusiastic responses from the public. However, research evaluating the use and effectiveness of such sports-oriented repurposed under-bridge spaces remains limited.

A review of the literature reveals that most studies related to elevated highways focus on assessing the potential for the sustainable utilization of under-bridge spaces, analyzing design approaches for these spaces, or examining the impact of elevated highways on the quality of life and spatial usage of nearby residents. For example, Zaki et al. (2023) used a multi-criteria decision-making (MCDM) approach to propose five key criteria—social benefits, economic feasibility, environmental impact, infrastructure enhancement, and urban identity—to systematically evaluate the sustainable use of under-bridge spaces. They applied decision-making trial and evaluation laboratory (DEMATEL) technology to assess the causal relationships between these criteria [4]. Ahmed et al. (2024) discussed various spatial configurations of under-bridge spaces and corresponding approaches to their redevelopment [5]. Lak et al. (2022) conducted surveys to examine residents' perceptions of changes in environmental quality and quality of life before and after elevated highway construction [6]. Meanwhile, a small number of scholars have focused on users of under-bridge spaces as their research subjects and studied user satisfaction with these spaces. For instance, Sarhan et al. (2023) reviewed prior evaluation standards for open spaces and developed a five-level evaluation model encompassing functional performance, accessibility, comfort, safety, pleasure, and meaning [7]. Through surveys, they collected data on satisfaction perceptions from 150 users of three types of under-bridge spaces (vegetation, commercial, and transportation-oriented) in the Heliopolis

community in Egypt, examining the attributes that most influenced user satisfaction with these spaces through structural equation modeling. Nunma et al. (2021) used observation, visual questionnaires, and interviews to study children's needs for play spaces under elevated highways, analyzing their satisfaction with these spaces as playgrounds [8]. Although studies like these provide some insights, research on users of elevated bridge spaces remains limited, and there is a lack of studies on public perception of such spaces, especially of the sports-oriented urban under-bridge spaces. Moreover, there is no specialized post-occupancy evaluation system specifically designed to assess the use of these spaces.

Research on urban public space evaluation systems can provide important theoretical support for the establishment of post-occupancy evaluation systems for under-bridge spaces. Zhu (2003) proposed three key types of factors impacting the built environment—human, physical environmental, and social environmental factors—presenting a user-value-oriented subjective evaluation of the built environment from a methodological perspective [9]. Li (2014) suggested that accessibility, functional configuration, environmental quality, and the atmosphere of the space are core factors influencing the vitality of public spaces in residential areas, significantly affecting residents' user experience [10]. Cheng and Liu (2019) focused on the diversity of open spaces and commercial services, finding that increased diversity in public spaces enhances resident usage frequency, indirectly fostering neighborhood interaction and community trust [11]. Zhou and Lin (2020) divided the public space evaluation system into five dimensions—accessibility, safety, ecology, comfort, and culture—and conducted empirical research on public spaces along the banks of the Huangpu River [12]. Yan et al. (2021), based on social ecology theory, proposed that the accessibility, quality, safety, and user characteristics of community public spaces are essential factors in promoting social cohesion [13]. These studies on public space evaluation systems provide a theoretical foundation for establishing evaluation frameworks for spaces beneath elevated highways.

Recent population trends indicate that global cultural diversity is increasing across age groups, which highlights the growing need to address the demands of a multi-generational society. This shift underscores the importance of incorporating age-friendly urban design into planning practices [14,15]. Numerous studies have further emphasized the statistically significant differences among various age groups in their use of urban spaces [16]. These differences arise because each age group has distinct needs and perceptions when interacting with urban environments; however, current urban planning often fails to adequately accommodate vulnerable populations. For instance, due to their limited mobility, children primarily rely on parks within walking or cycling distance as spaces for independent physical activity [17]. Additionally, children tend to favor areas specifically designed for their age group, as such spaces offer both convenience and comfort. These areas also provide opportunities for social interaction with peers, which is essential for their development [18–20]. On the other hand, adults generally prefer visiting parks during quieter periods, such as in the afternoons or evenings, when these spaces are less crowded [21]. Moreover, safety and security play critical roles in influencing adults' choices of activity spaces for their children [22]. When selecting suitable spaces, adults tend to prioritize factors such as the landscape features and the cleanliness of facilities over mere proximity [5,20,23,24]. As individuals age, their needs and preferences for urban spaces evolve. Elderly users, for example, often gravitate towards less physically demanding activities due to declining health [25–29]. Furthermore, noise pollution tends to have a more pronounced negative impact on the elderly, making tranquil and accessible environments particularly important for this group [30]. These findings collectively highlight the pressing need for urban planners to consider the diverse and evolving requirements of different age groups. By fostering inclusive and accessible public spaces, cities

can better address the growing societal emphasis on equity and improve the overall quality of life for all generations.

In this context, how different age groups perceive urban public spaces has become an important research topic. Researchers have explored public perceptions of various types of urban public spaces from an age-based perspective, proposing improvement strategies accordingly. For example, Wu (2021) and colleagues evaluated the usage of community public spaces from an age-differentiated perspective, providing optimization strategies for different age groups [31]. Wong (2009) investigated the behavioral patterns of Hong Kong residents visiting urban parks and the perception differences among age groups [32]. Zhai et al. (2021) studied the level of attention given to various elements within 15 urban parks by users of different ages, investigating the correlation between environmental factors in public spaces and the age of respondents [33]. Elin et al. (2020) conducted walking interviews to examine how different age groups used urban parks and their differing management needs [18]. Mak et al. (2019) examined the characteristics, behaviors, and preferences of urban park users and analyzed the influence of various demographic factors on usage patterns by calculating a factor importance index [24]. Li (2019) analyzed the needs of various age groups in urban public spaces from an all-ages perspective, summarizing the theories of inclusive communities and design, and suggested strategies to create age-friendly public spaces [34]. Moore et al. (2015) examined the environmental barriers in children's activity spaces and proposed strategies to enhance their usability and inclusiveness for children with disabilities [35]. Some scholars have also conducted research from the perspective of facility needs among users of different age groups in urban public spaces. For example, Rivera et al. (2021) explored adolescents' perspectives on important park features influencing park visits, park-based physical activities, and social interactions. Through walking interviews, they summarized the characteristics of the "ideal park" [36]. Liao (2022), taking an intergenerational perspective, analyzed the service facility needs among different age groups and proposed an integrated planning approach for community public service facilities. This approach, through policy guidance, spatial planning, functional design, and operational management, aims to integrate multigenerational facilities and promote the development of age-friendly communities [37]. Lindberg et al. (2015) utilized the System for Observing Play and Recreation in Communities (SOPARC) to investigate the usage intensity of different urban green spaces and recreational facilities among age groups, revealing mismatches between the intended target groups and actual users of certain facilities [19]. However, while research on public space perception from an all-age perspective has flourished, most studies focus on community public spaces and urban parks, with relatively limited research on urban spaces under elevated highways. Therefore, there is a pressing need to supplement this area of study.

This study adopts an all-ages perspective, using Jinan's Yanshan Overpass Lowline Park as a case study of a sports-oriented public space under an elevated highway. Through observation, interviews, and importance–satisfaction analysis (ISA), it examines the distribution differences of user groups across age stages and their relationship with spatial elements. The study analyzes variations in the importance and satisfaction ratings of different spatial elements among users of various ages. Based on these findings, it further proposes strategies to enhance the space for each age group, aiming to provide insights for designing age-friendly sports spaces under elevated highways in the future.

2. Materials and Methods

2.1. Research Object

This study focuses on the Yanshan Interchange Lowline Park and its surrounding green spaces. The Yanshan Interchange Lowline Park (hereafter referred to as the "Lowline Park") is located in Jinan, Shandong Province, China (Figure 1), situated in a warm temperate continental monsoon climate zone with hot, rainy summers and cold, dry winters. The Lowline Park is a sports and recreational area for residents, transformed from an underutilized space beneath an elevated highway. Officially opened on 1 October 2021, it is the first high-quality under-bridge activity space in Shandong Province, initiated by the government, designed by professional architects, and maintained by municipal authorities. The park integrates cultural, recreational, and fitness functions. The surrounding environment of the Lowline Park is complex, including residential, commercial, and office areas. It spans 550 m in length and 50 m in width, with a design area of approximately 28,000 square meters. Divided by the East Second Ring Road, it comprises two distinct functional zones, East and West. The eastern zone includes seven functional areas: a skate park, a multi-sport court (including fields for soccer, badminton, and flexible ball games), a street basketball court, a ping pong court, a 24 h urban library, a performance plaza, and a parking lot. The western zone retains the original parking lot and four gateball courts, with redesigned pedestrian paths, green belts, and parking spaces, along with upgrades to the existing gateball facilities (Figure 2).

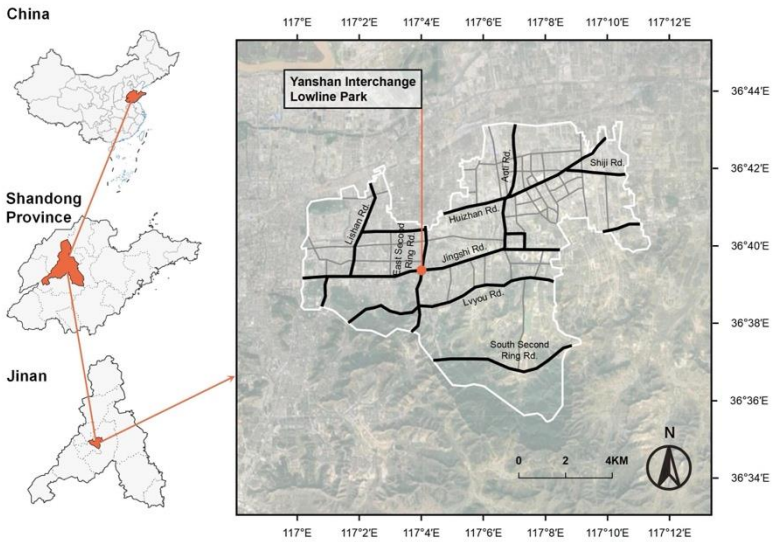

Figure 1. Geographic location of Jinan.

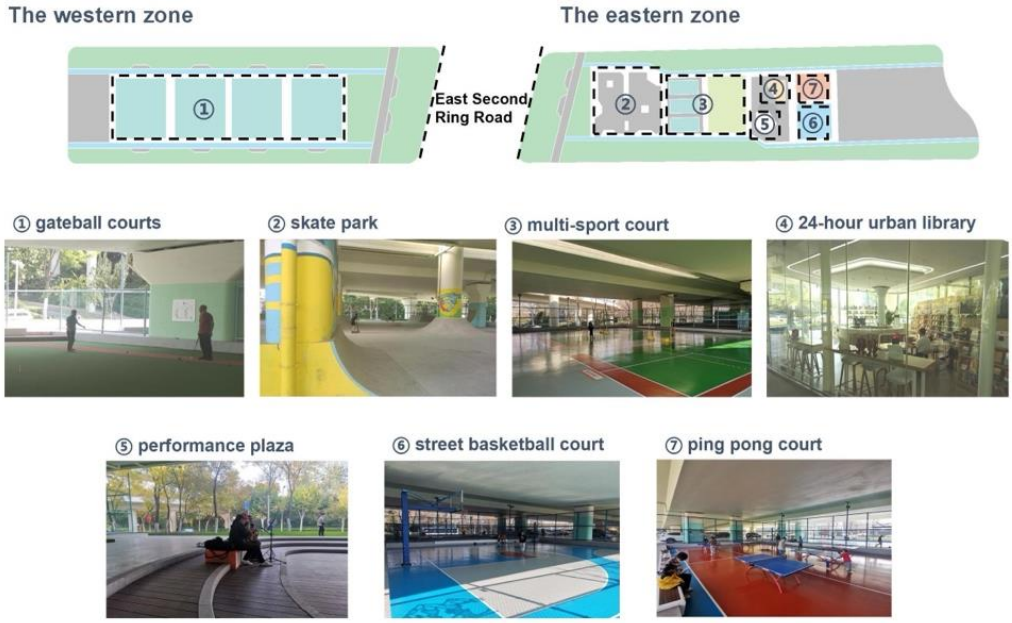

Figure 2. Site plan of the Yanshan Interchange Lowline Park and its functional spaces.

2.2. Research Methods

2.2.1. Establishment of an Evaluation System

This study selected evaluation indicators based on theories from behavioral architecture, Maslow's hierarchy of needs [38], *the Chinese Walkable City evaluation standards* [39], the classification of outdoor activities into three types in *Contact and Space* [40], Rancière's theory of aesthetic fairness in "distribution of the sensible" [41], and other urban public space evaluation systems. Five primary criteria were established—"Accessibility", "Safety", "Comfort", "Aesthetic Appeal", and "Cultural Value". These were further refined into 26 secondary evaluation indicators tailored to the specific context of Lowline Park, thereby forming a post-use evaluation system for public spaces under urban elevated highways (Table 1).

Table 1. Post-occupancy evaluation system for public spaces under urban elevated highways and respondents' perceptions of indicator levels.

Criterion Level	Indicator Level	Perception of Indicator Level
Accessibility	1. Convenience of Crossing Roads to Access the Park [42]	The convenience for pedestrians crossing roads from surrounding streets to access the park, including the availability of sufficient safety features for crossing (e.g., crosswalks, traffic lights) and whether the design of crossing paths is reasonable (e.g., appropriate timing of traffic lights, adequate distance, location, and number of crosswalks).
	2. Convenience of Entrance Locations [43]	Whether the geographical distribution of park entrances is reasonable, positioned in high-traffic or easily accessible areas to allow for convenient and quick entry and exit.
	3. Number of Park Entrances [43]	Whether the total number of park entrances is sufficient to minimize detours, allowing visitors to choose the nearest entrance based on their location or preference.

	4. Visual Recognition of Park Entrances [43,44]	Whether entrances have clear signage or directional markers that allow pedestrians to easily identify entrance locations, ensuring they can smoothly find their way into the park.
	5. Connectivity Between Different Functional Areas within the Park [43,45]	The ease of moving between different functional areas within the park, including whether there are convenient pathways and adequate signage that enable people to navigate smoothly between zones.
	6. Number of Nearby Bus Stops [44]	Whether there is a sufficient number of nearby bus stops to ensure high connectivity between the park and public transportation, making it easy for visitors without private vehicles to reach and leave the park by bus.
	7. Location Distribution of Nearby Bus Stops [44]	Whether the locations of bus stops are reasonably distributed in relation to the park entrances. Conveniently located stops can provide easy connections for park visitors, allowing them to quickly walk to the park entrance after disembarking, thus enhancing the park's accessibility for public transportation users.
Safety	8. Security Management in the Park [45]	Whether there are adequate security personnel, patrol frequency, and monitoring measures in place to ensure visitor safety in the park, and if current management practices effectively prevent criminal activity.
	9. Safety of Surrounding Traffic for Pedestrians and Non-Motorized Vehicles [45]	Condition of surrounding roads, including vehicle speed, traffic volume, signage, pedestrian crossings (traffic lights, crosswalks), and designated pathways for pedestrians and non-motorized vehicles to avoid conflicts with motor vehicles.
	10. Lighting Conditions in the Park [44,45]	Adequacy and brightness of lighting installations (especially at night), ensuring visitors can clearly see paths to avoid safety issues from insufficient lighting or glare; assessment of areas lacking lighting or where lighting is overly bright.
	11. Condition of Sports Facilities [44]	Maintenance and usability of sports facilities in the park (e.g., tables and courts); whether they are in good condition, conveniently accessible, and adequately maintained to reduce accident risks for users.
	12. Safety of Internal Facilities [42,44]	Design, structural stability, and regular maintenance of internal facilities, such as benches, railings, and children's play equipment, with warning signs around damaged items to prevent injuries due to facility failure.
	13. Overall Safety of Internal Park Areas [42,44]	General safety conditions of different areas within the park, including pathway smoothness, anti-slip treatment, absence of hazardous terrain, and clear surfaces free from debris or trash that could cause visitors to slip or fall.
Comfort	14. Sound Environment in the Park 44]	Whether there is noise in the park that disturbs visitors' activities.
	15. Air Quality in the Park [44]	Whether the air quality in the park is good, free from unpleasant odors or pollution, ensuring a healthy and comfortable experience for visitors.
	16. Distribution of Activity Areas [46]	Whether the placement of various activity areas is reasonable, such as quiet areas being separated from lively ones,

		and whether the layout is convenient for visitors to find desired areas without interference. Presence of clear signage or landmarks.
	17. Number of Activity Areas [46]	Whether the number of activity areas is sufficient to meet the needs of visitors of different ages and interests, providing enough space for people to enjoy activities without overcrowding.
	18. Size of Activity Areas [46]	Whether the size of activity areas is spacious enough to accommodate the expected number of users, avoiding overcrowding and ensuring comfort.
	19. Accessibility Facilities [45,46]	Availability and adequacy of accessibility facilities, such as ramps at entrances, clear signage for accessible paths, tactile paving, non-slip pathways, accessible seating, handrails, accessible restrooms, and activity facilities for those with mobility limitations (e.g., wheelchair users and the elderly).
	20. Placement of Garbage Bins and Seating [46]	Whether garbage bins and seating are sufficient, well located, well maintained, easily accessible, and do not obstruct walking paths or other activities, helping maintain cleanliness and provide resting areas.
	21. Placement of Bookstores and Restrooms [45,46]	Ease of locating bookstores and restrooms within the park, with adequate capacity, good maintenance, and convenient access without interfering with other activity areas.
Aesthetics	22. Aesthetic Quality of Plant Landscape Design [45]	Whether the arrangement of plants in the park is visually appealing and well maintained, including the variety of plant species, seasonal color changes, layering, and overall harmony of plant layouts.
	23. Aesthetic Quality of Pathway Paving [45]	Whether the park's ground surfaces are attractive; whether the paving materials, patterns, and color combinations of park pathways harmonize with the environment, creating a visually appealing appearance.
	24. Aesthetic Quality of Color Coordination in the Park [42,45]	Whether the color coordination of the overall park landscape is harmonious and pleasing, including the colors of the ground, walls, fences, bridge pillars, lighting, plants, facilities, and decorations, enhancing the visitors' visual experience.
	25. Aesthetic Quality of Landscape Features and Structures [42,45]	Whether the appearance of sculptures, lighting fixtures, seating, and other structures in the park is attractive and well-coordinated with the surroundings, including the design aesthetics of landscape elements (e.g., sculptures and water features).
Cultural Relevance	26. Reflection of Jinan's Historical and Cultural Characteristics in the Park [44]	Whether the design and layout of the park incorporate elements of Jinan's history and cultural identity, including traditional architectural styles, statues of historical figures, cultural symbols, and local plants. This also includes decorative items related to historical and cultural characteristics, such as sculptures, slogans, and murals, and whether cultural events are held within the park.

2.2.2. Data Collection Method

This study primarily employed field observations, questionnaire surveys, and interviews to conduct a spatial perception study of Lowline Park users across four age groups:

children and adolescents (5–18 years), young adults (19–35 years), middle-aged adults (36–60 years), and seniors (over 60 years) (Table 2).

Table 2. Definitions and characteristics of four different age groups.

Population Category	Age Group	Characteristics
Children and adolescents	5–18 years *	This group is in a stage of physical growth, developing cognitive abilities, and learning foundational knowledge. Most individuals in this group are students and have not yet entered society independently.
Youth	19–35 years	This group is in the stage of learning professional skills, building social connections, and integrating into society. Most individuals in this stage complete the transition from family roles to social roles.
Middle-aged	36–60 years	This group is in the stage of building families and advancing careers. Most individuals carry responsibilities for both family and society at this stage, and they pay attention to the education of their children and the care of their parents.
Elderly	60 years and above	This group experiences a decline in physiological functions. Most individuals in this stage focus less on career development and are more involved in family and social activities.

* In this study, only children aged 5 and above with a certain level of comprehension ability were surveyed. Generally, children over the age of 5 can understand the questions and provide responses with the assistance of their guardians.

The study consisted of a total of three rounds of surveys. The first round, a preliminary survey, was conducted in October 2022 with four on-site investigations of the Lowline Park and random interviews with 50 users. Based on the characteristics of the underbridge space and users' actual experiences, the evaluation system was adjusted accordingly, and a questionnaire and structured interview outline were developed. The second round of surveys took place in November 2022, with six on-site investigations. A questionnaire survey was conducted with 56 users from different age groups (17 children and adolescents, 20 youths, 10 middle-aged users, and 9 elderly users). Based on the responses and feedback, ambiguous or unclear questions in the questionnaire were revised repeatedly. Additionally, structured interviews were conducted with 20 users (5 from each age group: children and adolescents, youth, middle-aged, and elderly) to gather data on user satisfaction, needs, and suggestions for improvement, aiming to investigate the specific needs of different age groups (interview guide is attached as Table S11).

The third and final round of surveys was conducted from March to April 2023, covering four weekdays and five non-working days. The study began with on-site observations, where the researcher recorded users' activity times, locations, and behavior types in Lowline Park between 7 a.m. and 9 p.m. This information was documented primarily through photography. Through these observations and photographic documentation, the study tracked the usage patterns and user behaviors at different times of the day, while also identifying existing issues within the park. Additionally, a questionnaire survey was conducted, asking users from different age groups to rate the importance and satisfaction of five aspects of Lowline Park: accessibility, safety, aesthetics, cultural value, and comfort. The study first collected data on crowd numbers and spatial distribution for each area. Then, stratified random sampling and questionnaires were administered to users of various age groups at different locations in the park. The first section of the questionnaire collected basic demographic information, including age, gender, occupation, education level, transportation method to the park, distance traveled, frequency of visits, and time

spent at the Lowline Park. The second section applied a five-point Likert scale, assigning values from "Very Unimportant" to "Very Important" and "Very Dissatisfied" to "Very Satisfied", with scores ranging from 1 to 5, allowing respondents to rate the importance and satisfaction of the Lowline Park's evaluation indicators. For the final survey, the questionnaire language was adjusted to be comprehensible for the general public, who may not be familiar with academic terminology related to park landscapes and spatial elements. For example, "security management in the park" was rephrased as "Are there enough security personnel and surveillance measures in the park, and do current management practices effectively prevent crime?" (questionnaire is attached as Table S10). For respondents with reading difficulties, such as seniors and children, the answers were obtained through interviews. Structured interviews were conducted for children and seniors who had trouble understanding the questionnaire, with their ratings and other basic information recorded immediately after each interview.

Children aged 5–7 have a short attention span, a limited vocabulary, and restricted comprehension abilities. With the assistance of guardians, researchers use simple and straightforward language to explain the questions in the questionnaire, providing clarification for more abstract questions or unfamiliar vocabulary until the children understand the meaning of the questions and provide an answer.

Informed consent was obtained from all participants, ensuring their confidentiality and the right to withdraw from the study at any time without any consequences. For children, parental consent was obtained, and their participation in interviews and questionnaire completion was supervised by their guardians. All information collected was stored anonymously and used exclusively for research purposes, in strict adherence to ethical guidelines to protect participants' privacy and safety (Table 3).

Table 3. Survey types and number of respondents in three rounds of research.

	Survey Period	Duration	Survey Type	Number of Participants				
				Children	Youth	Middle-Aged	Elderly	Total
First Survey (Pre-survey)	October 2022	4 days	Interview	/	/	/	/	50
Second Survey (Pre-survey)	November 2022	6 days	Questionnaire	16	19	11	6	52
			Interview	5	5	5	5	20
Third Survey (Formal Survey)	March–April 2023	9 days	Questionnaire	38	37	17	17	109

In the formal survey, the sample size was determined using the Slovin's formula. According to statistical data from the management of low-line parks, the average monthly reservation count during fee-charging periods is 1999. In this study, the total number of reservations during both fee-charging and free periods was estimated by multiplying the reservation count by 1.8. This calculation yielded an average daily park visitor count of approximately 131, and subsequently, the total number of park users over 9 days was estimated to be about 1061. Setting the effective population size (N) in Slovin's formula as 1061 and assuming a sampling error (e) of 0.1, this indicates a 90% confidence level that the sample size accurately represents the population. This process determined the minimum required sample size (n) to be 106 respondents.

$$n = \frac{N}{1 + Ne^2} = \frac{1061}{1 + (1061 \times 0.1^2)} = 91$$

Equation: Basic Formula for Ratios [47]

In the third round of the formal survey, a total of 116 questionnaires were distributed, with 109 valid responses collected, resulting in an effective response rate of 93.96%. The sample size was sufficient to evaluate user satisfaction and perceived importance of low-line parks during the 9-day survey period. Stratified sampling was applied to each age group, and snowball sampling was employed at each site to randomly select participants from each age group for the survey. The proportion of respondents from each age group was no less than 10% of their respective population. Ultimately, the collected questionnaires included responses from 38 children and adolescents, 37 young adults, 17 middle-aged adults, and 17 seniors. The statistical analysis software SPSS 26.0 was used for data processing, and the reliability of the questionnaire was tested using Cronbach's alpha, resulting in a reliability coefficient of 0.880, indicating high reliability.

2.2.3. Importance–Satisfaction Analysis (ISA)

Importance–satisfaction analysis (ISA) is a method that has been widely applied in recent years to evaluate urban public spaces. By analyzing the importance and satisfaction ratings users assign to different spatial characteristics, ISA assesses users' spatial perceptions and plots these scores within corresponding quadrants to determine management priorities for improvements across various elements of urban public spaces [48]. The importance–satisfaction method assessed the perceived importance and satisfaction with the spatial attributes of Lowline Park among users from four age groups: children and adolescents, young adults, middle-aged adults, and seniors. By analyzing the differences between these groups, this approach provides valuable insights to planners and designers, helping them understand public perceptions of the park's spatial features. Based on survey questionnaires, users evaluated importance and satisfaction regarding accessibility, safety, and 26 other indicators. According to the evaluation results, a two-dimensional coordinate system was constructed, with the x- and y-axes representing the importance and satisfaction of each evaluation indicator, respectively. The evaluation results for each indicator fall into one of four quadrants, corresponding to different improvement priorities: Quadrant I represents high importance–high satisfaction, indicating that the service level of these indicators should be maintained. Quadrant II represents low importance–high satisfaction, suggesting that the design resources for these indicators can be redirected to improve other services. Quadrant III represents low importance–low satisfaction, indicating that the service of these indicators need not be a design priority. Quadrant IV represents high importance–low satisfaction, suggesting that the service level of these indicators should be prioritized for optimization and improvement.

3. Results

The demographic characteristics of the respondents reflect the diversity of Lowline Park users. Analyzing these characteristics shows that among the 109 respondents, children aged 5–18 comprised the largest proportion (34.9%), followed by young adults aged 19–35 (33.9%). Both middle-aged adults aged 40–46 and seniors over 60 each accounted for 15.5% (Tables S1–S5). In terms of gender distribution, male users (73.4%) outnumbered female users (26.6%), indicating that Lowline Park is more appealing to men, with a lack of amenities specifically catering to female users. Regarding occupation, students made up the largest portion of respondents at 46.7%, followed by retirees, blue-collar workers, and white-collar workers, together accounting for 32%. Homemakers and healthcare professionals were less represented, making up only 4.5% of park visitors. For education, the majority of respondents held a bachelor's or associate degree or lower, comprising 88% of the sample. In terms of usage frequency, 55.9% of respondents visited Lowline Park at least once a week, with 37.6% visiting daily and 18.3% visiting several times a month. Considering the time spent per visit, 66.9% of respondents stayed between 1 and 3 h.

Looking at the respondents' residence, 47.7% were local residents from nearby neighborhoods. This suggests that Lowline Park not only serves nearby community residents but also has a broader reach.

The study found significant differences in the spatiotemporal distribution and spatial perceptions of Lowline Park usage across different age groups. In terms of spatiotemporal distribution, each age group displayed unique patterns of temporal and spatial clustering in their use of the park. Regarding spatial perceptions, all age groups placed high importance on safety and comfort, though satisfaction levels for these aspects were low. Additionally, there were notable differences in how each age group perceived secondary spatial environment indicators.

3.1. Spatial Usage and Differences Among User Groups

In this study, user activity times were divided into early morning (before 8:00), morning (8:00–11:00), midday (12:00–15:00), afternoon (16:00–19:00), and evening (after 20:00). There are noticeable spatiotemporal differences in the distribution of users from different age groups in Lowline Park. The general age-density ranking of users, from highest to lowest, is as follows: elderly, youth, children, and middle-aged adults. Each age group is present in the park at various times, with elderly and children primarily active in the early morning and morning, youth most densely present at midday and in the afternoon, and middle-aged adults mainly frequenting the park in the afternoon and evening. The activity preferences vary significantly among age groups, with a diverse range of activities. The elderly make versatile use of the gateball courts, engaging in activities like diabolo spinning, gateball, square dancing, and shuttlecock kicking. Additionally, they play ping pong in the designated area and perform music in the performance plaza. Youth and children share similar activity types, mostly utilizing sports facilities for activities such as basketball, soccer, badminton, skateboarding, and reading or studying at the 24 h urban library. However, there are distinctions between the two groups: children might play games on the gateball courts, while youth often prefer performing street dance or engaging in street workouts in those areas. Middle-aged adults mainly visit the gateball courts in the evening. Some join the elderly in square dancing, while others participate in fitness activities with the youth, with many middle-aged users accompanying their children for leisure and recreation (Table 4).

Table 4. Activity records of users in the Yanshan Interchange Lowline Park.

Time	Users	Activities	Location
Before 8:00	Elderly	Morning exercise	gateball courts, performance plaza
8:00–12:00	Elderly	Diabolo, gateball, ping pong, musical performance	gateball courts, performance plaza, ping pong court
	Children	Basketball, reading, skateboarding, games	street basketball court, 24 h urban library, skate park, gateball courts
12:00–15:00	Youth	Basketball, football, badminton, skateboarding, reading	street basketball court, multi-sport court, skate park, 24 h urban library
	Children	Basketball, football, badminton, skateboarding, reading, games	street basketball court, multi-sport court, skate park, 24 h urban library, gateball courts

15:00–20:00	Elderly	Diabolo, gateball, ping pong, musical performance	gateball courts, performance plaza, ping pong court
	Youth	Basketball, football, badminton, skateboarding, reading	street basketball court, multi-sport court, skate park, 24 h urban library
	Children	Basketball, football, badminton, skateboarding, reading, games	street basketball court, multi-sport court, skate park, 24 h urban library, gateball courts
After 20:00	Elderly	Square dancing, shuttlecock kicking	gateball courts
	Middle-aged	Running, square dancing, fitness	gateball courts
	Youth	Running, street dance, fitness, reading	gateball courts, 24 h urban library
	Children	Games	gateball courts

Observations and interviews revealed two key issues with how users utilize the space. First, there is a mismatch between the opening hours of activity areas and peak usage times for different user groups, resulting in a significant supply–demand gap. The usage of activity areas varies considerably over time. In the early morning and morning, the western gateball courts are mainly used by the elderly and children, while the eastern areas, such as the badminton courts, soccer field, and skatepark, have low attendance and utilization. In the afternoon, youth and children mainly engage in activities in the eastern area, with elderly users staying in the west, leading to higher utilization of the eastern spaces during this period. In the evening, activity spaces with facilities in the eastern area close, causing nearly all users to congregate in the western area, where crowding exceeds the area's capacity and occasionally leads to conflicts among groups. Secondly, there is a mismatch between the types of activity spaces and the needs of the user groups. Currently, most spaces are designed for middle-aged and young adults, while the groups who use the park more frequently and for longer periods are children and the elderly. For children, the available activities lack sufficient safety features and appeal. For the elderly, most areas with sports facilities are not suitable for those unable to engage in intense physical activity. The gateball courts, frequently used by the elderly, lack comfort, safety, and accessible design features. As a result, there is a severe shortage of designated spaces suited to the physical and psychological needs of children and elderly users.

3.2. Importance–Satisfaction Evaluation and Differences in Perception of Lowline Park Elements Across Age Groups

3.2.1. Overall Importance–Satisfaction Analysis of Users

The average ratings for the overall importance of and satisfaction with Lowline Park's spatial environment elements reflect users' varying perceptions of accessibility, safety, aesthetics, comfort, and cultural relevance. These differences reveal users' needs to some extent. The average importance ranking of primary indicators is as follows: Safety (4.34) > Comfort (4.18) > Cultural Relevance (4.16) > Accessibility (3.96) > Aesthetics (3.94). The average satisfaction ranking is as follows: Aesthetics (4.16) > Accessibility (4.13) > Cultural Relevance (4.08) > Safety (4.07) > Comfort (3.89). A comparison reveals that the average importance ratings for safety, comfort, and cultural relevance are higher than their satisfaction ratings, indicating that users have higher expectations and needs for these indicators. The largest difference is seen in comfort (difference of 0.29), suggesting that the

comfort of the under-bridge space needs improvement. The satisfaction ratings for aesthetics and accessibility are higher than their importance ratings, indicating that users are relatively satisfied with these aspects of the under-bridge space.

According to the matrix analysis, safety and cultural relevance are in Quadrant I, meaning that users value these indicators highly, and they meet public expectations, so these strengths should be maintained. Comfort is in Quadrant IV, indicating that users consider this indicator important, but the actual experience falls short of their expectations, suggesting further optimization is needed. Aesthetics and accessibility fall within Quadrant II, indicating that users find these indicators less important but are highly satisfied with them, implying no immediate need for improvement (Figure 3).

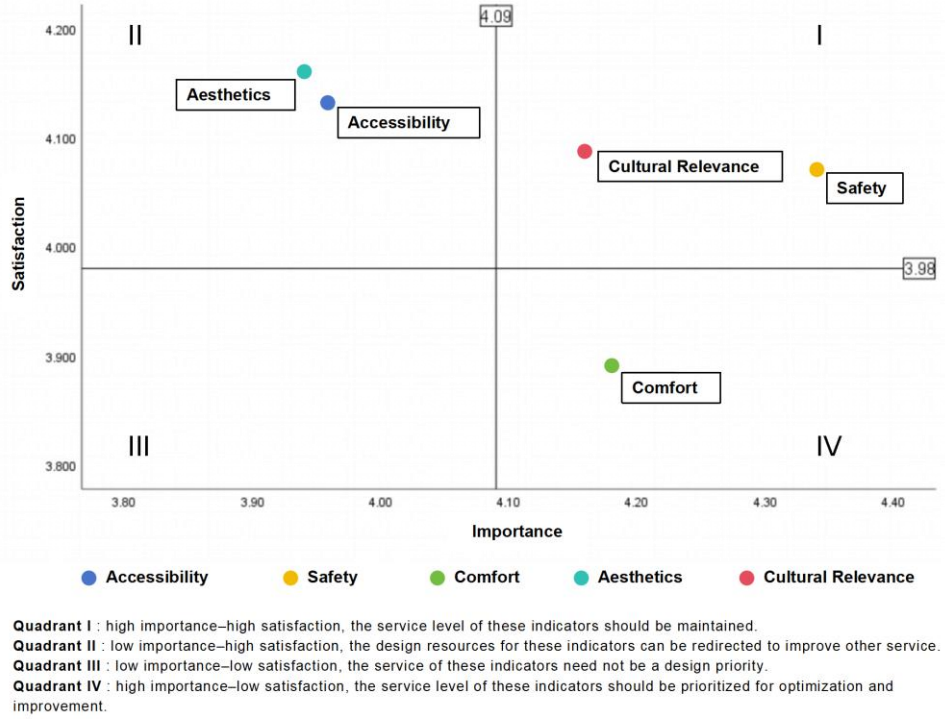

Figure 3. Importance–satisfaction matrix of users' overall perception of Lowline Park.

3.2.2. Importance–Satisfaction Evaluation for the Children's Group

The overall satisfaction mean for the children's group is slightly higher than the importance mean, but the difference is small, indicating that children are generally satisfied with Lowline Park (Figure 3). The importance ranking of the primary indicators is as follows: Comfort (4.14) > Safety (4.10) > Aesthetics (4.04) > Cultural Relevance (4.00) > Accessibility (3.82). The satisfaction ranking is as follows: Cultural Relevance (4.75) > Aesthetics (4.18) $\geqslant$ Accessibility (4.18) > Comfort (3.92) > Safety (3.91). A comparison of the differences between importance and satisfaction shows that the satisfaction means for Comfort (difference of 0.23) and Safety (difference of 0.18) are both lower than their respective importance means. The largest gap is in Comfort, indicating an urgent need for improvement in this area, particularly in terms of enhancing comfort in the under-bridge space for children.

The urgency of improvement measures was prioritized through ISA. According to the matrix (Figure 4), the following indicators fall within Quadrant I: convenience of crossing the road to access the park (1), convenience of entrance locations (2), internal safety of the park areas (13), air quality in the park environment (15), location of activity areas

within the park (16), number of activity areas (17), size of activity areas (18), and the arrangement of facilities such as trash bins and seating (20). This indicates that the children's group has a high level of recognition and satisfaction with these eight indicators, which should be maintained. The following indicators fall within Quadrant IV: lighting conditions in the park (10), safety of internal facilities (12), sound environment in the park (14), and the arrangement of the book bar and restrooms (21). This suggests that the children's group considers these four indicators to be of high importance, but the actual functionality does not meet their expectations. These should be prioritized for targeted improvement in subsequent design efforts.

A paired sample *t*-test was conducted to assess whether there was a statistically significant difference between the importance and satisfaction ratings among the children's user group for Lowline Park, identifying potential areas for improvement in specific evaluation factors (Table S6). According to the paired sample test results, aside from three aesthetic indicators (park pavement design, landscape color scheme, and landscape features and structures) and two accessibility indicators (convenience of crossing the road and number of entrances), which showed positive directionality (*t*-value is positive), all the other indicators displayed negative directionality (the *t*-value is negative). There was a particularly significant difference in the safety and comfort indicators ($p < 0.05$), with the satisfaction ratings being significantly lower than the importance ratings. This indicates that children perceive a need for improvements in comfort and safety, especially regarding the number and size of activity areas, the park's sound and air quality, and the safety of internal spaces.

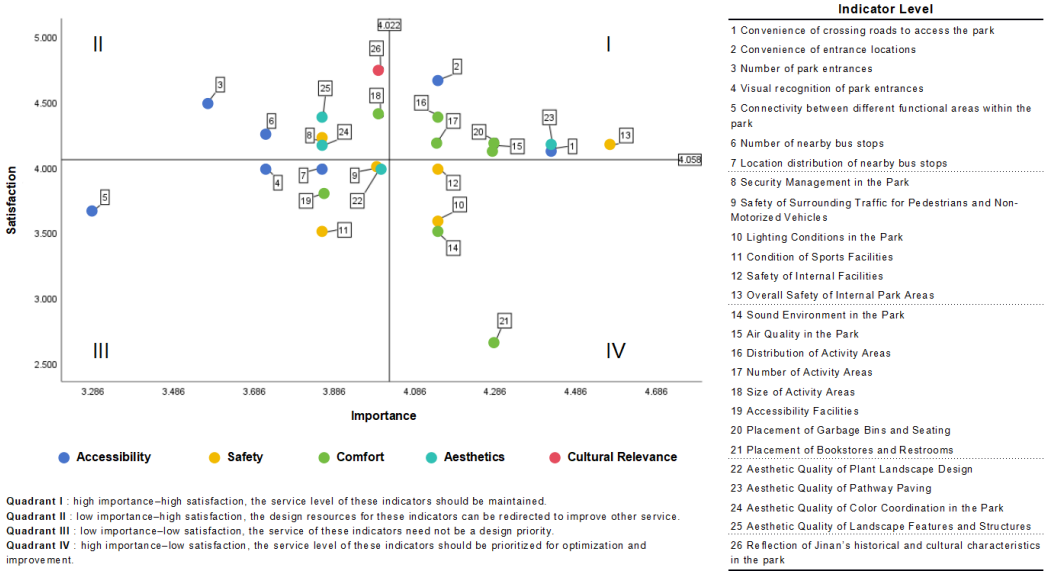

Figure 4. Importance–satisfaction matrix of secondary evaluation indicators for the children's group in Lowline Park.

3.2.3. Importance–Satisfaction Evaluation for the Youth Group

The overall mean satisfaction score for the youth group is significantly lower than the mean importance score, suggesting that several evaluation criteria fail to meet the youth group's needs. The mean importance ranking of the primary indicators is as follows: Cultural Relevance (4.48) > Safety (4.37) > Comfort (4.27) > Accessibility (4.11) > Aesthetics (3.92). For satisfaction, the ranking is: Safety (4.13) > Aesthetics (4.11) > Accessibility (4.09) > Cultural Relevance (4.06) > Comfort (3.93). A comparison of importance and satisfaction scores reveals that satisfaction scores for cultural relevance, comfort, safety, and

accessibility all fall below their corresponding importance scores. The largest gaps are observed in cultural relevance (a difference of 0.42) and comfort (a difference of 0.34), indicating an urgent need for improvement in these areas of the under-bridge space for the youth group.

The matrix diagram (Figure 5) shows that the following indicators fall within Quadrant I: pedestrian safety in the surrounding traffic environment (9), lighting conditions in the park (10), current usage of sports tables and courts (11), safety of internal facilities (12), availability of accessible facilities (19), arrangement of trash bins and seating (20), and the reflection of Jinan's historical culture and urban characteristics within the park (26). This placement indicates that the youth group has high recognition and satisfaction with these seven indicators, and their strengths should be maintained. However, the convenience of entrance locations (2), visibility of park entrances (4), safety within park areas (13), air quality in the park (15), number of activity areas (17), size of activity areas (18), and the arrangement of the book bar and restrooms (21) fall within Quadrant IV. This indicates that the youth group considers these seven indicators to be of high importance, but the actual functionality does not meet their expectations, and targeted improvements should be made in future designs.

A paired-sample *t*-test was conducted to evaluate whether there is a statistically significant difference between the importance and satisfaction ratings for Lowline Park among youth users (Table S7). According to the paired-sample test results, aside from two aesthetic indicators (paving of park pathways and landscape elements/structures) and one accessibility indicator (location of nearby bus stops), which showed positive results (positive *t*-values), all other indicators displayed negative results (negative *t*-values). There is a particularly significant difference in safety and comfort indicators ($p < 0.05$), with satisfaction scores markedly lower than importance scores. This suggests that the youth group perceives a need for improvements in comfort and safety, especially regarding the current condition of sports facilities (such as tables and courts), internal site safety, and the park's sound environment and air quality.

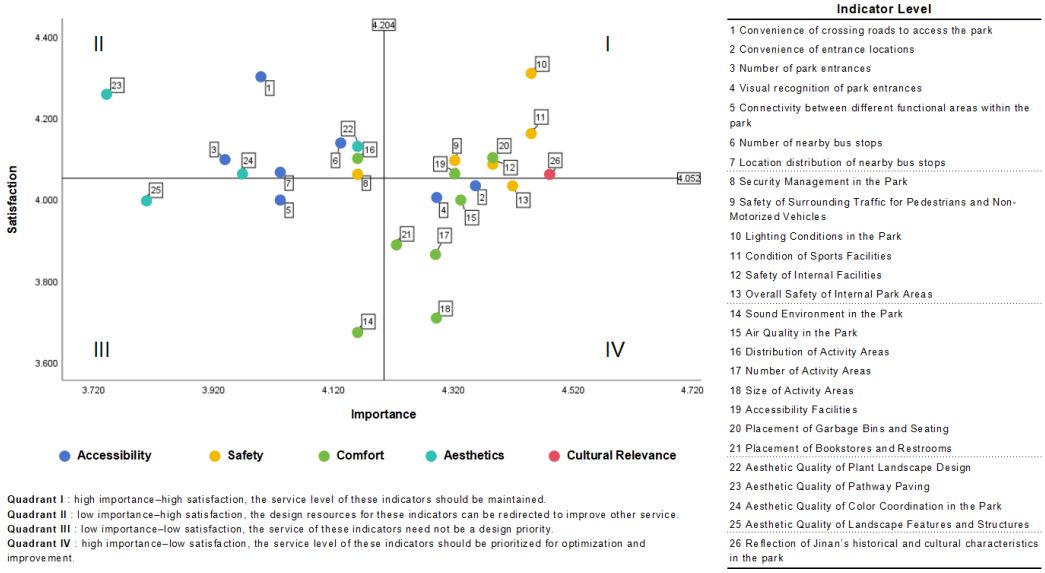

Figure 5. Importance–satisfaction matrix of secondary evaluation indicators for the youth group in the Lowline Park.

3.2.4. Importance–Satisfaction Evaluation for the Middle-Aged Group

The overall mean satisfaction score for the middle-aged group is slightly lower than the mean importance score, suggesting that some evaluation criteria do not fully meet this

group's needs. The mean importance ranking for the primary indicators is as follows: Safety (4.69) > Comfort (4.22) > Cultural Relevance (4.17) > Accessibility (4.05) > Aesthetics (3.92). In terms of satisfaction, the ranking is: Aesthetics (4.21) > Accessibility (4.19) > Safety (4.18) > Comfort (3.83) > Cultural Relevance (3.82). Comparing the differences between importance and satisfaction, it is evident that satisfaction scores for safety, comfort, and cultural relevance fall below their importance scores, with relatively large gaps. This indicates an urgent need for improvements in these aspects of the under-bridge space to better serve the middle-aged group's expectations.

The matrix diagram (Figure 6) shows that the convenience of entrance locations (2), security management within the park (8), current usage of sports tables and courts (11), internal facility safety (12), safety within park areas (13), and accessibility features (friendliness toward people with limited mobility) (19) fall within Quadrant I. This indicates that the middle-aged group has high recognition and satisfaction with these six indicators, and their strengths should be maintained. Indicators in Quadrant IV include pedestrian and non-motorized vehicle safety in the surrounding traffic environment (9), lighting conditions in the park (10), air quality in the park environment (15), the number of activity areas in the park (17), the size of activity areas (18), and the arrangement of the book bar and restrooms (21). These placements suggest that the middle-aged group considers these six indicators highly important, but their actual functionality does not meet expectations. Therefore, targeted improvements should be made in future designs.

A paired-sample *t*-test was used to assess whether there is a statistically significant difference between the importance and satisfaction ratings of middle-aged users for Lowline Park, identifying potential areas for improvement in specific evaluation elements (Table S8). According to the paired-sample test results, aside from four aesthetic indicators (park paving, landscape colors, landscape elements, and built structures) and two accessibility indicators (ease of crossing streets and number of entrances) showing positive responses (with positive t-values), all other indicators exhibited negative responses (with negative *t*-values). Notably, there was a significant difference in safety and comfort indicators ($p < 0.05$), with satisfaction ratings significantly lower than importance ratings. This indicates that middle-aged users perceive room for improvement in aspects such as comfort and safety, especially regarding the number and size of activity areas, sound and air quality, and safety within internal park spaces.

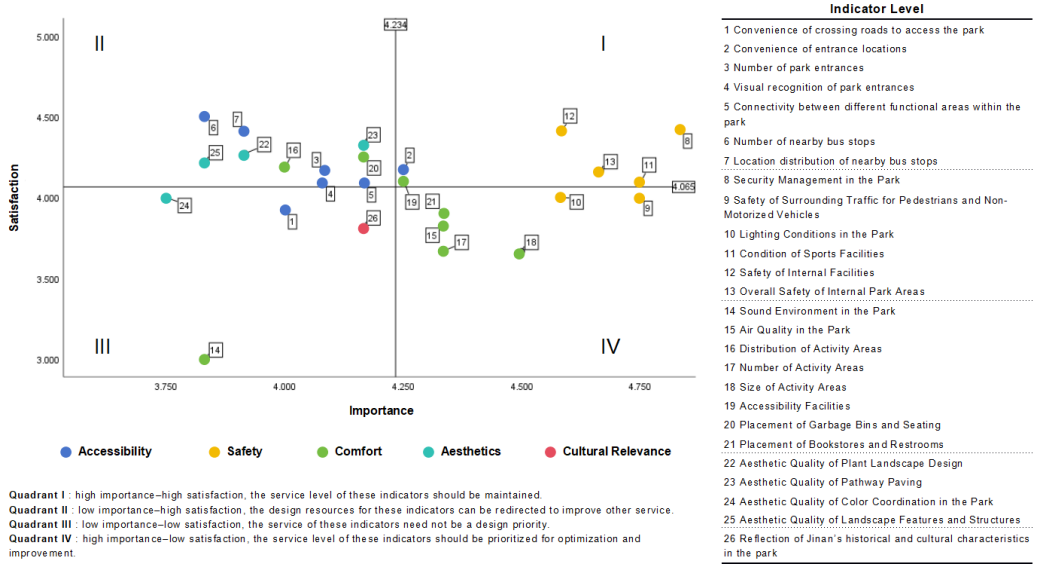

Figure 6. Importance–satisfaction matrix of secondary evaluation indicators for the middle-aged group in the Lowline Park.

3.2.5. Importance–Satisfaction Evaluation for the Elderly Group

The overall mean satisfaction score for the elderly group is slightly lower than the mean importance score, though the difference is minimal, indicating that the elderly group is generally satisfied with Lowline Park. Nonetheless, a few evaluation criteria still fall short of fully meeting their needs. The importance ranking for the primary indicators is as follows: Safety (4.45) > Comfort (4.02) > Accessibility (3.86) > Cultural Relevance (3.82) > Aesthetics (3.77). For satisfaction, the ranking is: Safety (4.21) > Aesthetics (4.15) > Accessibility (4.02) > Cultural Relevance (3.81) > Comfort (3.78).

A comparison of the importance and satisfaction scores reveals that satisfaction levels for safety and comfort are notably lower than their importance scores, with relatively large gaps. This suggests a pressing need for improvements in these areas of the under-bridge space to better address the elderly group's expectations.

According to the matrix diagram (Figure 7), the following indicators fall within Quadrant I, meaning that the elderly group has high recognition and satisfaction with these seven factors: security management of the park (8), safety of pedestrians and non-motorized vehicles crossing nearby roads (9), lighting conditions in the park (10), safety of internal facilities (12), safety of internal park areas (13), number of activity areas in the park (17), and the arrangement of trash bins and seating facilities (20). These strengths should be maintained. The following indicators fall within Quadrant IV, indicating that the elderly group considers them important, but the actual functionality does not meet their expectations: convenience of the location of park entrances (2), current usage of sports tables and courts (11), air quality in the park environment (15), availability of accessible facilities (friendly for people with limited mobility) (19), and the arrangement of the book bar and restrooms (21). These aspects should be improved in future designs. The following indicators fall within Quadrant III, meaning both importance and satisfaction are relatively low: number of park entrances (3), visibility of park entrances (4), ease of moving between different areas in the park (5), size of activity areas in the park (18), aesthetic quality of landscape features and structures in the park (25), and reflection of Jinan's historical culture and urban characteristics in the park (26). These factors do not need to be prioritized in the future development of under-bridge spaces.

A paired-sample *t*-test was conducted to assess whether there is a statistically significant difference between importance and satisfaction ratings for Lowline Park among elderly users (Table S9). According to the paired-sample test results, aside from accessibility indicators (excluding "convenience of entrance locations") and aesthetic indicators, which showed positive results (positive t-values), all other indicators displayed negative results (negative t-values). There is a particularly significant difference in comfort indicators ($p < 0.05$), with satisfaction scores significantly lower than importance scores. This suggests that the elderly group perceives a need for improvement in comfort, particularly regarding air quality in the park environment, accessibility features, and the arrangement of the book bar and restrooms.

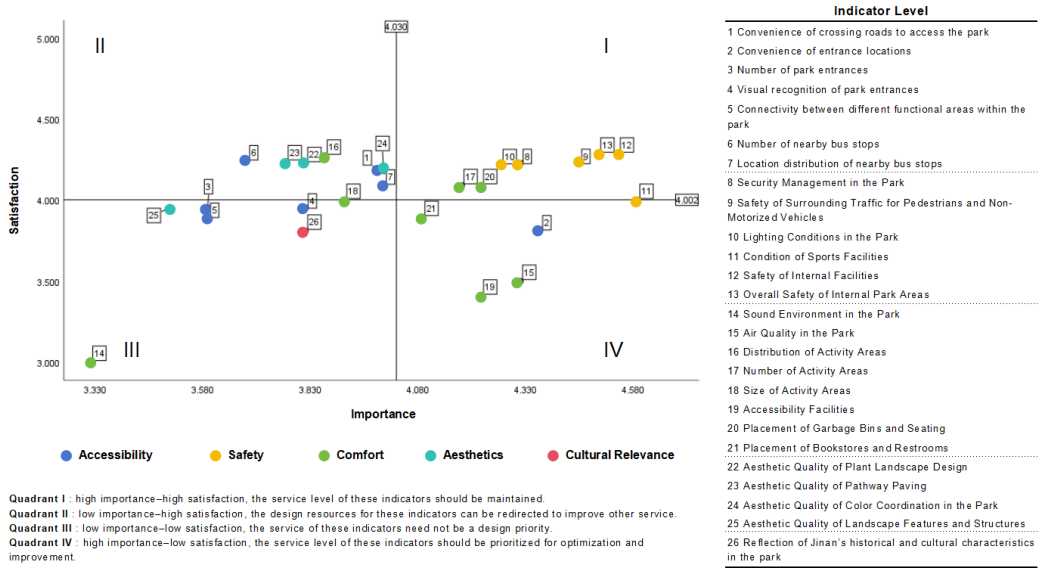

Figure 7. Importance–satisfaction matrix of secondary evaluation indicators for the elderly group in the Lowline Park.

3.2.6. Comparative Analysis of Importance–Satisfaction Evaluations Across Age Groups

Based on the differences in the mean importance–satisfaction values, there are both similarities and differences in how the four groups perceive the evaluation indicators. For children, the importance ratings for safety and comfort are higher than the satisfaction ratings. Youth rate accessibility, safety, comfort, and cultural relevance as more important than satisfactory. The middle-aged and elderly groups also rate safety, comfort, and cultural relevance as more important than satisfactory. This further analysis shows that all the age groups have high expectations for improvements in safety and comfort. Youth have additional expectations for improvements in accessibility, while youth and middle-aged and elderly groups express expectations for improvements in cultural relevance, which are particularly strong for youth and middle-aged users. No group shows a notable demand for improvements in aesthetics (Table 5).

Table 5. Primary indicators with importance scores higher than satisfaction scores in spatial perception for different groups and the differences.

Category of User Groups	Difference between Importance and Satisfaction Scores for Primary Indicators				
	Accessibility	**Safety**	**Comfort**	**Aesthetics**	**Cultural Relevance**
Overall	/	0.27	0.29	/	0.08
Children	/	0.18	0.23	/	
Youth	0.02	0.24	0.34	/	0.42
Middle-aged	/	0.51	0.39	/	0.35
Elderly	/	0.24	0.24	/	0.01

The quadrant placement of the 26 secondary indicators also shows both similarities and differences among the four groups. All the groups agree on the importance of the arrangement of the book bar and restrooms (21) and express dissatisfaction with them (Table 6).

Children consider the lighting conditions (10), safety of internal facilities (12), and sound environment (14) important but unsatisfactory. Compared to other groups, they

are less sensitive to air quality (15) but place more importance on the convenience of crossing the road to the park (2), sound environment (14), location of activity areas (16), and aesthetic quality of pavement design (23).

Youth find the convenience of entrances (2), visibility of park entrances (4), safety of internal areas (13), air quality (15), number of activity areas (17), and size of activity areas (18) important but unsatisfactory. Compared to other groups, they place more importance on the visibility of park entrances (4) and the representation of Jinan's history and culture (26).

Middle-aged users consider pedestrian and non-motor vehicle safety in the surrounding traffic (9), lighting conditions (10), air quality (15), and the number (17) and size (18) of activity areas important but unsatisfactory. Compared to the other groups, they are less sensitive to the visibility of park entrances (4), express lower satisfaction with the convenience of crossing the road to the park (1), and view facilities like trash bins and seating (20) as less important.

Elderly users consider the convenience of entrance locations (2), current condition of sports facilities like tables and courts (11), air quality (15), and accessibility facilities (19) important but unsatisfactory. Compared to the other groups, they have the highest demand for improvements in accessibility facilities (19).

Table 6. Importance–satisfaction comparative analysis for children, youth, middle-aged, and elderly groups (Quadrants I, II, III, and IV represent the importance–satisfaction quadrants)

Criteria Level	Indicator Level	Category of User Groups				Inconsistency between Importance and Satisfaction
		Children	Youth	Middle-Aged	Elderly	
Accessibility	1. Convenience of crossing the road to access the park	I	II	III	II	Important—Children; Not important—Youth, Middle-aged, Elderly Satisfied—Children, Youth, Elderly; Not satisfied—Middle-aged
	2. Convenience of the location of park entrances	I	**IV** *	I	**IV**	Important—All; Satisfied—Children, Middle-aged; Not satisfied—Youth, Elderly
	3. Number of park entrances	II	II	II	III	/
	4. Visibility of park entrances	III	**IV**	II	III	Important—Youth; Not important—Children, Middle-aged, Elderly Satisfied—Middle-aged; Not satisfied—Children, Youth, Elderly
	5. Ease of moving between different areas within the park	II	III	II	III	/
	6. Number of nearby public transportation stops	II	II	II	II	/
	7. Location of nearby public transportation stops	III	II	II	II	/
Safety	8. Security management of the park	II	II	I	I	Important—Middle-aged, Elderly; Not important—Children, Youth Satisfied—All
	9. Safety of pedestrians and non-motorized vehicles in the surrounding traffic environment	III	I	**IV**	I	Important—Youth, Middle-aged, Elderly; Not important—Children Satisfied—Youth, Elderly; Not satisfied—Children, Middle-aged
	10. Lighting conditions in the park	**IV**	I	**IV**	I	Important—All; Satisfied—Youth, Elderly; Not satisfied—Children, Middle-aged
	11. Current usage of sports tables and courts in the park	III	I	I	**IV**	Important—Youth, Middle-aged, Elderly; Not important—Children

					Satisfied—Youth, Middle-aged; Not satisfied—Elderly, Children
	12. Safety of internal park facilities	**IV**	I	I	I	Important—All Satisfied—Youth, Middle-aged, Elderly; Not satisfied—Children
	13. Safety of internal park areas	I	**IV**	I	I	Important—All; Satisfied—Children, Middle-aged, Elderly; Not satisfied—Youth
Comfort	14. Noise levels in the park environment (whether there is noise disturbance)	IV	III	III	III	Important—Children; Not important—Youth, Middle-aged, Elderly Not satisfied—All
	15. Air quality in the park environment	I	**IV**	**IV**	**IV**	Important—All; Satisfied—Children; Not satisfied—Youth, Middle-aged, Elderly
	16. Location of activity areas within the park	I	II	II	II	Important—Children; Not important—Youth, Middle-aged, Elderly Satisfied—All
	17. Number of activity areas in the park	I	**IV**	**IV**	I	Important—All; Satisfied—Children, Elderly; Not satisfied—Youth, Middle-aged
	18. Size of activity areas in the park	II	IV	IV	III	Important—Youth, Middle-aged; Not important—Children, Elderly Satisfied—Children; Not satisfied—Youth, Middle-aged, Elderly
	19. Availability of accessible facilities in the park (friendliness towards people with limited mobility)	III	I	I	**IV**	Important—Youth, Middle-aged, Elderly; Not important—Children Satisfied—Youth, Middle-aged; Not satisfied—Children, Elderly
	20. Arrangement of trash bins, seating, and other facilities in the park	I	I	II	I	Important—Children, Youth, Elderly; Not important—Middle-aged Satisfied—All
	21. Arrangement of the book bar and restrooms in the park	**IV**	**IV**	**IV**	**IV**	Important—All; Not satisfied—All
Aesthetics	22. Aesthetic quality of the park's plant landscape arrangement	III	II	II	II	/
	23. Aesthetic quality of the park's pavement design	I	II	II	II	Important—Children, Not important—Youth, Middle-aged, Elderly; Satisfied—All
	24. Aesthetic quality of the park's landscape color combinations	II	II	III	II	/
	25. Aesthetic quality of landscape features, structures, and other facilities in the park	II	III	II	III	/
Cultural Relevance	26. Reflection of Jinan's historical culture and urban characteristics in the park	II	I	III	III	Important—Youth; Not important—Children, Middle-aged, Elderly Satisfied—Children, Youth; Not satisfied—Middle-aged, Elderly

* Quadrant IV in this table has been bolded. It represents high importance and low satisfaction, suggesting that the service level of these indicators should be prioritized for optimization and improvement.

3.3. Usage Needs and Differences Across Age Groups

Using a structured interview guide, this study conducted interviews with 20 users (5 from each age group: children, youth, middle-aged, and elderly), gathering evaluations of Lowline Park and more specific suggestions for future improvements from different age groups. Overall, the main improvement requests from park users focused on enhancing windbreak facilities, removing entry fees, increasing child-friendly areas, and adjusting the timing

of nighttime lighting. Adult users expressed clear concerns about the fee system and lack of windbreak facilities, highlighting that Lowline Park's comfort level in winter is inadequate and that the fairness of public amenities needs improvement. Both middle-aged and elderly groups emphasized the importance of making the park more child-friendly, indicating a strong public demand for family-friendly public spaces.

Specific to different age groups, people of different ages have varying needs for Lowline Parks: children hope for more activity spaces and facilities tailored to them, such as additional play areas, cooling facilities, and convenient commercial services to meet their needs for social interaction and activities. The youth group is concerned with the park's comfort, convenience, and affordability, suggesting longer lighting hours, a simplified reservation process, and more windbreak facilities to improve the climate adaptability of sports areas. Middle-aged users, in addition to free space use and more windbreak and rest facilities, particularly requested more child-friendly activity areas to create a family-friendly experience. The elderly group emphasized simplifying management, reducing fees, increasing restroom facilities, and using greenery and color improvements to reduce noise and enhance aesthetic appeal (Table 7).

In summary, feedback from all age groups reflects a comprehensive demand for the multifunctionality, convenience, and comfort of Lowline Park, indicating that park planning needs to balance the specific needs of different age groups to enhance overall satisfaction and inclusivity in urban public services.

Table 7. Suggestions for Lowline Park from different age groups in interviews.

Age Group	Age	Gender	Suggestions for Lowline Park
Children	7	Male	In summer, it's hot; hope there are more areas for children to play and run, and also a playground.
	5	Female	Hope there are more places for children to play to attract more children to come, as there are no friends in the park now.
	11	Female	Hope there are more places for children to play.
	5	Male	Hope a shop will open.
	11	Female	Turn on the lights earlier in winter.
Youth	20	Female	Turn on the lights earlier.
	22	Male	Turn on the lights earlier.
	22	Male	1. Complex reservation system, low accessibility for elderly. 2. The badminton court is greatly affected by windy weather.
	31	Female	Mop more frequently; there is a lot of dust, and the ground is very slippery.
	34	Male	Issue with charging fees.
Middle-aged	54	Male	Issue with charging fees.
	47	Female	1. Wind-blocking facilities needed. 2. Issue with charging fees.
	39	Male	Increase wind-blocking resting areas.
	37	Male	Expand the area of the basketball court.
	52	Female	Add wind-blocking facilities.
Elderly	64	Female	1. Complex management. 2. Issue with charging fees. 3. Restrooms are too far away.
	69	Male	Add wind-blocking facilities to courts for light sports like badminton and table tennis.
	62	Male	1. Issue with charging fees. 2. Wind-blocking facilities and ball containment enclosures are essential for table tennis courts. 3. Add channels for supervision and feedback.
	65	Female	Noise is high; should increase tall, dense trees on the park edges near roads to reduce noise and decrease traffic distraction for those exercising.
	64	Male	Road paving should be more vibrant and colorful, suitable for children.

4. Discussion

4.1. Analysis of the Reasons for Perceptual Differences Among the Four Groups

Our observations reveal that the activity spaces in Lowline Park are primarily used by the intended target age groups, and no specific area is used by all age groups in similar proportions. The Theory of Planned Behavior suggests that physiological needs, psychological motivations, social environment, and facility suitability influence behavioral choices [49], while an individual's attitude toward a behavior, subjective norms (perceived social pressure from significant others), and perceived behavioral control (such as barriers and facilitators) determine their intent to use a space [50]. Regarding the design and planning of Lowline Park, there is a degree of inclusive, activity-oriented intent, though it remains at a superficial level without deep analysis of the complex needs of each age group. For example, a skatepark for children, soccer and basketball courts for young adults, a ping pong court for middle-aged users, and a gateball court for seniors were included, resulting in clustering by age group. The spatiotemporal differences in Lowline Park usage among age groups are mainly influenced by physical and psychological factors, as well as available leisure time. Elderly and children tend to visit in the morning, largely due to their flexible schedules, early bedtime habits, and the belief among seniors that morning exercise benefits health [40]. The accompanying travel patterns of elderly and children also contribute to higher numbers of child users in the morning. Young adults and middle-aged users, on the other hand, prefer visiting the park in the afternoon or evening when they are less busy. This trend is also supported by the study of Reichert et al. (2007) [21].

The results show that child users have high expectations for improved safety and are dissatisfied with the lighting conditions, the safety of internal facilities, and the noise levels. Safety is a fundamental internal driving force for children's development, playing a crucial role in their cognitive, social, emotional, and self-evaluation growth [51]. In urban public spaces, a sense of security is the foundation for children to engage in social activities. Therefore, in urban public spaces under elevated highways, child users primarily seek safety features such as sufficient lighting and security facilities. In addition to "safety and security", the "basic services" of a site are also important indicators for child users in perceiving an environment as friendly [23]. Therefore, child users tend to prefer convenient and comfortable facilities and desire designated areas suited to their age group, where they can interact with peers. This conclusion is also supported by other studies [18–20]. This also explains why child users have higher expectations for improved comfort. The study results further indicate that child users value the ease of crossing to the park, the acoustic environment, the distribution of activity areas, and the aesthetic quality of the pathways more than the other age groups. This can be explained by the fact that children are in a stage of physical development, where they are generally more sensitive to noise [52], which may account for their prioritization of the comfort of the acoustic environment. Additionally, due to their relatively lower physical strength and lower endurance, having to cross multiple roads with traffic lights before entering the park may make children feel both exhausted and unsafe. As a result, the road accessibility of the park is highly valued by child users. When children participate in activities, a safe, convenient, and aesthetically pleasing environment enhances their experience and sense of engagement, making the location of activity areas particularly important to them. For children, simple and refreshing colors directly stimulate healthy psychological development [53]. As the park under the bridge is covered by an elevated highway, with a predominantly gray roof, children—due to their limited life experience and unique perspective—are more easily attracted by the park's facilities and vivid visual colors than by elements like landscape features or urban culture.

In addition to having high expectations for improvements in safety and comfort, the youth users also have expectations for enhanced accessibility and cultural relevance. They express dissatisfaction with the convenience and visibility of park entrances, the safety of the internal areas, the air quality, and the quantity and size of the activity areas. They place greater importance on the visibility of entrances and elements within the park that reflect Jinan's historical and cultural characteristics. According to data from the National Bureau of Statistics, young people are generally optimistic and cheerful, and their environmental needs are primarily driven by self-fulfillment and relaxation [54]. Therefore, compared to the aesthetic quality of the environment, young people are more concerned with the quality of the activity spaces and the physical and mental enjoyment these spaces provide [36]. In addition, they have a stronger preference for sports that are competitive and cathartic [55]. They place greater emphasis on the accessibility of spaces, such as the visibility of entrances, as well as the safety and comfort of sports fields, plazas, and leisure facilities. Additionally, compared to other age groups, youth users are often not satisfied with just the basic functionality of activity spaces, they also value the cultural atmosphere created in public spaces [56]. As a result, they have a stronger desire for urban public spaces under elevated highways to convey cultural meaning.

In addition to having high expectations for improvements in safety and comfort, middle-aged users also have higher expectations for cultural relevance. They express dissatisfaction with the pedestrian and non-motorized vehicle safety in terms of the surrounding traffic, the lighting conditions, the air quality, and the quantity and size of the activity areas. Compared to other groups, they are less satisfied with the ease of crossing roads. Middle-aged users often face the greatest life and work pressures, have limited leisure time, and have a strong sense of family responsibility [57]. Previous studies have shown that more than one-third of middle-aged park users are married with children, exhibiting a significant pattern of family-accompanied visits [23,24,58]. When visiting parks under elevated highways, they typically bring their families along, with some even needing to use strollers [59]. Therefore, their primary concern is the safety of the space, followed by the comfort that the facilities provide for them and their families, with particular attention to the park's child-friendliness. This also explains why middle-aged users have high expectations for improvements in safety and comfort, as well as their lower satisfaction with road accessibility. The importance and expectations that middle-aged users place on the cultural aspects of urban public spaces are not only a reflection of their personal psychological needs but are also closely related to their roles in family and society. They hope to find a sense of belonging through these spaces, fulfill the mission of cultural heritage, and enhance their quality of life.

The elderly group has high expectations for improvements in safety and comfort. They express dissatisfaction with the convenience of park entrances, the condition of exercise facilities, air quality, acoustic environment, and the availability of accessible facilities. Compared to other groups, they have a higher demand for improvements in accessibility. As elderly users age, they face challenges such as declining physical health, significantly increased economic vulnerability, transportation difficulties, reduced spatial navigation ability, and a shrinking social network due to factors like death, relationship breakdowns, health issues, retirement, and accessibility challenges [25–29]. From a physical needs perspective, the deterioration of physical functions, decreased mobility, and reduced stamina result in a diminished ability for elderly users to respond to environmental factors [58,60–62]. Therefore, elderly users prioritize the safety and comfort of spaces and closely monitor the availability of facilities. They place high value on the convenience of entrance locations, the current condition of sports facilities like tables and courts, air quality in the park, and the presence of accessible facilities. From a psychological needs per-

spective, as elderly individuals' social networks decrease, they become particularly susceptible to social isolation [63]. Consequently, they seek to participate in social and physical activities in Lowline Park to strengthen their connections with others. Additionally, economic vulnerability has a greater impact on elderly users' willingness to participate in park activities than accessibility does; if there are fees associated with using the park facilities, their willingness to use the space would be significantly reduced [64–66]. As a result, elderly users have expressed strong dissatisfaction with the fee policy in Lowline Park, and compared to other age groups, they have a higher demand for affordability in activity spaces.

4.2. Optimization Strategies for Under-Bridge Parks Based on Age-Specific Needs

In summary, sports-oriented public spaces under urban elevated highways, such as Jinan's Yanshan Interchange Lowline Park—government-led, professionally designed, and municipally managed—should focus on addressing two key issues: the mismatch between activity times and peak usage hours, and the inconsistency between facility provision and the needs of different user groups. Additionally, improvements should be prioritized for the primary and secondary indicators in Quadrant IV of the importance–satisfaction matrix, which are high in importance but low in satisfaction. It is essential to fully consider the unique needs of each user group to create an under-bridge public space that accommodates all age groups.

The first recommendation is to optimize the time, area, and activity-type configuration of the activity space. To address the issues of the uneven spatial area and distribution identified by the elderly, youth, and child user groups, the size and function of the spaces could be flexibly adjusted according to the numbers of users and activity types at different times. For example, fixed partitions could be replaced with movable adjustable ones, allowing spaces to be reconfigured based on user needs. In the morning, a larger fitness area could be allocated for elderly users, while in the afternoon, the same area could be transformed into a soccer field for children, and in the evening, it could serve as an entertainment zone for youth. This approach would allow for the efficient and quality use of low-traffic spaces through quick adjustments to meet demand. To ensure that vulnerable groups can conduct activities safely, comfortably, and conveniently in the park, exclusive activity venues can be set up to meet the actual needs of the child and elderly users. For child users, the most important thing is to set up a dedicated children's activity area, including play structures, interactive game zones, a plant garden, and small sports fields. Nearby, a designated parent supervision area should be provided for safety. Parent–child interaction facilities, such as playgrounds and science-based interactive experience areas, can be enhanced. These spaces could include parent–child swings, climbing structures, and interactive educational exhibits to promote parent–child relationships. For elderly users, an area with barrier-free activity facilities can be set up and kept away from basketball courts and football fields, to avoid mutual interference.

The second recommendation is to enhance the safety and comfort of the activity spaces. An intelligent lighting system would improve users' experience. An intelligent lighting system should automatically adjust the brightness based on the time, weather, and activity type, including nighttime lighting to avoid overly bright or dark areas, thereby enhancing safety. Installing wider ticket gates at park entrances and additional ramps or replacing stairs with ramps could improve the accessibility of families with strollers and balance the experience of people with mobility difficulties and the elderly. Furthermore, pedestrian entrances should be separated from non-motor vehicle parking areas to prevent entrance blockages and reduce risks for pedestrians. To reduce air pollution, additional greenery and air-purification facilities are recommended. For instance, trees, shrubs, grass, and ivy could be planted along the park side near roads to form a

multi-layered green barrier. Dust-removing and air-purification devices could also be installed in gathering areas to mitigate the effects of vehicle emissions, ensuring comfort and health for all age groups. Additionally, a feedback channel for users should be established, enabling a sustainable and effective optimization mechanism over time. In addition, around sports areas such as badminton courts, basketball courts, and ping pong tables, flexible windbreak facilities should be installed. During cooler seasons—autumn, winter, and early spring—wind panels can be closed to reduce wind exposure, while in summer, they can be opened to allow airflow and natural cooling. Auxiliary facilities, such as storage and changing rooms, should be added around sports areas, providing indoor areas with suitable temperatures during extreme seasons and offering temporary rest areas for users. Stores selling drinking water and snacks and offering the rental or sale of sports equipment could also enhance user convenience. In particular, for elderly users, comfortable and easy-to-clean seating should be provided along the main routes and scenic areas to facilitate rest. In the design, anti-slip flooring, protective barriers, and accessible restrooms should be installed to make the space more elderly friendly. Restrooms should be located near activity areas, equipped with clear and prominent directional signage; users should not intersect with motor vehicles along traffic routes, ensuring that people can access the facilities safely, conveniently, and comfortably.

The third recommendation is to improve the spatial inclusion to ensure that the needs of all age groups are met. For child users, a child-friendly wayfinding system that matches their height could be added along pathways or on either side, using colors or patterns to mark routes to children's activity areas. For youth and middle-aged users, a cultural and arts exhibition zone can be created to showcase Jinan's historical culture. Regular cultural events, such as traditional festival celebrations and art exhibitions, could enrich the cultural content of the under-bridge space. For elderly users, considering the complex traffic environment around the bridge space, an intelligent traffic signal control system can be implemented according to the real-time traffic flow, pedestrian crossing demand, and parking lot operating time, automatically adjusting the traffic-light waiting time, reducing the drivers and pedestrians, and setting an emergency control button, which would enhance the crossing safety and improve the traffic efficiency. Furthermore, a balanced approach to management revenue and citizens' rights should be considered when setting usage rules and fee standards. This could include reducing fees to accommodate lower-income individuals and offering discounts for vulnerable groups like the elderly and children.

5. Conclusions

This study examined user behavior and spatial perceptions in the Yanshan Interchange Lowline Park in Jinan, Shandong Province, China. Using observation and the importance–satisfaction analysis (ISA) method, combined with questionnaires and interviews, this study focused on analyzing the activity preferences and spatial environment perceptions of four age groups: child, youth, middle-aged, and elderly users. It explored the differences in perceptions among these groups and investigated the reasons behind these differences, providing a basis for prioritizing the renovation and optimization of spaces under overpasses.

This study found that the low-line park beneath the overpass provides a rich public space for exercise, significantly enhancing the quality of daily life for nearby residents. However, there are notable differences in the spatial and temporal usage patterns and perceptions among different age groups. The four age groups (child, youth, middle-aged, and elderly) exhibited distinct patterns in how they use the low-line park in time and space. A mismatch exists between the park's opening hours and the peak usage times for

different user groups, as well as between the activity areas and user needs. The importance–satisfaction analysis indicates that, overall, users place a higher importance on safety, comfort, and cultural features than their satisfaction levels suggest, highlighting greater expectations in these areas—particularly comfort, which requires urgent improvement. In contrast, users are relatively satisfied with the park's aesthetics and accessibility. All age groups express high expectations for improvements in safety and comfort. Youth users also desire better accessibility, while youth and middle-aged users have higher expectations for cultural relevance. None of the groups demonstrated significant expectations for improvements in aesthetics, suggesting that the current redesign of spaces under overpasses is generally well-received in this regard. However, meeting the needs of all age groups will require further improvements in safety, comfort, and cultural relevance. In addition, differences were observed in the perceptions of the 26 secondary indicators across the four age groups. Child users are dissatisfied with the lighting conditions, the safety of the internal facilities, and the noise levels, and they value the ease of crossing to the park, the distribution of the activity areas, and the aesthetic quality of the pathways more than other groups. Youth users express dissatisfaction with the convenience and visibility of park entrances, the internal area's safety, the air quality, and the quantity and size of the activity areas. They also place greater importance on entrance visibility and elements within the park that reflect Jinan's historical and cultural features. Middle-aged users are dissatisfied with the pedestrian and non-motorized vehicle safety in terms of the surrounding traffic, the lighting conditions, the air quality, and the quantity and size of the activity areas. Compared to other groups, they are less satisfied with the ease of crossing roads. Elderly users are dissatisfied with the convenience of park entrances, the condition of the exercise facilities, the air quality, and the availability of accessible facilities, showing a higher demand for accessibility improvements compared to other groups. The differing physical and psychological characteristics of each age group result in varying sensitivities to spatial information and distinct needs within the low-line park.

Based on the above analysis, this study proposes a series of optimization strategies, including adjusting the allocation of the time, area, and activity types within the activity spaces, enhancing the safety and comfort of the activity areas, and enriching the cultural connotation and inclusivity of the space. To address the specific needs of each age group, this study recommends tailoring space functionalities to different activity periods, for example, dedicated play areas for child users, additional rest areas and accessible facilities for elderly users, and enhanced cultural facilities to meet the cultural atmosphere expectations of youth and middle-aged users. Furthermore, this study highlights that the transformation of spaces under overpasses requires not only considerations of physical layout but also a focus on refining the management and operational mechanisms. This ensures that the accessibility, safety, and comfort of spatial facilities align with users' needs, particularly in balancing the requirements across different time periods and age groups.

This study provides practical theoretical support for the design and optimization of public spaces under overpasses, offering significant reference value for creating age-friendly spaces. However, this study has certain limitations, such as a relatively small sample size, which may affect the generalizability and accuracy of the results. Additionally, the timeliness of the findings may be impacted as park management continues to improve. Future research could expand the sample size and conduct ongoing tracking of changes in park management and user perceptions.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Table S1: User Demographic Characteristics; Table S2: Demographic Characteristics of Child Users; Table S3: Demographic Characteristics of Young Users; Table S4: Demo-

graphic Characteristics of Middle-aged Users; Table S5: Demographic Characteristics of Elderly Users; Table S6: Paired Sample t-test of Importance and Satisfaction of Children; Table S7: Paired Sample t-test of Importance and Satisfaction of Youth; Table S8: Paired Sample t-test of Importance and Satisfaction of Middle-Aged Adults; Table S9: Paired Sample t-test of Importance and Satisfaction of Elderly; Table S10: Post-Use Evaluation Questionnaire for the Lowline Park under Elevated Bridges; Table S11: Post-Use Evaluation Structured Interview Guide for the Lowline Park under Elevated Bridges.

Author Contributions: Conceptualization, X.W.; Methodology, Z.W., X.L. and X.W.; Software, Z.W.; Formal analysis, Z.W.; Investigation, Z.W., X.L. and H.L.; Writing—original draft, Z.W. and X.L.; Writing—review and editing, X.W.; Visualization, X.L. and H.L.; Project administration, H.L.; Funding acquisition, X.W. and H.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Ministry of Education of the People's Republic of China, grant number 202210422099, and Department of Education of Shandong Province of China, grant number M2023303.

Data Availability Statement: Data are contained within the article.

Acknowledgments: We sincerely thank the respondents who generously contributed their time to participate in the questionnaire and interview process. We also extend our gratitude to the Yanshan Interchange Bridge Management Authority for their invaluable cooperation. Furthermore, we would like to express our appreciation to Li Te, Li Luhan, and Guo Qiuhua for their support and assistance in this study.

Conflicts of Interest: The authors declare no conflicts of interest.

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