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Health-Oriented Evaluation of Park Walking Environments for Older Adults: Developing an Age-Friendly Assessment Tool Across Multiple Park Types

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Abstract

Against the backdrop of accelerating urbanization and population aging, urban parks have emerged as significant venues for enhancing the physical and mental well-being of older adults. The age-friendly quality of these spaces is directly linked to health equity and urban inclusiveness. Using the high-density historic district of Beilin in Xi'an as a case study, we developed an innovative assessment tool to evaluate the age-friendliness of park walking environments. Guided by the Health Impact Assessment (HIA) framework, this tool integrates subjective perceptions and objective data to diagnose environmental strengths and weaknesses across four dimensions: accessibility, safety, comfort, and health-related interactivity. Based on multi-source data and quantitative analysis, the study revealed key variations in the age-friendly attributes of different parks. Our field assessment focused on three representative park types: urban comprehensive, historic–cultural, and community leisure parks. The key findings are: (1) Safety was perceived by experts as the most critical dimension for older adults' health experience, with a weight of 0.49, accounting for nearly half of the total. However, significant variations exist in safety quality across different types of parks. (2) Age-friendly performance differed profoundly among park types. Benefiting from systematic management, the urban comprehensive park achieved balanced performance and a total score of 84.87. In contrast, the historic–cultural park, constrained by its linear morphology and historical functions, scored the lowest at 66.03, exhibiting notable deficits in safety and comfort. The community leisure park, while vibrant in community activity, attained an intermediate score of 74.76 due to insufficient attention to safety details. (3) The assessment outcomes highlight the association of park typology, site selection, and design sophistication with the lived experience and potential health benefits for older adults. This study provides a refined evaluation tool and tailored optimization strategies for the age-friendly renovation of diverse park types.

Keywords: Health Impact Assessment; park green space walking environment; the elderly; inclusive city

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1. Introduction

As global urbanization accelerates and population aging intensifies, the coordinated improvement of urban public health issues and the well-being of the elderly has become a core challenge facing the international community [1,2]. In China, where the population aged 60 and above reached 18% in 2020 and is projected to rise to 39% by 2050 [3], adapting health, economic, and social policies to address this demographic shift has become a national priority [4]. Consequently, creating health-promoting, livable environments is widely recognized as a crucial approach to addressing the challenges of an aging society [5]. As important public open spaces, the health benefits of urban parks have received increasing attention. Extensive research demonstrates that contact with natural settings offers multiple benefits: reducing psychological stress, encouraging physical activity [6,7], and strengthening social cohesion [8]. For older adults, parks with walking environments that are accessible, safe, comfortable, and conducive to health-related interaction are crucial venues for preserving holistic health and nurturing social bonds [9–11]. However, urban parks often suffer from issues such as insufficient accessibility and uneven quality [12], limiting their capacity to improve older adults' health. Therefore, the systematic evaluation and optimization of park walking environments for older adults is essential for building healthy, livable, and equitable cities [13]. Internationally, the Health Impact Assessment (HIA) serves as a key procedural framework for systematically evaluating the potential health impacts of policies and projects [1,14–16].

Initial research efforts focused on conceptualizing HIA and establishing its basic framework. Subsequent work has broadened the scope to incorporate diverse theoretical underpinnings, methodological approaches, and institutionalized implementation strategies [17,18]. These studies provide a methodological foundation for understanding the relationship between planning and health. However, effectively translating public health knowledge into concrete planning interventions still faces the challenge of bridging the gap between theory and practice [5]. Therefore, it is necessary to develop more operational HIA tools. The field of comprehensive park green space assessment has evolved to incorporate systematic, multidimensional, and multi-method approaches [19]. Scholarly work in this domain clusters around several key themes. One primary stream involves the assessment of ecosystem services and landscape values, with particular emphasis on climate regulation, biodiversity conservation, and the aesthetic quality provided by urban green spaces [20]. The second stream of research adopts a public health lens to assess green spaces, examining their contributions to enhancing physical activity [21], ameliorating mental well-being [22], and mitigating the risk of chronic disease [23]. The third category focuses on assessing spatial equity and accessibility issues. These studies frequently employ GIS-based spatial analysis, network analysis, and the two-step floating catchment area (2SFCA) method to uncover disparities in green space distribution across socioeconomic groups, thereby addressing questions of environmental justice [24]. Fourth, post-use evaluation and perception studies were conducted using methods such as questionnaires, behavioral observations, interviews, and, more recently, behavior mapping and public participation geographic information systems (PPGIS) [25–27].

Research on walking environments for older adults in park green spaces has primarily advanced through two interrelated dimensions: first, identifying environmental preferences and key factors influencing older adults' walking behavior, such as safety [28], comfort [29], accessibility [30], and health-related interactivity [8], and second, evaluation methods tailored to pedestrian environments for older adults should be developed. These primarily include the indicator system approach [31], behavioral perception methods [32,33], and new technology approaches, such as utilizing street view imagery [34] and mobile phone trajectory data [35] for objective analyses. Recent studies have emphasized the actual needs

of users. By integrating the cultural ecosystem services approach [36], they assessed the quality and equity of green space services for the elderly [19]. The findings reveal that high-quality green spaces are not equally accessible to all, potentially indicating distributional inequities [37].

However, from the perspective of building inclusive cities and supporting vulnerable groups in accessing transportation and public spaces, existing research still has the following limitations. First, older adults and other vulnerable populations receive insufficient targeted attention. Second, most park evaluation studies are designed for the general public [14] or consider older adults merely as a generic user group. This has led to a critical shortage of evaluation frameworks tailored to their distinct physiological, psychological, and socio-relational needs [38]. Accordingly, the current findings remain insufficient for guiding and improving inclusive designs that promote health equity and spatial well-being among older adults. Second, integration between research perspectives and HIA systems remains insufficient. Although theories such as environmental behavioral science and health geography are widely applied, existing studies have not fully integrated the systematic thinking and structured procedures of HIA [39]. Much of the current research is confined to identifying individual environmental factors or analyzing associations between a single factor and a specific health outcome. A systematic evaluation framework that links the "objective environment," "users' subjective experiences," and "final health outcomes" into a coherent logical chain is lacking. Consequently, studies struggle to systematically diagnose and reveal the collective relationships between environmental features and the multilevel health of older adults. Third, empirical data from localized field research is insufficient. Despite the extensive use of various theoretical models in existing research [40], studies on the actual experiences and needs of older adults in diverse park environments are scarce. Excessive reliance on macro-level data or theoretical predictions while neglecting empirical evidence from observations, interviews, and questionnaires undermines the persuasiveness of research conclusions and the precision of design guidance. These shortcomings underscore the need to further explore age-friendly walking environments in older parks. Specifically, we urgently need to develop a new, comprehensive evaluation tool. This tool must center on the elderly population, integrate systems thinking of Health Impact Assessment (HIA), be grounded in field research, and effectively bridge the entire process from planning to design.

To provide scientific evidence and practical tools for promoting inclusive, age-friendly urban environments, this study developed a health-oriented assessment tool specifically tailored to evaluate park walking environments for older adults. The tool draws on the systematic thinking of Health Impact Assessment (HIA) and integrates four core dimensions: accessibility, safety, comfort, and health-related interactions. Using field survey data from three park types in Beilin District, Xi'an, this study demonstrates the tool's utility in diagnosing environmental strengths and weaknesses. It also addresses shortcomings in existing research, such as insufficient attention to older adults and the lack of a specialized evaluation system. This study provides not only a systematic evaluation tool but also empirical evidence for optimizing age-friendly walking environments in parks.

2. Study Area and Data

2.1. Study Area

This study focuses on the central urban districts of Xi'an, encompassing six administrative districts: Beilin, Xincheng, Lianhu, Yanta, Baqiao, and Weiyang. According to data from China's Seventh National Population Census, Beilin District, a high-density historic urban area, has the highest aging rate among these districts at 20.19%. Its elderly

population density reaches 6542.77 people per square kilometer (Table 1), making it a highly representative case for studying aging populations in dense urban settings.

Table 1. Aging Rates in Xi'an's Central Urban Areas (Compiled from Data of the Seventh National Population Census by China's National Bureau of Statistics).

District	Size (km^2)	Total Resident Population	Population Aged 60 and Above	Aging Population Ratio (%)	Density of Aging Population (Persons/km^2)
Beilin District	23.36	756,840	152,839	20.19	6542.77
Xincheng District	31.2	644,702	128,592	19.95	4121.54
Lianhu District	43	1,019,102	182,279	17.89	4239.05
Yanta District	152	1,202,038	162,616	13.53	1069.84
Baqiao District	324.5	593,962	90,519	15.23	278.95
Weiyang District	262	733,403	94,093	12.83	359.113

To systematically compare the impact of walking environments in different park types on the health of older adults, this study selected three representative park categories based on the functional classification in the Xi'an Urban Green Space System Plan, namely, urban comprehensive park, historic–cultural park, and community leisure park. This selection also considered the spatial distribution balance and service coverage (Figure 1).

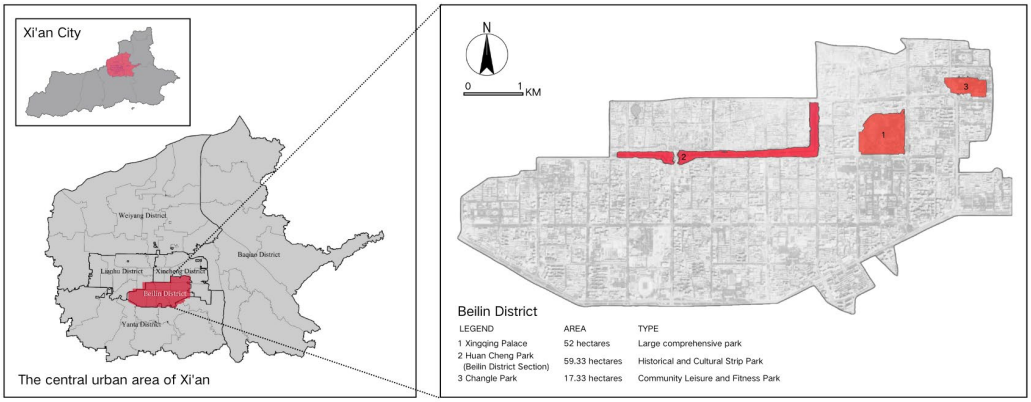


Figure 1. Research Area Schematic. Administrative boundary of the study area, sourced from the National Geographical Information Center of China [41]; Park boundary of the study area, redrawn and adapted based on the study scope map from [24].

Xingqing Palace Park, located in the eastern Beilin District, is an urban comprehensive park covering approximately 52 hectares. It features a planar layout with lakes, woodlands, plazas, and diverse cultural facilities, serving as a large-scale, multi-functional recreational space. Huancheng Park is located in the city center, with the Beilin District section covering an area of approximately 59.33 hectares. It has been designated as a historic–cultural park. The park was built around the ruins of the Ming Dynasty city wall, stretching in a narrow strip of land. It primarily serves the elderly residents of Xi'an's old city district, surrounding the moat. Changle Park is located in the northeast corner of the Beilin District and covers an area of approximately 17.33 hectares. It is a community leisure park. The park features a compact layout centered around a centralized sports field and fitness facilities, primarily serving the elderly residents of eight surrounding communities, including Yongle and Jin Kang.

These three types of parks exhibit significant differences in functional characteristics, spatial layout, scale, and scope of services; however, all serve as public open spaces frequently used by the elderly in Beilin District on a daily basis. By comparing the differences

in park types, we can effectively reveal their impact on the health benefits of walking environments for older adults, thereby providing a basis for developing precise evaluation and optimization strategies tailored to different park types.

2.2. Research Data

We conducted the survey of park walking environments for older adults in three parks within Beilin District, Xi'an: Xingqing Palace Park, Huancheng Park, and Changle Park. We distributed 200 questionnaires in each park, totaling 600. The valid response rates were 96% (n = 192) for Xingqing Palace Park, 93.5% (n = 187) for Huancheng Park, and 94.5% (n = 189) for Changle Park. The researchers conducted a statistical analysis of the collected questionnaire data and integrated the basic information of the survey data (Table 2).

Table 2. Integration of Basic Research Data.

Variable	Items	Xingqing Palace Park (n = 192)	Huancheng Park (n = 187)	Changle Park (n = 189)	Total (N = 568)
Gender	Male	102 (53.1%)	99 (52.9%)	90 (47.6%)	291 (51.2%)
	Female	90 (46.9%)	88 (47.1%)	99 (52.4%)	277 (48.8%)
Age Group (Years)	60–64	55 (28.6%)	43 (23.0%)	58 (30.7%)	156 (27.5%)
	65–69	62 (32.3%)	52 (27.8%)	64 (33.9%)	178 (31.3%)
	70–74	41 (21.4%)	60 (32.1%)	38 (20.1%)	139 (24.5%)
	75–79	23 (12.0%)	20 (10.7%)	19 (10.0%)	62 (10.9%)
	≥80	11 (5.7%)	12 (6.4%)	10 (5.3%)	33 (5.8%)
Primary Mode of Travel	Walking	76 (39.6%)	89 (47.6%)	92 (48.7%)	257 (45.2%)
	Public Transit	73 (38.0%)	64 (34.2%)	40 (21.2%)	177 (31.2%)
	Bicycle/E-bike	36 (18.8%)	23 (12.3%)	53 (28.0%)	112 (19.7%)
	Other *	7 (3.6%)	11 (5.9%)	4 (2.1%)	22 (3.9%)
Exercise Frequency	Daily or more	49 (25.5%)	43 (23.0%)	44 (23.3%)	136 (23.9%)
	3–5 times per week	56 (29.2%)	45 (24.1%)	55 (29.1%)	156 (27.5%)
	1–2 times per week	62 (32.3%)	78 (41.7%)	67 (35.4%)	207 (36.4%)
	Occasionally	25 (13.0%)	21 (11.2%)	23 (12.2%)	69 (12.2%)
Usual Activity Duration	<1 h	21 (10.9%)	20 (10.7%)	22 (11.6%)	63 (11.1%)
	1–2 h	98 (51.0%)	96 (51.3%)	96 (50.8%)	290 (51.1%)
	>2 h	73 (38.0%)	71 (38.0%)	71 (37.6%)	215 (37.9%)
Peak Activity Period	Morning (before 10:00)	58 (30.2%)	85 (45.5%)	52 (27.5%)	195 (34.3%)
	Evening (16:00–20:00)	104 (54.2%)	72 (38.5%)	107 (56.6%)	283 (49.8%)

* "Other" includes taxi, private car, or being driven by family members.

3. Research Methodology

3.1. Overarching Framework

The core objective of this study was to develop a specialized evaluation tool and conduct an empirical analysis. This study addresses the global trends of urbanization and aging. Simultaneously, it aims to fill a critical gap in current research: the absence of a Health Impact Assessment (HIA) system specifically designed to evaluate the health effects of urban parks on older adults. The research framework is illustrated in Figure 2. First, the study integrated cutting-edge findings from the International Health Indicators System to establish an HIA system for walking environments for the elderly in urban parks. This system encompasses four dimensions—accessibility, safety, comfort, and health-related interactivity—and their corresponding weightings. Subsequently, the study selected three representative park types within Xi'an's Beilin District: an urban comprehensive park, a historic–cultural park, and a community leisure park. Data were collected through questionnaires, field surveys, and on-site interviews. Finally, the study calculated the HIA scores for each sample and conducted a comprehensive comparative analysis, thereby

identifying existing challenges in park walking environments that are unfavorable to older adults. This ultimately provides empirical evidence and actionable measures for creating inclusive and age-friendly environments.

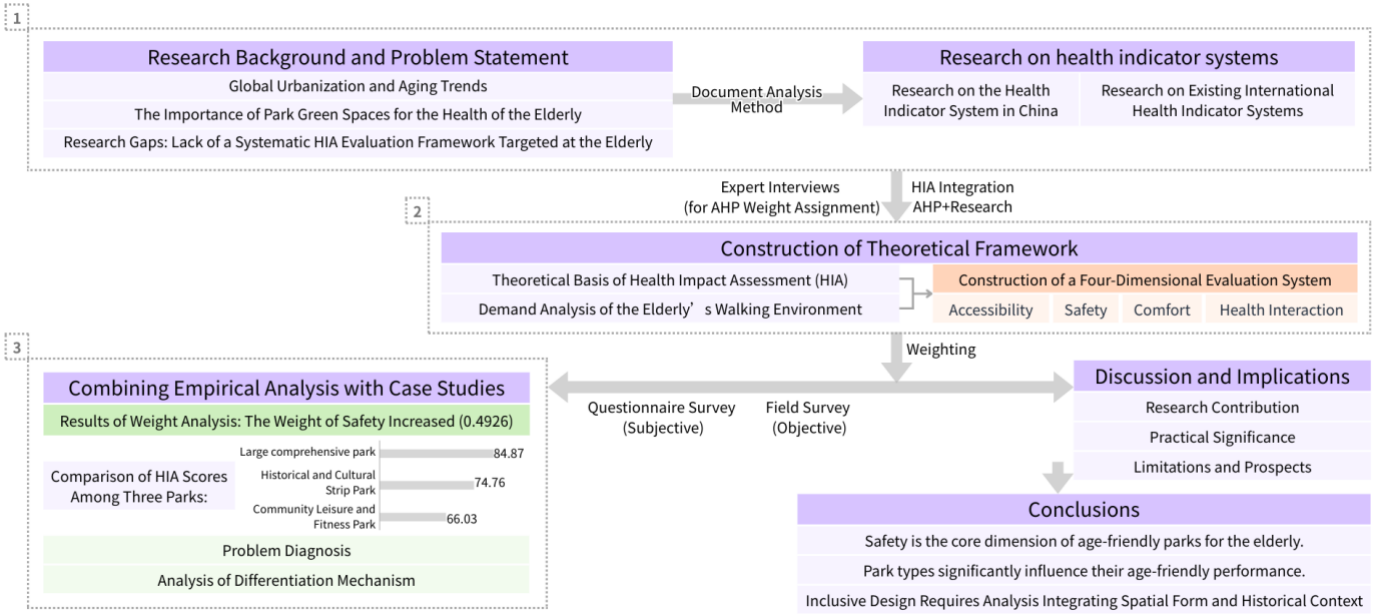


Figure 2. Research Framework Diagram.

3.2. Index System Construction

3.2.1. Research Foundation

The theoretical framework of the assessment tool developed in this study for the walking environment of older adults in parks and green spaces has clear theoretical and indicator sources. The indicator system is based on Maslow's Hierarchy of Needs Theory. It extensively draws upon relevant international principles and standards. For example, the indicators of healthy cities set by the World Health Organization (WHO) regarding the accessibility of public spaces and the principles of health promotion, the environmental comfort requirements of the evaluation index system for healthy cities in China, and safety and environmental entries in the Design for Health (DFH) rapid health impact assessment tool. The findings of Paudel et al. (2023) on the importance of park walking path microdesign for the health of older adults [42] were also integrated to ensure that the evaluation system had both an international perspective and local applicability. The specific hierarchical structure is illustrated in Figure 3.

In this study, the Analytic Hierarchy Process (AHP) was used to construct and determine the weights of HIA indicators of the walking environment for older adults in parks and green spaces. AHP, originally developed by Saaty [43] as a systematic multi-criteria decision-making tool, is centered on the decomposition of complex decision problems into a hierarchical structural system [44,45]. This method is based on two basic concepts: hierarchical structure and weight assignment. By constructing a hierarchical model containing a target layer, a guideline layer, a sub-criteria layer, and a program layer, a systematic analysis of the complex problem is realized, and the HIA system of the walking environment for the elderly in parks and green spaces is established. The method calculates a composite weight by quantitatively comparing the relative importance of the elements in each tier. This type of evaluation can deal with both objective environment and subjective health perceptions and is therefore particularly suitable for the comprehensive evaluation questions addressed in this study. Figure 4 illustrates the basic hierarchical structure of the AHP.

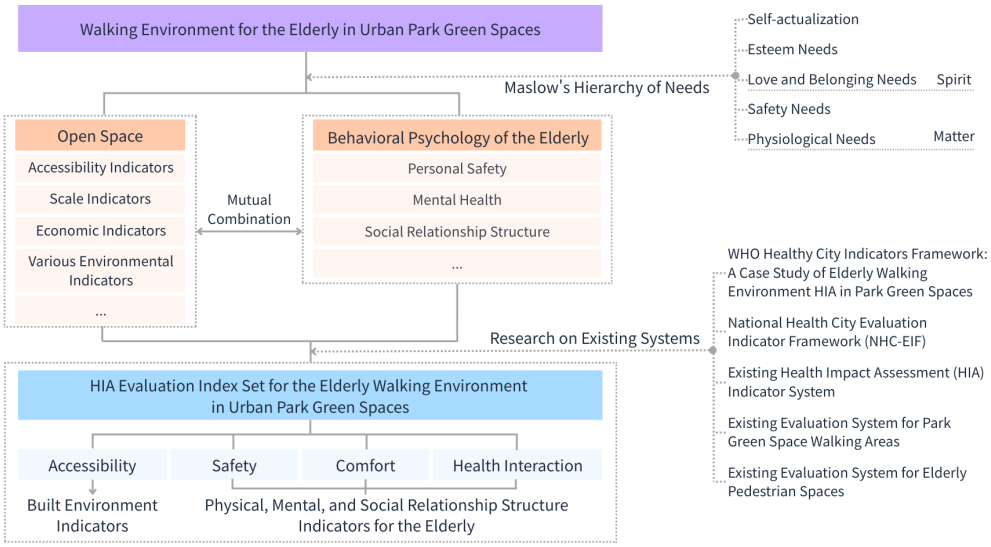


Figure 3. Framework map for the selection of indicators.

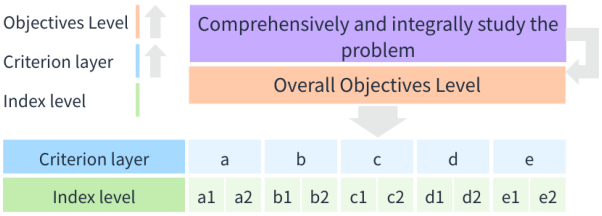


Figure 4. Diagram of the basic hierarchical structure of hierarchical analysis.

During implementation, this study strictly followed the three key steps of AHP. First, as shown in Figure 4, a hierarchical model was constructed. The hierarchical structural model proposed in this study establishes a total of 25 items, ranging from the overall objective of assessing the health impacts of walking environments for the elderly in parks and green spaces to specific assessment factors. To determine the relative importance of the elements of each tier, 20 experts in relevant fields were invited to participate in this study. Saaty's 1–9 scale was used to systematically compare elements within the same tier two-by-two busing an expert questionnaire, and a judgment matrix was constructed to minimize subjective errors. Finally, the valid questionnaire data were tested for consistency, and the consistency ratio (CR) was calculated to assess the logical consistency of the expert judgment. When the CR value is less than 0.1, the judgment matrix is determined to have acceptable consistency, thus ensuring the reliability of the final weight calculation results.

3.2.2. Preliminary Construction of HIA Indicators for Walking Environment for the Elderly in Parks and Green Spaces

The tool for senior walking environments in parks and green spaces constructed in this study systematically categorizes the health needs of older adults into four spatial evaluation dimensions: accessibility, safety, comfort, and health-related interactivity. The system combines objective indicators and subjective needs (Figure 5).

The accessibility dimension focuses on how easy or difficult it is for older adults to reach and access park spaces, focusing on distance and time [46]. The safety dimension focuses on the personal safety and risk prevention of older adults when they are active in parks, which is the primary prerequisite for outdoor activities [47]. The comfort dimension assesses the physical quality and psychological feelings of the environment in terms of the subjective perception and use experience of older adults [48]. The Healthy Interactivity Dimension, on the other hand, emphasizes the critical role of parks as places that promote

health-related interactivity for the mental health of older adults [8]. This categorization not only considers the spatial characteristics of parks and green spaces but also highlights the special needs of older people for their environment. Each dimension contains specific evaluation indicators, which together build a complete evaluation system, providing a systematic tool for subsequent empirical research and design optimization.

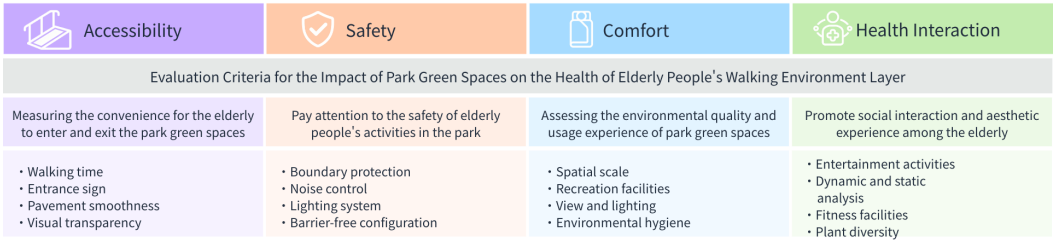


Figure 5. Health Impact Assessment (HIA) Indicator Delineation for Elderly Walking Environment in Parks and Green Spaces.

The specific classification of environmental health impact assessment factors for senior walking trails in park green spaces is shown in Appendix A, Table A1.

3.2.3. HIA Modeling of the Walking Environment for Seniors in Parks and Green Spaces

In this study, based on HIA, a hierarchical model was developed for assessing the impact of the walking environment in parks and green spaces on the health of the elderly population. The model contains four tiers.

- Objective Level (O): Assessment of the impact of parkland walking environments on the health of the older population.
- Criteria Level (A): It covers four main indicators: accessibility, safety, comfort, and health-related interactivity.
- Sub-criteria Level (B): This is broken down into eight composite metrics, such as external accessibility and internal accessibility.
- Alternative Level (C): Contains 25 detailed health assessment factors;
- The details are presented in Table 3.

Table 3. A four-level HIA rapid rating system for the walking environment for older adults in parks and green spaces (author's own work).

Factor Category	Specific Factor	Score Range	Scoring Instructions
Accessibility (4 items)	A1 Time spent walking to the park	1–5 points	A shorter walking time corresponds to a score closer to 5, while a longer time corresponds to a score closer to 1.
	A2 Park entrance location	1–5 points	A more conspicuous and convenient entrance corresponds to a score closer to 5, while a less conspicuous and convenient one corresponds to a score closer to 1.
	A3 Unobstructed park circulation routes	1–5 points	Smooth, direct routes (with no detours) correspond to a score closer to 5, while obstructed or circuitous routes correspond to a score closer to 1.
	A4 Clear sightlines along park paths	1–5 points	Good path visibility with no obstructions corresponds to a score closer to 5, while obstructed sightlines correspond to a score closer to 1.

Table 3. *Cont.*

Factor Category	Specific Factor	Score Range	Scoring Instructions
Safety (9 items)	A5 Defined park boundaries	1–5 points	Clearer boundaries and a greater sense of security correspond to a score closer to 5, while less defined boundaries and a weaker sense of security correspond to a score closer to 1.
	A6 Absence of intrusive traffic noise	1–5 points	Less traffic noise within the park corresponds to a score closer to 5, while more traffic noise corresponds to a score closer to 1.
	A7 Vegetation safety (maintenance)	1–5 points	Regular pruning of greenery corresponds to a score closer to 5, while infrequent pruning corresponds to a score closer to 1.
	A8 Non-irritating plant odors	1–5 points	The absence of plants with strong or irritating odors corresponds to a score closer to 5, while the presence of such plants corresponds to a score closer to 1.
	A9 Nighttime lighting adequacy	1–5 points	A well-functioning nighttime lighting system corresponds to a score closer to 5, while an inadequate or poorly functioning lighting system corresponds to a score closer to 1.
	A10 Safety of activity facilities	1–5 points	Facilities that are sturdy and free of sharp edges or damage correspond to a score closer to 5, while facilities with such hazards or structural instability correspond to a score closer to 1.
	A11 Accessibility facilities	1–5 points	A more complete provision of accessibility facilities corresponds to a score closer to 5, while a less complete provision corresponds to a score closer to 1.
	A12 Clarity of park signage system	1–5 points	Clearer and more legible signage corresponds to a score closer to 5, while less clear and legible signage corresponds to a score closer to 1.
	A13 Completeness of security & emergency systems	1–5 points	More complete security and first-aid systems correspond to a score closer to 5, while less complete systems correspond to a score closer to 1.
Comfort (6 items)	A14 Diversity of activity spaces	1–5 points	A greater variety of activity space types corresponds to a score closer to 5, while a smaller variety corresponds to a score closer to 1.
	A15 Spatial scale suitability for elderly activities	1–5 points	A spatial scale that better meets the activity needs of older adults corresponds to a score closer to 5, while a scale that is less suitable for their needs corresponds to a score closer to 1.
	A16 Sufficiency of seating/rest facilities	1–5 points	A more adequate provision of rest facilities corresponds to a score closer to 5, while a less adequate provision corresponds to a score closer to 1.
	A17 Internal ventilation & lighting conditions	1–5 points	Good natural ventilation and sunlight exposure correspond to a score closer to 5, while poor ventilation and limited sunlight exposure correspond to a score closer to 1.
	A18 Summer shading from vegetation	1–5 points	Adequate shading from plants during summer days corresponds to a score closer to 5, while inadequate shading corresponds to a score closer to 1.
	A19 Path cleanliness and hygiene	1–5 points	Clean and well-maintained paths correspond to a score closer to 5, while poorly maintained or unclean paths correspond to a score closer to 1.

Table 3. *Cont.*

Factor Category	Specific Factor	Score Range	Scoring Instructions
health-related interactivity (6 items)	A20 Richness of recreational activities	1–5 points	A more diverse range of recreational activities corresponds to a score closer to 5, while a less diverse range corresponds to a score closer to 1.
	A21 Clear zoning between rest and activity areas	1–5 points	A clear separation between rest and activity areas, preventing mutual disturbance, corresponds to a score closer to 5, while a poor separation corresponds to a score closer to 1.
	A22 Sufficiency of recreational & fitness facilities	1–5 points	An adequate provision of recreational and fitness amenities corresponds to a score closer to 5, while an insufficient provision corresponds to a score closer to 1.
	A23 Proximity to children's facilities	1–5 points	Closer proximity to children's play areas corresponds to a score closer to 5, while greater distance from such areas corresponds to a score closer to 1.
	A24 Diversity of plant configurations	1–5 points	A more diverse plant composition corresponds to a score closer to 5, while a less diverse composition corresponds to a score closer to 1.
	A25 Aesthetic design of park structures	1–5 points	More aesthetically pleasing architectural features or structures correspond to a score closer to 5, while structures with less aesthetic consideration correspond to a score closer to 1.

3.2.4. Thresholds for HIA Indicators of Walking Environment for the Elderly in Parks and Green Spaces—Determination and Analysis of Weights

In order to determine the relative weights of the elements at different levels, an expert questionnaire was designed for this study (Appendix A).

In AHP, the eigenvector W corresponding to the largest eigenvalue λ_{max} of the judgment matrix A is normalized to represent the relative importance ranking weight of each factor at the same level with respect to the specific factor at the previous level. The maximum eigenvalue λ_{max} is expressed as:

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} \quad (1)$$

In order to test the accuracy of the expert scoring results, a consistency test was performed after the weights were calculated, and the consistency ratio (CR) was calculated using the following formula:

$$CR = \frac{CI}{RI} = \frac{\frac{\lambda_{max}-n}{n-1}}{RI} \quad (2)$$

where CI denotes the consistency index, and RI denotes the average value of the random consistency index. When $CR < 0.1$, the judgment matrix satisfies the consistency test [45].

We invited a panel of 20 participants, including experts and local residents, to complete the AHP questionnaire. Four questionnaires were excluded due to incompleteness or obvious logical errors, leaving 16 valid responses for further analysis. These 16 datasets were then imported into the YAAHP V10.3 software for consistency testing. Five questionnaires had consistency ratios (CR) exceeding the acceptable threshold of 0.1 and were therefore excluded. The remaining 11 questionnaires, all with CR values below 0.1 (ranging from 0.02 to 0.09), were used to derive the final weights. All original judgment matrices for these 11 participants are provided in Appendix B (Tables A2–A14).

In AHP, the computation of the judgment matrices of the m-bit experts requires the computation of the ordering vector of each judgment matrix as follows:

$$W^c = (W_1^c, W_2^c, ..., W_n^c)^T, c = 1, 2, ..., m \quad (3)$$

The integrated ranking vector W is computed as follows:

$$W_j = \sum_{c=1}^{m} \lambda_c W_j^c, j = 1, 2, \ldots, n \quad (4)$$

In order to maintain the objectivity of the evaluation, this study set the weights of each expert to be the same:

$$W_j = \frac{1}{m}\left(\sum_{c=1}^{m} W_j^c\right), j = 1, 2, \ldots, n \quad (5)$$

Based on the above methodology, the absolute total ranking weights of the four-level indicator system of the HIA for the walking environment for the elderly in parks and green spaces were calculated (Table 4).

Table 4. Absolute total ranking weights for the four-level HIA indicator system.

Criteria Level (A)	Absolute Weight	Sub-Criteria Level (B)	Absolute Weight	Alternative Level (C)	Absolute Weight
A1	0.1964	B11	0.1198	C111	0.0803
				C112	0.0395
		B12	0.0766	C121	0.0502
				C122	0.0264
A2	0.4926	B21	0.25	C211	0.1033
				C212	0.0293
				C213	0.0276
				C214	0.0177
				C215	0.0722
		B22	0.2426	C221	0.0788
				C222	0.0586
				C223	0.0246
				C224	0.0805
A3	0.156	B31	0.0939	C311	0.048
				C312	0.0117
				C313	0.0342
		B32	0.062	C321	0.0212
				C322	0.0086
				C323	0.0322
A4	0.1551	B41	0.1128	C411	0.0392
				C412	0.0274
				C413	0.0321
				C414	0.014
		B42	0.0423	C421	0.0243
				C422	0.0179

3.2.5. Weighting Analysis of the HIA Rapid Evaluation System

The hierarchical analysis of the final weighting results reveals the relative importance of each health influencer, as shown in the weighting below (Figure 6).

1. Criteria Level (A)

In the criterion dimension (A), safety received the highest weight (0.4926), indicating that experts consider it the most important dimension for age-friendly environments.

Accessibility ranked second with a weight of 0.1964, while Comfort and Healthy Interaction had similar weights of 0.1560 and 0.1551, respectively.

2. Sub-criteria Level (B)

At the sub-criteria level (B), the weights of site safety and facility safety contributed the most. Notably, social interaction was significantly weighted higher than visual aesthetics, suggesting that from an expert perspective, environmental features that promote social connection have a more positive impact on the health of older adults than pure landscape aesthetics.

3. Alternative Level (C)

At the specific indicator level (C), the top five most heavily weighted factors are all focused on the area of safety, in the following order: protection of site boundaries, security and rescue facilities, pedestrian accessibility time, safety of facilities, and nighttime lighting. In addition, accessibility and internal garden path accessibility also received high weightings. These results provide a clear quantitative basis for identifying key influencing factors and prioritizing intervention strategies.

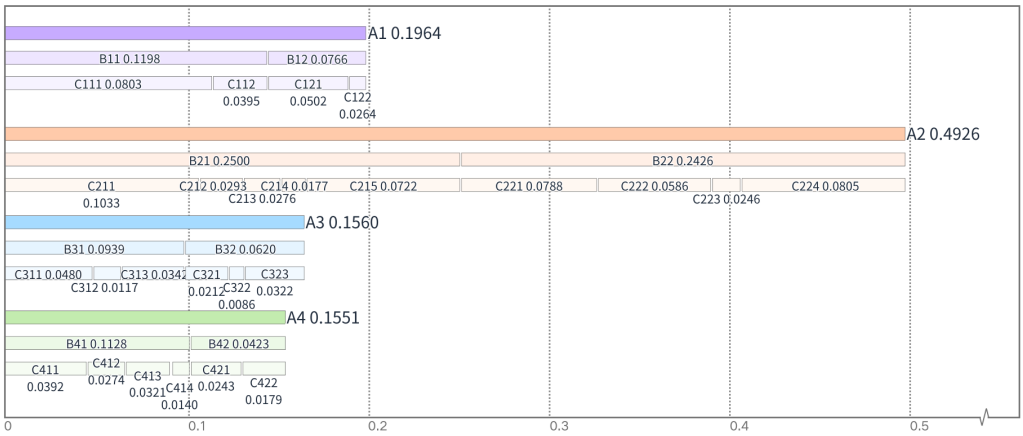


Figure 6. Schematic of the weighting analysis of the HIA rapid assessment system.

Based on the literature review and theoretical analysis, this study constructed a four-tier index system for HIA of the senior walking environment in parks and green spaces. The system integrates the research results of HIA, park green space evaluation, and senior walking environment assessment, and fully considers the characteristics of open space and the special needs of the elderly group. The weights assigned to each indicator level were determined through expert consultation and YAAHP V10.3 software calculations. This multi-level evaluation model with a weighting system not only realizes the structuring and quantification of complex health impact issues, but also provides a scientific measurement tool and analysis system for subsequent empirical evaluation in the region.

3.3. Data Collection

3.3.1. Subjective Data Acquisition

1. Expert data processing

The expert panel involved in this study was multidisciplinary, comprising researchers, park designers, park managers, and local residents. The researchers had expertise in urban planning, landscape architecture, environmental psychology, and older adult behavior studies, bringing relevant research experience to the panel. The designers and managers contributed frontline practical knowledge, with a deep understanding of park space design and daily operations. Local resident representatives were older adults who regularly used

the parks under study, ensuring that the assessment framework genuinely reflected the lived experiences and priorities of the end-users. This composition ensured that the developed tool integrated academic rigor, practical feasibility, and user-centered perspectives. The purpose of the study and the manner in which the data were used were explained to all experts, and there was no potential conflict of interest.

2. The elderly data processing

Data collection was conducted from March to May 2024 by a trained research team. The study was conducted on older people aged 60 and above who would be engaged in activities in the selected parks. The survey was conducted mainly on weekdays and weekends, covering three daily time periods (8:00–10:00, 14:00–16:00 and 16:00–18:00) to ensure coverage of park users during the different time periods. Respondents were selected through random field sampling: trained interviewers approached older people in the main activity areas and invited them to participate. To ensure a balanced representation of parks, it was planned to distribute 200 questionnaires per park, with an even distribution of valid responses and an overall valid response rate of 94.7%. Inclusion criteria were: (1) aged 60 and above; (2) currently engaged in leisure or exercise activities in the parks; (3) cognitive ability to understand and complete the questionnaire independently or with the assistance of others; and (4) voluntary participation. Exclusion criteria were (1) age below 60; (2) significant cognitive or communication impairment to understand the questionnaire; and (3) refusal to participate or withdrawal. To assess potential nonresponse bias, interviewers briefly recorded the gender and approximate age range (based on observations) of those who refused to participate in the survey. The main reasons for refusal included "scheduling constraints" or "unwillingness to be interviewed," and there was no evidence of systematic selection bias. The sample size met the requirements for subsequent statistical analysis.

Before the formal survey, a pilot test was conducted in Xingqing Palace Park in February 2024 with 30 randomly selected older adults. The purposes of the pilot test were to: (1) assess the clarity and comprehensibility of the questionnaire items; (2) evaluate the average completion time; and (3) identify any potential cultural or language barriers. Based on the pilot feedback, minor wording adjustments were made to improve clarity, such as rephrasing "path connectivity" to a more colloquial expression. The completion time was controlled to approximately 5–8 min. Data from the pilot test were not included in the final analysis.

Based on the established HIA system for the walking environment for older adults in parks and green spaces, a research questionnaire was designed and distributed in this study. The questionnaire is centered on four dimensions: accessibility, safety, comfort, and health-related interactivity, and contains 25 specific indicators, which are assessed using a 5-point Likert scale, with scores ranging from 1–5 representing "poor" to "very good" (see Table 5 for details). The score from 1 to 5 represents "very poor" to "very good" respectively (see Table 5 for details).

Table 5. A system of walking environment indicators for older adults in parks and green spaces.

Factor Category	Specific Factor	Score Range	Scoring Instructions
Accessibility (4 items)	A1 Time spent walking to the park	1–5 points	Shorter walking time → Score closer to 5 points. Longer time → Score closer to 1 point.
	A2 Park entrance location	1–5 points	More conspicuous and convenient entrance → Score closer to 5 points. Less so → Score closer to 1 point.
	A3 Unobstructed park circulation routes	1–5 points	Smooth, direct routes (no detours) → Score closer to 5 points. Obstructed or circuitous routes → Score closer to 1 point.
	A4 Clear sightlines along park paths	1–5 points	Good path visibility with no obstructions → Score closer to 5 points. Obstructed sightlines → Score closer to 1 point.

Table 5. *Cont.*

Factor Category	Specific Factor	Score Range	Scoring Instructions
Safety (9 items)	A5 Defined park boundaries	1–5 points	Clearer boundaries and greater sense of security → Score closer to 5 points. Less defined → Score closer to 1 point.
	A6 Absence of intrusive traffic noise	1–5 points	Less traffic noise within the park → Score closer to 5 points. More noise → Score closer to 1 point.
	A7 Vegetation safety (maintenance)	1–5 points	Regular pruning of greenery → Score closer to 5 points. Infrequent pruning → Score closer to 1 point.
	A8 Non-irritating plant odors	1–5 points	Absence of plants with strong/pungent odors → Score closer to 5 points. Presence of such plants → Score closer to 1 point.
	A9 Nighttime lighting adequacy	1–5 points	Well-functioning nighttime lighting system → Score closer to 5 points. Poor lighting → Score closer to 1 point.
	A10 Safety of activity facilities	1–5 points	Sturdy facilities, free of sharp edges or damage → Score closer to 5 points. Unsafe features present → Score closer to 1 point.
	A11 Accessibility facilities	1–5 points	More complete provision of accessibility facilities → Score closer to 5 points. Less complete → Score closer to 1 point.
	A12 Clarity of park signage system	1–5 points	Clearer, more legible signage → Score closer to 5 points. Less clear → Score closer to 1 point.
	A13 Completeness of security & emergency systems	1–5 points	More complete security and first-aid systems → Score closer to 5 points. Less complete → Score closer to 1 point.
Comfort (6 items)	A14 Diversity of activity spaces	1–5 points	Greater variety of activity space types → Score closer to 5 points. Less variety → Score closer to 1 point.
	A15 Spatial scale suitability for elderly activities	1–5 points	Spatial scale better meets elderly users' needs → Score closer to 5 points. Less suitable → Score closer to 1 point.
	A16 Sufficiency of seating/rest facilities	1–5 points	More adequate provision of rest facilities → Score closer to 5 points. Less adequate → Score closer to 1 point.
	A17 Internal ventilation & lighting conditions	1–5 points	Good natural ventilation and sunlight exposure → Score closer to 5 points. Poor conditions → Score closer to 1 point.
	A18 Summer shading from vegetation	1–5 points	Adequate shading from plants during summer days → Score closer to 5 points. Inadequate shading → Score closer to 1 point.
	A19 Path cleanliness and hygiene	1–5 points	Clean, well-maintained paths → Score closer to 5 points. Poor cleanliness → Score closer to 1 point.
health-related interactivity (6 items)	A20 Richness of recreational activities	1–5 points	More diverse recreational activities → Score closer to 5 points. Less diverse → Score closer to 1 point.
	A21 Clear zoning between rest and activity areas	1–5 points	Clear separation preventing interference → Score closer to 5 points. Poor separation → Score closer to 1 point.
	A22 Sufficiency of recreational & fitness facilities	1–5 points	Adequate quantity of recreational/fitness facilities → Score closer to 5 points. Insufficient quantity → Score closer to 1 point.
	A23 Proximity to children's facilities	1–5 points	Closer proximity to children's play areas → Score closer to 5 points. Farther away → Score closer to 1 point.
	A24 Diversity of plant configurations	1–5 points	More diverse plant arrangements → Score closer to 5 points. Less diverse → Score closer to 1 point.
	A25 Aesthetic design of park structures	1–5 points	More aesthetically pleasing structural design → Score closer to 5 points. Less aesthetically considered → Score closer to 1 point.

3.3.2. Objective Data Acquisition

This objective data collection aims to validate and supplement the results of the preliminary questionnaire and provide a diverse basis for data analysis. The specific information collected is summarized in the table below (Table 6).

Table 6. List of contents of the research on the walking environment space for the elderly in parks and green spaces.

Survey and Research Targets	Content of the Research
Park entrance and exit	Entrance location, neighborhood features, entrance landscaping
Main walking paths	Road network structure, road width, road greening, barrier-free facilities, tree species and vegetation conditions
Entrances and exits to major structures (e.g., pavilions, porches, restrooms, etc.) through which the pedestrian path passes	Location and environmental profile, paving form, the presence or absence of steps, barrier-free facilities, the number and location of landscape vignettes, the number, quality, location and material of ancillary fitness facilities, etc.
Lighting condition	Number and spacing of streetlights, overall lighting condition of the pedestrian environment
Utility	Type, number and maintenance of facilities, utilization, overall environmental conditions of the surroundings

3.3.3. Statistical Analysis

To verify the reliability of the health impact assessment (HIA) instrument with 25 indicators constructed in this study as a reusable scale, we tested the reliability of 568 valid questionnaire data collected. The internal consistency of the scale was assessed by the Clonal Bach coefficient, which showed that the Clonal Bach α coefficient of the total scale was 0.92, and the α coefficients of the four core dimensions-accessibility (4 items), safety (9 items), comfort (6 items) and health interactivity (6 items) were 0.78, 0.88, 0.83 and 0.81, respectively. The α coefficients of all dimensions were above the recommended threshold of 0.7, indicating that this assessment tool has excellent internal consistency reliability.

All statistical analyses were performed using SPSS 26.0. Descriptive statistics, including means and standard deviations, were calculated for each dimension and for the overall HIA score. To compare differences among the three parks, independent samples *t*-tests were conducted for each dimension and for the overall HIA score. Effect sizes were calculated using Cohen's d. The significance level was set at $p < 0.05$.

4. Results

4.1. HIA Score Results for Each Park

Based on the weighting system for elderly walking environments in park green spaces outlined in Section 3 of this article, the scoring table for elderly health factors in park walking environments, and the objective evaluation of park conditions, this study analyzes HIA evaluation scores for urban comprehensive park, historic–cultural park, and community leisure parks. The calculation formula is:

$$W_n = f(x) = \sum_{i=1}^{n} (T_n X_n)(4-1) \quad (6)$$

In this study, T_n represents the relative weight coefficient, indicating the specific score value for each evaluation indicator, while W_n corresponds to the comprehensive score of the indicator level. The research employs a 5-point scale as the scoring standard for the original questionnaire, where 5 indicates the highest level of satisfaction, and 1 represents the lowest level of satisfaction. To ensure consistency and comparability in data analysis,

this study converts the original 5-point scale scores to a percentage-based scoring system. The specific conversion formula is as follows:

$$f(x) = 20W_n(4-2) \tag{7}$$

4.1.1. Xingqing Palace Park HIA Score Results

As shown in Figure 7, Xingqing Palace Park, functioning as an urban comprehensive park, achieves the highest HIA score in the Comfort dimension at the Criteria Level, while the Accessibility dimension receives the lowest score.

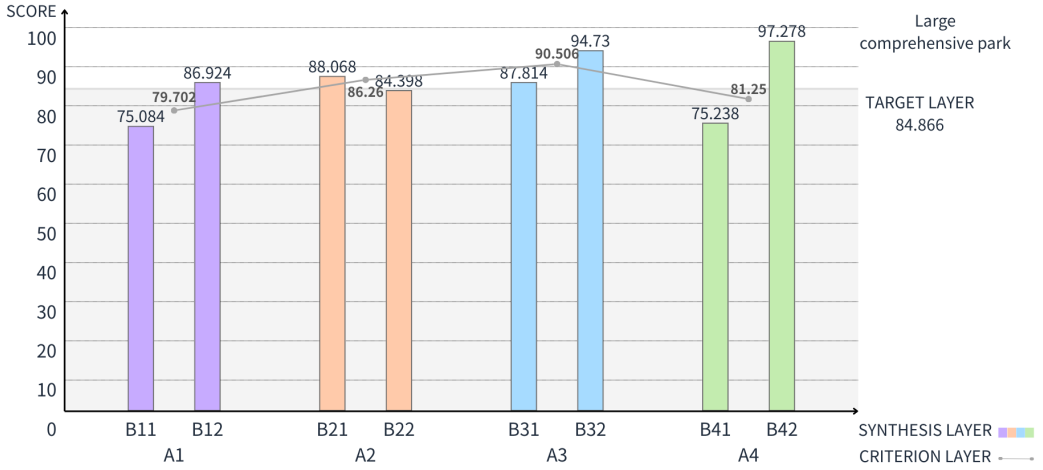


Figure 7. Schematic Diagram of Health Impact Assessment Scores for Xingqing Palace Park.

As for the eight indicators at the Comprehensive Level, all scores are relatively high, exceeding the passing threshold of 60 points. The score for the Visual Aesthetics indicator reaches a notable high of 97 points, while the scores for the External Accessibility and Social Interaction indicators are comparatively lower.

Furthermore, the formula for calculating the HIA score at the Objective Level is the sum of the HIA scores at the Criteria Level multiplied by their respective relative weights. Based on this calculation, Xingqing Palace Park achieves a final health quality score of 84.866 for its elderly walking environment.

The detailed calculation process is provided in Appendix C, Table A15.

4.1.2. Huancheng Park HIA Score Results

As shown in Figure 8, due to its linear morphology and location, the score for the Accessibility indicator in Huancheng Park is significantly higher than those of the other three indicators, reaching 75 points.

Due to insufficient consideration of age-friendly design for pedestrian environments, the Huancheng Park scored the lowest in safety metrics at just 63 points. Its scores for comfort and health-related interactivity were 64.672 points and 64.41 points.

Moreover, the eight comprehensive levels of the Huancheng Park scored relatively low, with both behavioral comfort and social interaction falling below 60 points. Safety of the site and facilities was average, scoring under 65 points, while visual aesthetics received a higher score.

Based on this calculation, Huancheng Park achieves a final health quality score of 66.03 for its elderly walking environment.

The detailed calculation process is provided in Appendix C, Table A16.

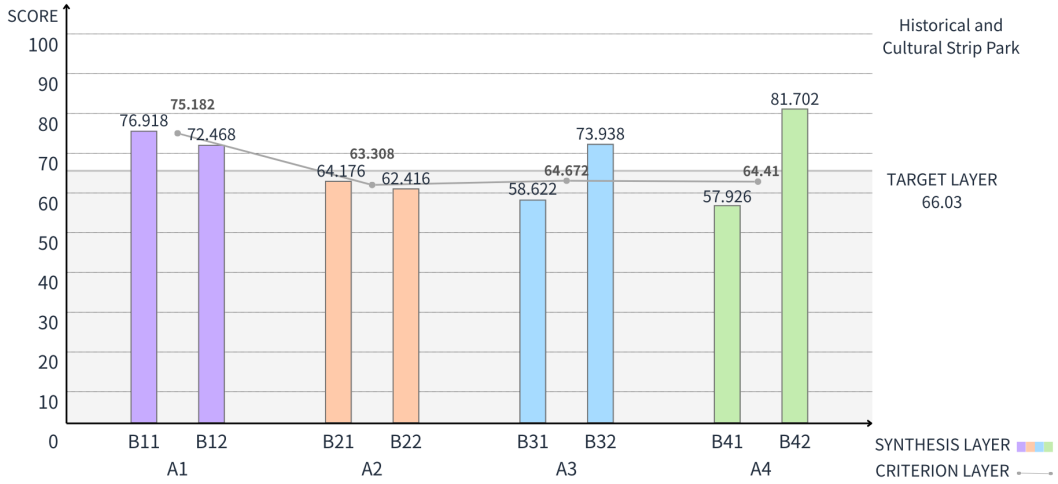


Figure 8. Schematic Diagram of Health Impact Assessment Scores for Huancheng Park.

4.1.3. Changle Park HIA Score Results

As shown in Figure 9, Changle Park, as a community leisure park, achieved a high comfort index score of 83 points.

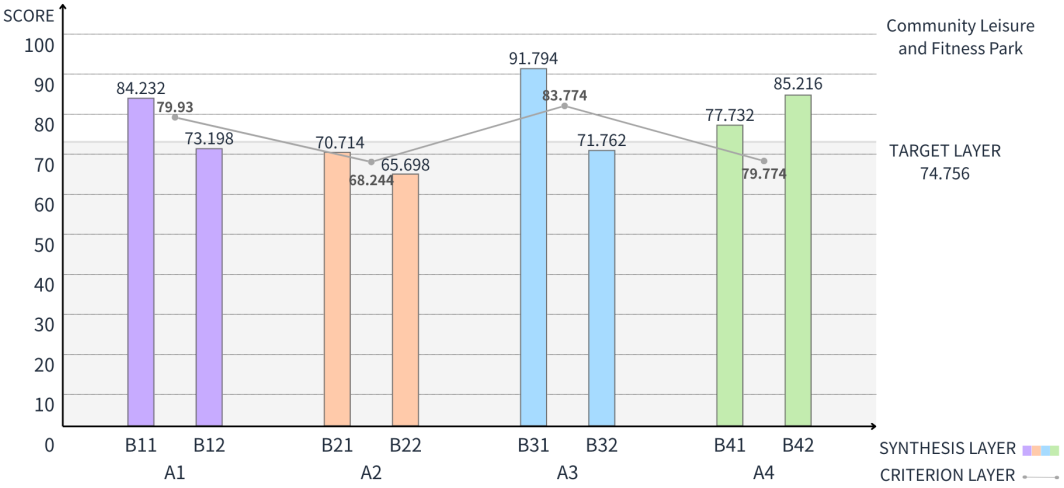


Figure 9. Schematic Diagram of Health Impact Assessment Scores for Changle Park.

The safety score is relatively low at 68 points. Due to insufficient consideration of age-friendly design for the walking environment at Changle Park, its accessibility and health-related interactivity scores are 79.93 points and 79.774 points, respectively.

Changle Park scored well across all eight comprehensive level indicators, with each exceeding 60 points. Among these, the behavioral comfort indicator achieved the highest score at 91 points, indicating that Changle Park offers a highly comfortablewalking environment.

The facility safety metric scored the lowest at just 65 points, indicating that Changle Park has shortcomings in areas such as accessibility facilities and security/emergency medical facilities.

Based on this calculation, Changle Park achieves a final health quality score of 74.756 for its elderly walking environment.

The detailed calculation process is provided in Appendix C, Table A17.

4.2. Comprehensive Analysis of Park HIA Score Comparisons

The radar chart and composite score (Figure 10) clearly reveal the significant differences in the health impacts of walking environments across the three park types for older

adults, along with their underlying logic. Based on the overall scores, Xingqing Palace Park performed the best with 84.87 points; Changle Park came in second with 74.76 points; while Huancheng Park scored the lowest at 66.03 points. This ranking is not coincidental, but rather the result of the synergistic effects of park type, spatial form, management standards, and age-friendly design.

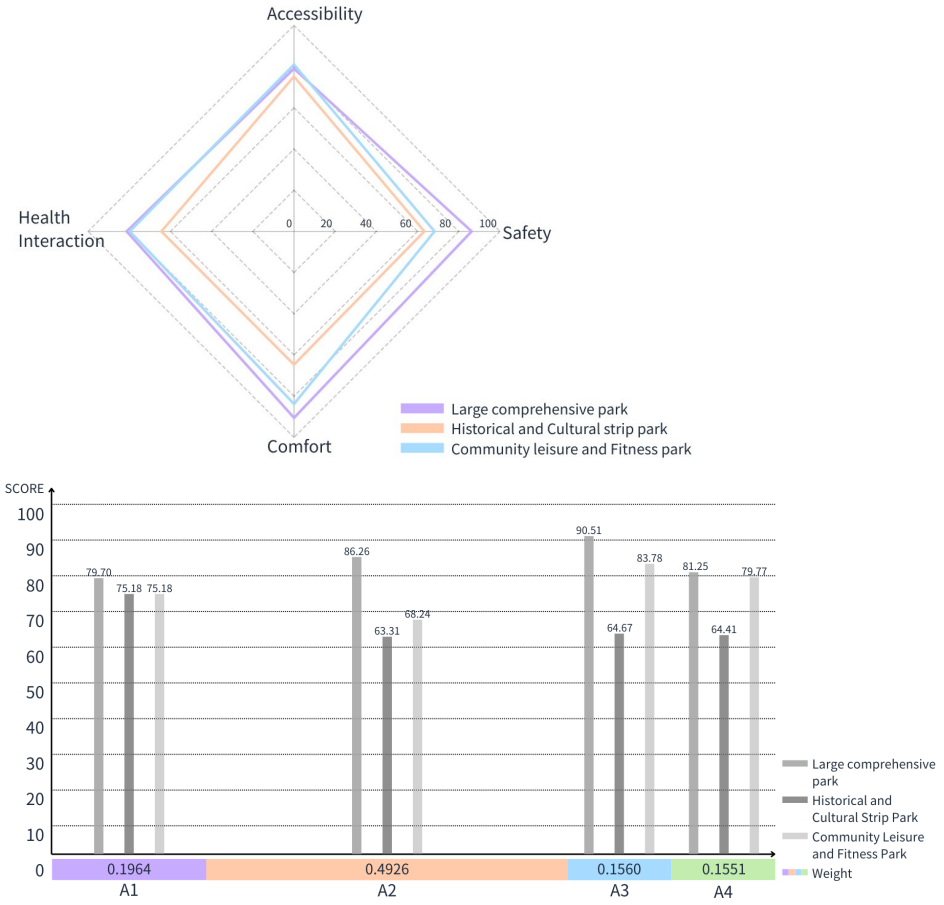


Figure 10. Comparative Analysis of HIA Scores for Three Parks.

All three parks scored above 75 points in accessibility, indicating that they generally meet basic requirements for spatial coverage and entrance accessibility. Among them, the Huancheng Park scored 76.92 points for external accessibility due to its linear layout, which provided a slight advantage. However, its internal accessibility score was relatively low at 72.47 points, primarily because of its monotonous path design and lack of convenient internal loops. Xingqing Palace Park's large scale results in significant distances between attractions, making internal accessibility a relative weakness. It scored 86.92 points—higher than the other two sample parks but lower than its own scores in other dimensions. Changle Park, as a community park, is most closely integrated with the surrounding residential areas and achieved the highest external accessibility score of 84.23 points.

In terms of safety, its weight of 0.4926 indicates that experts view safety as the most important dimension for evaluating park walking environments. Xingqing Palace Park demonstrates a clear advantage in this dimension, scoring 86.26 $\pm$ 13.0 points. Its systematic management ensures well-defined boundaries, comprehensive security facilities, and ample nighttime lighting, providing an excellent walking environment for the elderly. In contrast, Changle Park scored relatively low on safety, with a total score of 68.24 $\pm$ 13.0 points. Its weaknesses were particularly evident in the facility safety subcategory, where it scored only 65.70 points. Specific issues included outdated accessibility facilities, uneven ground

surfaces, and insufficient security camera coverage. Huancheng Park has the most serious safety issues, with a total score of 63.31 ± 13.0, and both its site safety and facility safety scores are lower, at 64.18 and 62.42, respectively. Field research confirmed the park's severe lack of nighttime lighting, lack of emergency aid, and mixing of people and vehicles in some sections, all of which combine to create barriers to use for seniors.

Commodity dimensions significantly influence park usage experiences and senior engagement. Changle Park demonstrates exceptional comfort, scoring 83.77 ± 12.0 points—particularly excelling in behavioral comfort with a high score of 91.79. This achievement stems from the park's diverse activity spaces, abundant fitness facilities, and vibrant social atmosphere, all of which effectively promote daily activities among older adults. Xingqing Palace Park achieved the highest comfort score of 90.51 ± 12.0 points, reflecting its comprehensive strengths in spatial scale, greenery and shade coverage, and environmental hygiene. In contrast, Huancheng Park scored only 64.67 ± 12.0 points for comfort. Its linear layout struggles to create comfortable areas for lingering and activities. Combined with insufficient seating and other resting facilities, along with limited shade during summer, this reduces seniors' willingness to stay and shortens their activity duration.

Health-related interactivity directly impacts older adults' social engagement and mental health issues [8]. Xingqing Palace Park, with its beautiful scenery, achieved a visual aesthetics score of 97.28, providing an excellent aesthetic experience and tranquil atmosphere. Changle Park scored higher in social interaction at 77.73 ± 11.0 points, reflecting its role as a community space fostering neighborly connections. Huancheng Park performed weakly in this dimension with a total score of only 64.41 ± 11.0 points. Its monotonous linear landscape and limited interactive facilities constrained the richness of recreational activities and social engagement.

The assessment revealed significant differences in age-friendly performance among the three park types. Safety carried the highest weight (0.49) in the evaluation system, indicating that experts consider it the most important dimension for older adults. Independent samples *t*-tests (Table 7) further indicated that the urban comprehensive park performed significantly better in safety and comfort than both the historic–cultural park and the community leisure park, with a *p*-value of less than 0.001. Although the historic–cultural park demonstrated good external accessibility, its scores for safety and comfort were significantly lower than those of the other two park types, also at a *p*-value of less than 0.001. This finding suggests that high accessibility does not necessarily equate to effective health-promoting functions.

Table 7. Comparison of HIA dimension means across the three parks, based on independent samples *t*-tests.

Comparison Group (Park A vs. Park B)	Comparison Dimension	Mean (M_1, M_2)	Mean Difference (MD)	SD	Standard Error (SE)	t-Value	*p*-Value
Xingqing Palace park vs. Huancheng park	Accessibility (A1)	3.985, 3.759	0.226	0.5	0.051	4.429	<0.0001
	Safety (A2)	4.313, 3.165	1.148	0.65	0.067	17.194	<0.0001
	Comfort (A3)	4.525, 3.234	1.291	0.6	0.062	20.857	<0.0001
	Health-related interactivity (A4)	4.063, 3.221	0.842	0.55	0.057	14.789	<0.0001
	Total HIA score	84.87, 66.03	18.84	8	0.82	22.976	<0.0001
Xingqing Palace park vs. Changle park	Accessibility (A1)	3.985, 3.996	−0.011	0.5	0.051	−0.215	0.830
	Safety (A2)	4.313, 3.412	0.901	0.65	0.067	13.493	<0.0001
	Comfort (A3)	4.525, 4.188	0.337	0.6	0.062	5.444	<0.0001
	Health-related interactivity (A4)	4.063, 3.989	0.074	0.55	0.057	1.303	0.193
	Total HIA score	84.87, 74.76	10.11	8	0.82	12.329	<0.0001

Table 7. *Cont.*

Comparison Group (Park A vs. Park B)	Comparison Dimension	Mean (M_1, M_2)	Mean Difference (MD)	SD	Standard Error (SE)	t-Value	*p*-Value
Huancheng park vs. Changle park	Accessibility (A1)	3.759, 3.996	−0.237	0.5	0.052	−4.563	<0.0001
	Safety (A2)	3.165, 3.412	−0.247	0.65	0.067	−3.699	0.0002
	Comfort (A3)	3.234, 4.188	−0.954	0.6	0.062	−15.403	<0.0001
	Health-related interactivity (A4)	3.221, 3.989	−0.768	0.55	0.057	−13.486	<0.0001
	Total HIA score	66.03, 74.76	−8.73	8	0.82	−10.645	<0.0001

In this study, a significance analysis was conducted on the values at different levels of the three sample parks, and the results are shown in Figure 11.

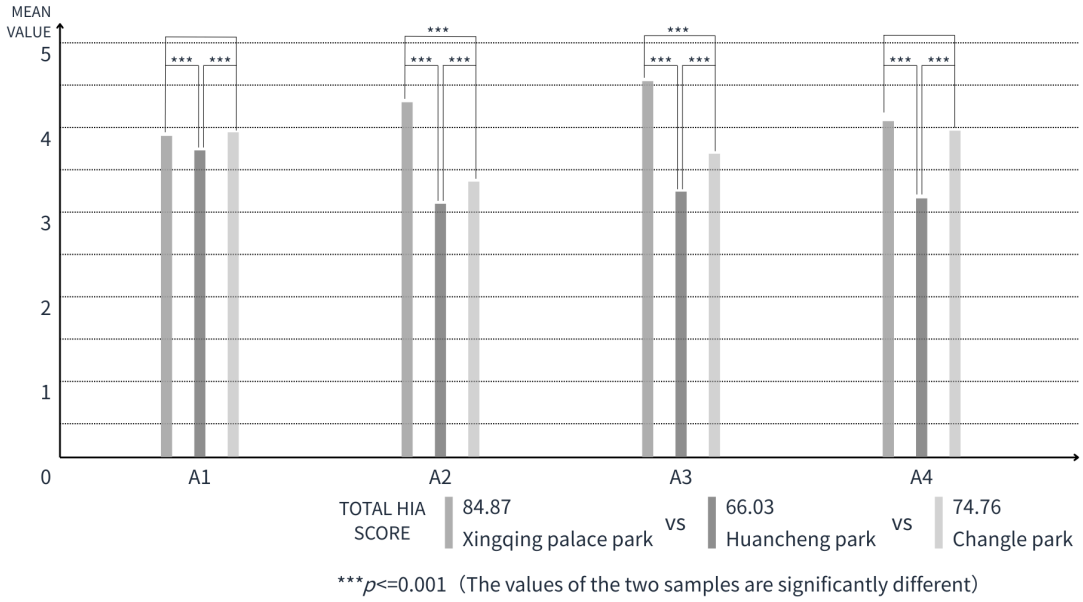


Figure 11. Comparison of HIA Dimension Means in Three Types of Sample Parks.

Comprehensive analysis indicates that the primary challenge facing urban park green spaces has shifted from ensuring sufficient quantity to optimizing quality and service effectiveness. The case of the Ring Park serves as a stark warning: despite its excellent external accessibility due to its layout, its actual utility as a health-promoting space is significantly diminished by dual deficiencies in safety and comfort. This demonstrates that spatial advantages do not automatically translate to efficient services, nor does high route accessibility equate to rich park content. For the elderly, safety is the primary determinant of their willingness to use parks, while comfort and health-promoting interactions directly influence usage frequency, duration, and the health benefits gained.

5. Discussion

5.1. HIA System for Walking Environments for Seniors in Parks and Green Spaces

As key public spaces that support the physical and mental health of older adults, the age-appropriate quality of parkland is directly related to urban health equity. However, much of the existing research focuses on single-dimensional or broad landscape evaluations and lacks systematic diagnostic tools that address the complex health needs of older adults. Therefore, this study has established a park walking environment HIA system that integrates four dimensions: accessibility, safety, comfort, and health-related interactivity.

The core innovations of the system are: first, it realizes the transformation from needs to space; the framework is based on Maslow's theory of needs, and transforms the multi-level needs of the elderly, ranging from safety and shelter to social participation, into specific and quantifiable spatial indicators; second, through the establishment of quantifiable spatial indicators, it can accurately locate the core contradictions of different parks in the area of aging, thus promoting the formulation of targeted strategies.

The tool has both a solid theoretical foundation and strong operationalization. It provides a reliable basis for the precise improvement of environmental health space.

5.2. Precise Optimization Strategy Based on Multi-Type Comparison and Four-Dimensional Diagnosis

Three types of typical parks, large comprehensive parks, historic–cultural parks, and community leisure parks, were selected for comparison in this study. The research found that the type of park directly affects its spatial form, functional layout, and management style, which in turn shapes its respective strengths and weaknesses. Based on the systematic assessment of the four dimensions, we propose targeted optimizations and recommendations that can be used for reference (Table 8):

Table 8. Focus of optimization strategy for three types of parks based on four-dimensional diagnosis.

Park Type	Core Optimization Orientation	Accessibility (A1)	Safety (A2)	Comfort (A3)	Health-Related Interactivity (A4)
Large comprehensive parks	Efficiency Improvement and Quality Improvement	Optimize internal guides and external connections to improve usage efficiency.	Maintain a systematic safety advantage and do regular maintenance.	Improvement of microclimate and open space layout.	Focused Enhancement: Increasing the number of activity spaces and cultural facilities for all ages
Historic–cultural parks	Enhanced security and patching features	Ensure easy access to all entrances and road continuity	Key enhancements: additional smart security and full coverage accessibility in harmony with the landscape.	Incorporate diversified leisure facilities at the nodes.	Installation of cultural interpretation and interactive facilities in conjunction with heritage.
Community leisure parks	Maintaining vitality and security	Maintain good pedestrian accessibility to neighborhoods.	Focus on enhancement: Establishment of a high-frequency inspection and maintenance system and timely replacement of old equipment.	Maintain and optimize the event space and shade environment.	Encourage community activities and optimize the spatial layout.

Integrated urban parks should focus on improving their effectiveness and setting quality benchmarks. Specifically, their systemic strengths in safety management and facility maintenance need to be maintained. At the same time, the focus is on enhancing interactive features, such as adding social spaces and cultural activity points that encourage communication among different age groups. In addition, the guidance signs and transportation facilities within the park should also be improved to address the inconvenience caused by the large size of the park in terms of internal movement.

The transformation of historic–cultural parks focuses on making up for security loopholes and supplementing functional facilities. First of all, it is necessary to systematically solve the core problem of potential safety hazards, adopt intelligent lighting and safety monitoring technologies in line with historical features, and ensure the smooth flow of barrier-free passages throughout the process. At the same time, at key locations in the park, rest facilities should be cleverly integrated to enhance the comfort of these areas. The core strategy of community leisure parks is to maintain vitality and ensure safety. Such parks should continue to give full play to their own advantages, improve comfort, provide rich activity venues, and at the same time promote healthy interaction and maintain the vitality of community exchanges. In addition, it is necessary to establish a refined management and maintenance mechanism, regularly overhaul and update old fitness equipment, and provide barrier-free facilities.

5.3. Research Limitations and Future Prospects

In this study, a multidimensional HIA model was developed using hierarchical analysis, questionnaires, and field surveys. However, there are some limitations in this study. First, as a cross-sectional study, it is difficult to determine the causal relationship between environmental characteristics and health behaviors, based mainly on subjective perceptions and static environmental data.

In interpreting the results of this study, it is important to place them in the context of its cross-sectional design. The data presented reflect an association, rather than a causal relationship, between park environment characteristics and health-related perceptions of older adults at a particular point in time. While the HIA framework provides a systematic approach to assessing potential health impacts, the cross-sectional nature of this study meant that we could not determine whether the observed environmental features directly led to changes in health outcomes or whether there were other unmeasured factors (e.g., personal health status, socioeconomic background, personal preferences) that could influence park use patterns and health perceptions. Therefore, the relationships identified in this study should be viewed as correlational rather than causal. For example, the finding that safety had the highest weight (0.49) in the HIA system suggests that older adults perceive safety as the most important dimension in the park walking environment; however, this does not necessarily mean that improved safety features will directly lead to better health outcomes. It is possible that older adults who are otherwise in better physical condition or more active may have different perceptions of safety, or that those parks with better safety features attract older adults with specific socioeconomic characteristics. Future longitudinal studies or quasi-experimental designs are needed to determine the causal relationship between environmental improvements in parks and health outcomes.

Second, the psychometric validation of the assessment tools is still not fully developed. Although this study constructed an indicator system based on HIA theory and expert consultation, and determined the weights of each indicator through the Analytic Hierarchy Process (AHP), it did not conduct a complete psychometric test. Specifically, although we have tested the internal consistency reliability of the tool through the clonal Bach coefficient (total scale $\alpha = 0.92$, each dimension α is between 0.78–0.88), indicating that the tool has good internal consistency, but Confirmatory factor analysis was not performed to confirm whether the preset four-dimensional structure (accessibility, safety, comfort, health interactivity) fits well with the data, nor was the test–retest reliability of the tool evaluated to test its cross-time.

Third, the weighting system of the HIA remains somewhat subjective, despite the fact that it was subjected to expert consultation and consistency tests. It should be noted that the expert panel did include local older adult residents who regularly used the study

parks, which was intended to ensure that the assessment framework reflected the genuine experiences and needs of end-users. However, even with the inclusion of older representatives, the depth of their participation in the weight determination process remained limited. This limitation is discussed from two perspectives: ① the complexity of the AHP pairwise comparison process may have posed operational difficulties for some older adults, limiting their direct involvement in the weight assignment task; ② the views of a small number of older representatives cannot fully capture the heterogeneous needs of the entire older adult population, as older adults with different ages, health conditions, and activity preferences may have divergent judgments on the importance of various environmental factors. Therefore, while the current weighting system achieved consensus at the expert level, it remains essentially an "expert proxy judgment" rather than a direct quantification based on the preferences of a large sample of older adults. The weighting system could be further calibrated in the future by collecting data on the preferences of a large number of older adults using more accessible methods (such as simplified AHP, ranking methods, or discrete choice experiments).

Fourth, there is a potential selection bias in the survey content. The questionnaire of this study is limited to the elderly who are active in the park, and does not include those who do not often go to the park or are not elderly. There may be systematic differences in health status, mobility, needs and perceptions of the environment between the two groups of people. Therefore, the results of this study mainly reflect the perspective of "park users" and may not be generalized to the entire elderly population. Future research can include more elderly people who do not use parks frequently through community recruitment and other methods to reduce selection bias.

Fifth, we did not collect more detailed indicators on park use, such as the number of visits per week or the length of each visit, which limited our ability to analyze the relationship between different patterns of use and perceived health. As a result, this study could not rule out the possibility that there may be underlying systematic differences between age groups or exercise frequency, nor could it distinguish between high and low frequency users, or between first-time visitors and regulars in terms of their evaluations. Therefore, these findings primarily reflect the overall extent of the health impacts of the three parks on the walking environment for older adults, and do not explore differences between different groups of older adults.

Sixth, the regional specificity of the study limits the universal applicability of the conclusions. All three sample parks are located in Beilin District, Xi'an, a high-density old city with a specific historical background, population density and urban form. Parks in different cities and regions may have significant differences in their surrounding environment, user composition and management models. Therefore, the applicability of the assessment tool constructed in this study and its diagnoses should be carefully validated when applied in other cities or regions.

What is more, the seasonal constraints of data collection and a lack of objective indicators. All field surveys and questionnaire distribution for this study were completed in spring (March to May), failing to cover park use in other seasons, such as summer and winter. In particular, indicators such as "summer shade" in the "comfort" dimension are only evaluated based on the perception of spring, which may deviate from the actual experience of summer. In addition, this study is mainly based on the subjective perception of the elderly, and cannot be verified in combination with objective health indicators (such as actual visit frequency, physical activity level, blood pressure, heart rate, etc.). Future research should consider data collection across seasons and integrate objective health surveillance methods to obtain more comprehensive and accurate assessment results.

Finally, future research could use objective and dynamic data, such as GPS trajectories and physical activity monitoring, to track real behavioral patterns of older adults in parks. At the same time, a longitudinal study design was incorporated to observe the changes in health behaviors and the benefits of older adults before and after age-appropriate park improvements over time. On this basis, a dynamic health impact prediction and assessment model was constructed to upgrade the static evaluation framework of this study into a tool with prediction and simulation functions for assessing the changes in health benefits brought about by different interventions. In addition, the refined governance framework can be extended to more types of urban green spaces to promote the establishment of more systematic and precise inclusive urban green spaces.

6. Conclusions

This study developed and applied a health-oriented assessment tool for evaluating age-friendly walking environments in parks. The tool incorporates four core dimensions: accessibility, safety, comfort, and health-promoting interactivity. We employed it in an empirical evaluation of three representative park types in Beilin District, Xi'an: the urban comprehensive park known as Xingqing Palace Park, the historic–cultural park known as Huancheng Park, and the community leisure park known as Changle Park.

The evaluation revealed significant differences in age-friendly performance across the three park types. Safety received the highest weight (0.49), indicating that experts perceived it as the most critical dimension for older adults' health perception. Statistical analysis showed that the comprehensive park performed significantly better in safety and comfort than both the historic–cultural park and the community leisure park ($p < 0.001$). Although the historic–cultural park demonstrated good accessibility, its safety and comfort scores were significantly lower than those of the other two park types ($p < 0.001$).

The primary contribution of this study lies in constructing and validating a structured assessment framework for age-friendliness. This framework provides an empirical basis for identifying specific deficiencies in park walking environments and for developing targeted optimization strategies. Our findings also show that park typology—namely urban comprehensive parks, historic–cultural parks, and community leisure parks—presents distinct age-friendly characteristics and challenges due to inherent variations in their historical functions, spatial layouts, and management approaches. Consequently, a standardized renovation approach is unlikely to be effective. Instead, tailored strategies that consider park typology are needed (Figure 10).

Future age-friendly urban planning should shift from merely pursuing quantitative green space targets to genuinely enhancing the health benefits derived from such spaces, promoting evidence-based interventions. Subsequent research could collect longitudinal data and employ more robust statistical models to further verify the applicability and explanatory power of this assessment tool across diverse urban contexts.

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Abbreviations

The following abbreviations are used in this manuscript:

HIA	Health Impact Assessment
AHP	Analytic Hierarchy Process
WHO	the World Health Organization
YAAHP	Yet Another AHP
CR	Consistency Ratio
CI	Consistency Index
RI	Random Consistency
DHF	Design for Health
2SFCA	two-step floating catchment area

Appendix A

HIA System Expert Consultation Form

Based on prior literature research, it has been found that urban green spaces are closely related to physical activity among older adults. Optimizing the green spaces themselves and their surrounding built environments can actively leverage the guiding role of urban green spaces in promoting older adults' usage and activities, thereby enhancing their physical health. Therefore, this paper establishes an environmental health impact evaluation system for senior walking trails in park green spaces.

Given your extensive professional expertise in this field, your assistance and guidance are urgently needed for this research. Your insights are of paramount importance to us. We sincerely hope you can take the time to complete this questionnaire amidst your busy schedule. We deeply apologize for any inconvenience this may cause and extend our most sincere gratitude.

I. Environmental Health Impact Assessment Factors for Senior Walking Trails in Park Green Spaces (Table A1).

Table A1. Environmental Health Impact Assessment Factors for Senior Walking Trails in Park Green Spaces.

Criterion Layer	Comprehensive Layer	Specific Health Impact Assessment Factor Layer
Accessibility A1	B11 External Accessibility	C111 Walking travel time is not long C112 Entrance is prominent and convenient
	B12 Internal Accessibility	C121 Internal park pathways are unobstructed C122 Visual permeability of spaces/sites is good
Safety A2	B21 Site Safety	C211 Site has clear boundaries to prevent vehicle passage C212 Site is free from noisy traffic sounds C213 Vegetation branches are trimmed to avoid causing injury C214 Avoid planting greenery with strong, irritating odors C215 Night lighting system is adequate
	B22 Facility Safety	C221 Structures and furnishings are sturdy, without sharp edges, damage, or other safety hazards C222 Barrier-free facilities are well-equipped C223 Park signage system is clear C224 Security and first-aid facilities are well-equipped

Table A1. *Cont.*

Criterion Layer	Comprehensive Layer	Specific Health Impact Assessment Factor Layer
Comfort A3	B31 Behavioral Comfort	C311 Spatial scale meets the activity needs of the elderly C312 Walking path width is adequate C313 Sufficient resting facilities
	B32 Perceptual Comfort	C321 Good ventilation and lighting conditions inside the park C322 Adequate shade in summer C323 Clean and well-maintained paths
Health Interaction A4	B41 Social Interaction	C411 Rich recreational activities C412 Clear distinction between rest areas and activity areas C413 Sufficient recreational and fitness facilities C414 Co-located with children's facilities
	B42 Visual Aesthetics	C421 Diverse plant configuration C422 Surrounding architectural landscape and structures have aesthetic design

II. Questionnaire Completion and Selection Methods

Please carefully consider the relative importance of each factor. For example, if you rank factors X, Y, Z, pairwise comparisons should yield X $\geq$ Y, Y $\geq$ Z, X $\geq$ Z. Should Z $\geq$ X occur, this creates a logical contradiction requiring reassessment and correction. Otherwise, completed questionnaires may introduce self-contradictions, compromising survey accuracy. Thank you!

III. Evaluation Factor Weight Assignment

Comparative Analysis of Relative Importance of Standard Layer Evaluation Factors: Comparative Factors: Accessibility; safety; comfort; health-related interactivity.

1. Priority Ranking: ( ) $\geq$ ( ) $\geq$ ( ) $\geq$ ( ).
2. Based on the above ranking of importance, compare the relative significance of each pair of factors.

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
Weight value	5/1	4/1	3/1	2/1	1/1	1/2	1/3	1/4	1/5	Weight value
Accessibility (1)										Safety (2) Comfort (3) health-related interactivity (4)
Safety (2)										Comfort (3) health-related interactivity (4)
Comfort (3)										health-related interactivity (4)

Comparison Factors: External accessibility; internal accessibility.

1. Priority Ranking: ( ) $\geq$ ( ).
2. Based on the above ranking of importance, compare the relative significance of each pair of factors.

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
Weight value	5/1	4/1	3/1	2/1	1/1	1/2	1/3	1/4	1/5	Weight value
External Accessibility (1)										Internal Accessibility (2)

Comparative factors: Short walking time required; prominent and convenient entrance to the venue.

1. Priority Ranking: ( ) ≥ ( ).
2. Based on the above ranking of importance, compare the relative significance of each pair of factors.

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
Weight value Short walking time required (1)	5/1	4/1	3/1	2/1	1/1	1/2	1/3	1/4	1/5	Weight value Prominent and convenient entrance to the venue (2).

Comparative Factors: Park pathways are well-maintained; spatial sightlines are unobstructed.

1. Priority Ranking: ( ) ≥ ( ).
2. Based on the above ranking of importance, compare the relative significance of each pair of factors.

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
Weight value Park pathways are well-maintained (1)	5/1	4/1	3/1	2/1	1/1	1/2	1/3	1/4	1/5	Weight value spatial sightlines are unobstructed. (2)

Comparative Factors: Site safety; facility safety.

1. Priority Ranking: ( ) ≥ ( ).
2. Based on the above ranking of importance, compare the relative significance of each pair of factors.

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
Weight value Site Safety (1)	5/1	4/1	3/1	2/1	1/1	1/2	1/3	1/4	1/5	Weight value Facility Safety (2)

Comparative Factors: The site has defined boundaries to prevent vehicle access; the area is free from disruptive traffic noise; branches of greenery are regularly trimmed to prevent injury; plants with pungent odors are avoided; and the nighttime lighting system is well-maintained.

1. Priority Ranking: ( ) ≥ ( ) ≥ ( ) ≥ ( ) ≥ ( ).
2. Based on the above ranking of importance, compare the relative significance of each pair of factors.

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
Weight value	5/1	4/1	3/1	2/1	1/1	1/2	1/3	1/4	1/5	Weight value

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
The site has defined boundaries to prevent vehicle access (1)										the area is free from disruptive traffic noise (2) branches of greenery are regularly trimmed to prevent injury (3) plants with pungent odors are avoided (4) the nighttime lighting system is well-maintained (5)
the area is free from disruptive traffic noise (2)										branches of greenery are regularly trimmed to prevent injury (3) plants with pungent odors are avoided (4) the nighttime lighting system is well-maintained (5)
branches of greenery are regularly trimmed to prevent injury (3)										plants with pungent odors are avoided (4) the nighttime lighting system is well-maintained (5)
plants with pungent odors are avoided (4)										the nighttime lighting system is well-maintained (5)

Comparison Factors: Compact design, sturdy facilities with no sharp edges or damage posing safety hazards; comprehensive accessibility features; clear park signage system; well-equipped security and first-aid facilities.

1. Priority Ranking: ( ) ≥ ( ) ≥ ( ) ≥ ( ).
2. Based on the above ranking of importance, compare the relative significance of each pair of factors.

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
Weight value	5/1	4/1	3/1	2/1	1/1	1/2	1/3	1/4	1/5	Weight value
Compact design, sturdy facilities with no sharp edges or damage posing safety hazards (1)										comprehensive accessibility features (2) clear park signage system (3) well-equipped security and first-aid facilities (4)
comprehensive accessibility features (2)										clear park signage system (3) well-equipped security and first-aid facilities (4)
clear park signage system (3)										well-equipped security and first-aid facilities (4)

Comparative factors: Behavioral comfort; perceived comfort.

1. Priority Ranking: ( ) ≥ ( ).
2. Based on the above ranking of importance, compare the relative significance of each pair of factors.

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
Weight value Behavioral comfort (1)	5/1	4/1	3/1	2/1	1/1	1/2	1/3	1/4	1/5	Weight value Perceived comfort (2)

Comparative Factors: Spatial dimensions that accommodate the activity needs of older adults; ample width of walkways; sufficient recreational facilities.

1. Priority Ranking: ( ) ≥ ( ) ≥ ( ).
2. Based on the above ranking of importance, compare the relative significance of each pair of factors.

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
Weight value	5/1	4/1	3/1	2/1	1/1	1/2	1/3	1/4	1/5	Weight value
Spatial dimensions that accommodate the activity needs of older adults (1)										ample width of walkways (2) sufficient recreational facilities (3)
ample width of walkways (2)										sufficient recreational facilities (3)

Comparative Factors: Good ventilation and lighting conditions within the park; provides shade during summer; clean pathways and good sanitation.

1. Priority Ranking: ( ) ≥ ( ) ≥ ( ).
2. Based on the above ranking of importance, compare the relative significance of each pair of factors.

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
Weight value	5/1	4/1	3/1	2/1	1/1	1/2	1/3	1/4	1/5	Weight value
Good ventilation and lighting conditions within the park; Provides shade during summer; (1)										Provides shade during summer (2) Clean pathways and good sanitation; (3)
Provides shade during summer (2)										Clean pathways and good sanitation; (3)

Comparative Factors: social interaction; visual aesthetics.

1. Priority Ranking: ( ) ≥ ( ).
2. Based on the above ranking of importance, compare the relative significance of each pair of factors.

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
Weight value Social Interaction (1)	5/1	4/1	3/1	2/1	1/1	1/2	1/3	1/4	1/5	Weight value Visual Aesthetics (2)

Comparative factors: Abundant recreational activities; clear demarcation between rest areas and activity zones; sufficient recreational and fitness facilities; integrated with children's amenities.

1. Priority Ranking: ( ) ≥ ( ).
2. Based on the above ranking of importance, compare the relative significance of each pair of factors.

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
Weight value	5/1	4/1	3/1	2/1	1/1	1/2	1/3	1/4	1/5	Weight value

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
Abundant recreational activities (1)										clear demarcation between rest areas and activity zones (2) sufficient recreational and fitness facilities (3) integrated with children's amenities (4)
clear demarcation between rest areas and activity zones (2)										sufficient recreational and fitness facilities (3) integrated with children's amenities (4)
sufficient recreational and fitness facilities (3)										integrated with children's amenities (4)

Comparative Factors: Rich plantings; aesthetic design of surrounding architectural landscapes and structures.

1. Priority Ranking: ( ) ≥ ( ).
2. Based on the above ranking of importance, compare the relative significance of each pair of factors.

Evaluation Factor	Very Important	Important	Fairly Important	Slightly Important	Equal	Slightly Important	Fairly Important	Important	Very Important	Evaluation Factor
Weight value	5/1	4/1	3/1	2/1	1/1	1/2	1/3	1/4	1/5	Weight value
Rich plantings (1)										aesthetic design of surrounding architectural landscapes and structures (2).

Appendix B

Judgment Matrix and Consistency Test of the Expert Questionnaire

Table A2. Criteria Level CR = 0.0989.

Ai/Aj	A1 Accessibility	A2 Safety	A3 Comfort	A4 Health-Related Interactivity	Wi
A1 Accessibility	1.0000	0.1429	0.3333	3.0000	0.0883
A2 Safety	7.0000	1.0000	7.0000	9.0000	0.6904
A3 Comfort	3.0000	0.1429	1.0000	5.0000	0.1779
A4 Health-related Interactivity	0.3333	0.1111	0.2000	1.0000	0.0434

Table A3. A1 Accessibility CR = 0.0000.

Ai/Aj	B11 External Accessibility	B12 Internal Accessibility	Wi
B11 External Accessibility	1.0000	0.1429	0.1250
B12 Internal Accessibility	7.0000	1.0000	0.8750

Table A4. A2 Safety CR = 0.0000.

Ai/Aj	B21 Site Safety	B22 Facility Safety	Wi
B21 Site Safety	1.0000	1.0000	0.5000
B22 Facility Safety	1.0000	1.0000	0.5000

Table A5. A3 Comfort CR = 0.0000.

Ai/Aj	B31 Behavioral Comfort	B32 Perceptual Comfort	Wi
B31 Behavioral Comfort	1.0000	3.0000	0.7500
B32 Perceptual Comfort	0.3333	1.0000	0.2500

Table A6. A4 Health-related Interactivity CR = 0.0000.

Ai/Aj	B41 Social Interaction	B42 Visual Aesthetics	Wi
B41 Social Interaction	1	7	0.875
B42 Visual Aesthetics	0.1429	1	0.125

Table A7. B11 External Accessibility CR = 0.0000.

Ai/Aj	C111	C112	Wi
C111	1.0000	5.0000	0.8333
C112	0.2000	1.0000	0.1667

Table A8. B12 Internal Accessibility CR = 0.0000.

Ai/Aj	C111	C112	Wi
C111	1.0000	5.0000	0.8333
C112	0.2000	1.0000	0.1667

Table A9. B21 Site Safety CR = 0.0836.

Ai/Aj	C211	C212	C213	C214	C215	Wi
C211	1.0000	9.0000	7.0000	9.0000	3.0000	0.5126
C212	0.1111	1.0000	0.3333	1.0000	0.1111	0.0359
C213	1.1429	3.0000	1.0000	5.0000	0.1429	0.0906
C214	0.1111	1.0000	0.2000	1.0000	0.1111	0.0337
C215	0.3333	9.0000	7.0000	9.0000	1.0000	0.3272

Table A10. B22 Facility Safety CR = 0.0392.

Ai/Aj	C221	C222	C223	C224	Wi
C221	1.0000	1.0000	5.0000	5.0000	0.4239
C222	1.0000	1.0000	3.0000	7.0000	0.3911
C223	0.2000	0.3333	1.0000	3.0000	0.1262
C224	0.2000	0.1429	0.3333	1.0000	0.0588

Table A11. B31 Behavioral Comfort CR = 0.0279.

Ai/Aj	C311	C312	C313	Wi
C311	1.0000	3.0000	1.0000	0.4054
C312	0.3333	1.0000	0.2000	0.1140
C313	1.0000	5.0000	1.0000	0.4806

Table A12. B32 Perceptual Comfort CR = 0.0772.

Ai/Aj	C321	C322	C323	Wi
C321	1.0000	0.3333	0.1111	0.0658
C322	3.0000	1.0000	0.1429	0.1488
C323	9.0000	7.0000	1.0000	0.7854

Table A13. B41 Social Interaction CR = 0.0616.

Ai/Aj	C411	C412	C413	C414	Wi
C411	1.0000	9.0000	3.0000	7.0000	0.5831
C412	0.1111	1.0000	0.1429	0.3333	0.0425
C413	0.3333	7.0000	1.0000	5.0000	0.2895
C414	0.1429	3.0000	0.2000	1.0000	0.0849

Table A14. B42 Visual Aesthetics CR = 0.0000.

Ai/Aj	C421	C422	Wi
C421	1.0000	0.3333	0.2500
C422	3.0000	1.0000	0.7500

Appendix C

Detailed HIA Score Calculation Tables for the Three Parks

Table A15. Score Calculation Process for the Comprehensive and Criteria Layers of Xingqing Palace Park.

Criteria Level	Absolute Weight	Comprehensive Layer	Absolute Weight	Relative Weight	Indicator Layer	Absolute Weight	Relative Weight	Weighted Indicator Score	Comprehensive Layer Score	Weighted Layer Score	Criteria Level Score
A1	0.1964	B11	0.1198	0.6100	C111	0.0803	0.6703	2.3661	3.7542	2.2900	3.9851
					C112	0.0395	0.3297	1.3881			
		B12	0.0766	0.3900	C121	0.0502	0.6554	2.8573	4.3462	1.6951	
					C122	0.0264	0.3446	1.4889			
A2	0.4926	B21	0.2500	0.5075	C211	0.1033	0.4132	2.0288	4.4034	2.2348	4.3130
					C212	0.0293	0.1172	0.5277			
					C213	0.0276	0.1104	0.5277			
					C214	0.0177	0.0708	0.3413			
					C215	0.0722	0.2888	0.9559			
					C221	0.0788	0.3248	1.3187			
		B22	0.2426	0.4925	C222	0.0586	0.2415	0.8720	4.2199	2.0782	
					C223	0.0246	0.1014	0.4198			
					C224	0.0805	0.3318	1.6093			
A3	0.1560	B31	0.0939	0.6019	C311	0.0480	0.5112	2.4843	4.3907	2.6429	4.5253
					C312	0.0117	0.1246	0.5806			
					C313	0.0342	0.3642	1.3258			
		B32	0.0620	0.3974	C321	0.0212	0.3419	1.5968	4.7365	1.8825	
					C322	0.0086	0.1387	0.6727			
					C323	0.322	0.1594	2.4669			
A4	0.1551	B41	0.1128	0.7273	C411	0.0392	0.3475	1.4109	3.7619	2.7359	4.0625
					C412	0.0274	0.2429	0.9619			
					C413	0.0321	0.2846	0.9932			
					C414	0.0140	0.1241	0.3959			
		B42	0.0423	0.2727	C421	0.0243	0.5745	2.7862	4.8639	1.3265	
					C422	0.0179	0.4232	2.0778			

Table A16. Score Calculation Process for the Comprehensive and Criteria Layers of Huancheng Park.

Criteria Level	Absolute Weight	Comprehensive Layer	Absolute Weight	Relative Weight	Indicator Layer	Absolute Weight	Relative Weight	Weighted Indicator Score	Comprehensive Layer Score	Weighted Layer Score	Criteria Level Score
A1	0.1964	B11	0.1198	0.6100	C111	0.0803	0.6703	2.5337	3.8459	2.3459	3.7951
					C112	0.0395	0.3297	1.323			
		B12	0.0766	0.3900	C121	0.0502	0.6554	2.7066	3.6234	1.4132	
					C122	0.0264	0.3446	0.9168			
A2	0.4926	B21	0.2500	0.5075	C211	0.1033	0.4132	1.5660	3.2088	1.6285	3.1654
					C212	0.0293	0.1172	0.4442			
					C213	0.0276	0.1104	0.4703			
					C214	0.0177	0.0708	0.3384			
					C215	0.0722	0.2888	0.3899			
					C221	0.0788	0.3248	1.0264			
		B22	0.2426	0.4925	C222	0.0586	0.2415	0.3213	3.1208	1.5369	
					C223	0.0246	0.1014	0.3529			
					C224	0.0805	0.3318	1.4202			

Table A16. *Cont.*

Criteria Level	Absolute Weight	Comprehensive Layer	Absolute Weight	Relative Weight	Indicator Layer	Absolute Weight	Relative Weight	Weighted Indicator Score	Comprehensive Layer Score	Weighted Layer Score	Criteria Level Score
A3	0.1560	B31	0.0939	0.6019	C311	0.0480	0.5112	1.7022	2.9311	1.7643	3.2336
					C312	0.0117	0.1246	0.1981			
					C313	0.0342	0.3642	1.0307			
		B32	0.0620	0.3974	C321	0.0212	0.3419	1.2207	3.6969	1.4693	
					C322	0.0086	0.1387	0.6325			
					C323	0.0322	0.5194	1.8437			
A4	0.1551	B41	0.1128	0.7273	C411	0.0392	0.3475	1.1711	2.8963	2.1064	3.2205
					C412	0.0274	0.2429	0.7190			
					C413	0.0321	0.2846	0.7940			
					C414	0.0140	0.1241	0.2122			
		B42	0.0423	0.2727	C421	0.0243	0.5745	2.1428	4.0851	1.1141	
					C422	0.0179	0.4232	1.9423			

Table A17. Score Calculation Process for the Comprehensive and Criteria Layers of Changle Park.

Criteria Level	Absolute Weight	Comprehensive Layer	Absolute Weight	Relative Weight	Indicator Layer	Absolute Weight	Relative Weight	Weighted Indicator Score	Comprehensive Layer Score	Weighted Layer Score	Criteria Level Score
A1	0.1964	B11	0.1198	0.6100	C111	0.0803	0.6703	2.9224	4.2116	2.5690	3.9965
					C112	0.0395	0.3297	1.2892			
		B12	0.0766	0.3900	C121	0.0502	0.6554	2.3331	3.6599	1.4275	
					C122	0.0264	0.3446	1.3269			
A2	0.4926	B21	0.2500	0.5075	C211	0.1033	0.4132	1.6156	3.5357	1.7944	3.4122
					C212	0.0293	0.1172	0.4583			
					C213	0.0276	0.1104	0.4582			
					C214	0.0177	0.0708	0.3250			
					C215	0.0722	0.2888	0.6787			
		B22	0.2426	0.4925	C221	0.0788	0.3248	0.7406	3.2849	1.6178	
					C222	0.0586	0.2415	0.5870			
					C223	0.0246	0.1014	0.3945			
					C224	0.0805	0.3318	1.5629			
A3	0.1560	B31	0.0939	0.6019	C311	0.0480	0.5112	2.5252	4.5897	2.7626	4.1887
					C312	0.0117	0.1246	0.5894			
					C313	0.0342	0.3642	1.4751			
		B32	0.0620	0.3974	C321	0.0212	0.3419	1.4464	3.5881	1.4260	
					C322	0.0086	0.1387	0.5784			
					C323	0.0322	0.5194	1.5633			
A4	0.1551	B41	0.1128	0.7273	C411	0.0392	0.3475	1.5395	3.8866	2.8266	3.9887
					C412	0.0274	0.2429	0.9401			
					C413	0.0321	0.2846	0.8907			
					C414	0.0140	0.1241	0.5163			
		B42	0.0423	0.2727	C421	0.0243	0.5745	2.5047	4.2608	1.620	
					C422	0.0179	0.4232	1.7561			

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