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Sustainable Well-being of Rural Environment: Elderly-oriented Evaluation of Outdoor Public Space Design in Suburban Villages - A Case Study of Beijing

Fanzhuo Ding [1], Yuwei Zheng [3], Jingyuan Zhu [4] and Chaoyang Li [1,2] *

[1] Academy of Arts and Design, Tsinghua University, Beijing, China

[2] China Institute for Rural Studies, Tsinghua University, Beijing, China

[3] School of Art and Design, Beijing Forestry University, Beijing, China

[4] Graduate School of Design, Harvard University, Cambridge, USA

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Principal Author(s):
Fanzhuo Ding, Doctoral student, Research on Rural Environmental Design & Social Innovation Design for Rural Areas.
Chaoyang Li, professor, Research interest on Rural Environmental Design.

Correspondence email: *
licy505@163.com

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Abstract: As societal developments progress and perceptions shift, there is a discernible aging trend in the global population. This trend results in a growing number of elderly individuals left living alone, leading to the development of loneliness and isolation among older people, which has seriously affected their state of mind and body in their twilight years. In this study, Post-occupancy Evaluation (POE) was conducted to construct an evaluation index system based on the following standard layers: Accessibility, Security, Comfortableness, Identifiability, Convenience, Wellness and Aesthetics. The index system analyzes the suitability of elderly care in 15 villages in suburban areas of Beijing, China, and the key findings are threefold:

(1) It is essential to improve the site's defenses against particular climates according to the actual situation and enhance the comfort of the whole day and year. These are also factors that need to be considered in order to increase the motivation of older persons to use outdoor public spaces.

(2) The evaluation results have been further refined and classified, unveiling four predominant concerns: *Insufficient safety measures, Poor comfort, and Limited social interaction* are the main factors affecting the motivation of the elderly to participate in outdoor activities.

(3) After synthesizing the results of qualitative and quantitative analysis, the following conclusions were drawn: Recommendations to enhance these public spaces for the elderly in suburban villages emphasize: Reducing the safety hazards of the space, Improving the comfort of rest, relaxation, socializing, fitness, Avoiding the functional areas of motion and static influence each other, Paying attention to the healing function of the space to be effectively segregated.

In conclusion, it is hoped that the results of the evaluation will improve the motivation of older people to engage in outdoor activities and guide them to face aging with a positive attitude.

Keywords: Rural environment; Elderly-oriented Evaluation; Suburban villages; Outdoor Public Spaces Design

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Introduction

Outdoor public spaces play a crucial role in older adults' daily social interactions. They provide a venue for their outdoor activities and serve as important areas for rest, dialogue, relaxation, and physical well-being [1]. Therefore, enhancing these spaces in villages can improve their perceived utility, alleviate feelings of loneliness among elderly village residents, enhance the quality of their lives after retirement, and foster their interest in outdoor pursuits. This, in turn, can increase their metabolic rates and ensure their optimal physical health [2, 3]. Optimizing environments for the elderly requires careful consideration of the issues highlighted in their feedback and evaluations. Tailored improvements should directly address these specific concerns. Although efforts to study and assess environmental and spatial aspects related to aging have started, several challenges still exist:

A significant portion of research on aging and the environment focuses on primary urban centers, while rural suburban settings are glaringly overlooked [4]. Evaluations of environmental aging in suburban villages often adapt urban-centric approaches or directly translate from urban experiences, resulting in misaligned criteria for assessing these specific rural suburban contexts [5]. Prevailing research on environmental aging tends to prioritize the design of new spaces, neglecting the revamp and adaptation of existing infrastructures to cater to aging populations [6]. Subjective interpretations of the needs for aging environments largely drive current assessments of environmental aging, potentially leading to evaluations that lack objectivity and fail to adequately uncover and address core issues [7]. In recent years, there has been a growing social focus on evaluating the age-friendliness of public spaces. The main domains of evaluation include: (1) Developing age-friendly communities from the perspective of urban planning and design [8, 9, 10, 11]. (2) Enhancing age-friendliness in urban park public spaces [12, 13, 14, 15]. Chinese researchers have also started to recognize the practicality of this approach and are beginning to concentrate on constructing and assessing age-friendly environments.

Post-Occupancy Evaluation (POE) has reached a level of maturity and is now widely utilized for evaluating urban built environments, which is also referred to as the "building and the environment towards the inevitable steps in the process of sustainable development" [16]. POE offers two distinct advantages: (1) It combines qualitative descriptive research with objective quantitative data analytics. This fusion of subjective perceptions and objective assessments ensures the scientific robustness of the evaluation findings [17]. (2) The assessment framework of POE is comprehensive, taking into account various elements such as natural surroundings, infrastructural provisions, physical experiences, and socio-cultural contexts. This holistic approach minimizes potential biases and ensures a well-rounded evaluation outcome. However, a notable trend in both domestic and international studies is their predominant focus on urban areas, neglecting evaluations of infrastructural quality and villager satisfaction in suburban villages. This oversight bears particular significance in China's efforts for rural rejuvenation, emphasizing the need to shift our attention towards suburban villages and rural communities to ensure comprehensive assessments and substantial improvements.

Suburban villages, characterized by their blend of urban and rural attributes, are located on the outskirts of cities. These settlements, resembling towns and encompassing urban-like features [18], have the advantage of being in close proximity to the city and serving as a platform for urban integration [19]. However, the living environments, recreational amenities, and outdoor spaces in suburban villages have primarily focused on meeting basic needs. A significant shortcoming is the lack of consideration given to the needs of older people, leaving them unprepared to navigate the challenges of aging. Currently, research on suburban villages primarily focuses on macro-level investigations, including suburban town urbanization [20], shifts in social and demographic dynamics within urban and rural contexts [21], and the urban development functions of suburban villages [22].

In view of these circumstances, the assessment of outdoor public spaces in suburban villages incorporates two notable innovations. Firstly, the evaluation adopts diversified methods for elderly-oriented evaluation. Utilizing POE to establish a specific evaluation system for China's suburban villages represents a novel exploration aimed at achieving more objective and scientifically valid evaluation results. Secondly, it provides precise perspectives on rural public environmental governance. While most efforts in rural environment development tend to focus on infrastructure, aiming to meet the diverse needs of all age groups, this study is more relevant and socially valuable as it targets vulnerable groups in rural areas. The specialized concerns of the elderly demographic often receive insufficient emphasis. Through this evaluation, we aim to identify the needs and critical aspects related to the construction of outdoor public spaces for older people in China's suburban villages, and provide insights for similar projects in the future.

Therefore, this study represents a focused and in-depth advancement in the refinement of rural environmental governance strategies. Moreover, by incorporating the assessment of aging suitability through POE, this research can impartially provide a comprehensive understanding of the strengths and weaknesses inherent in suburban village environments. Consequently, it can actively propose carefully tailored optimization strategies aimed at improving the quality of life for aging populations living in villages. In this way, this study contributes to the sustainable development of rural environments, effectively addressing the multifaceted challenges posed by aging demographics in rural settings.

Taking into account the aforementioned concerns, this research aims to enhance the depth and relevance of studying the challenges posed by insufficient aging infrastructures and inaccuracies in aging updates, particularly in relation to suburban villages. The study specifically focuses on suburban villages in Beijing and emphasizes the evaluation of outdoor public spaces. To rigorously assess these spaces, the empirical approach of POE is employed.

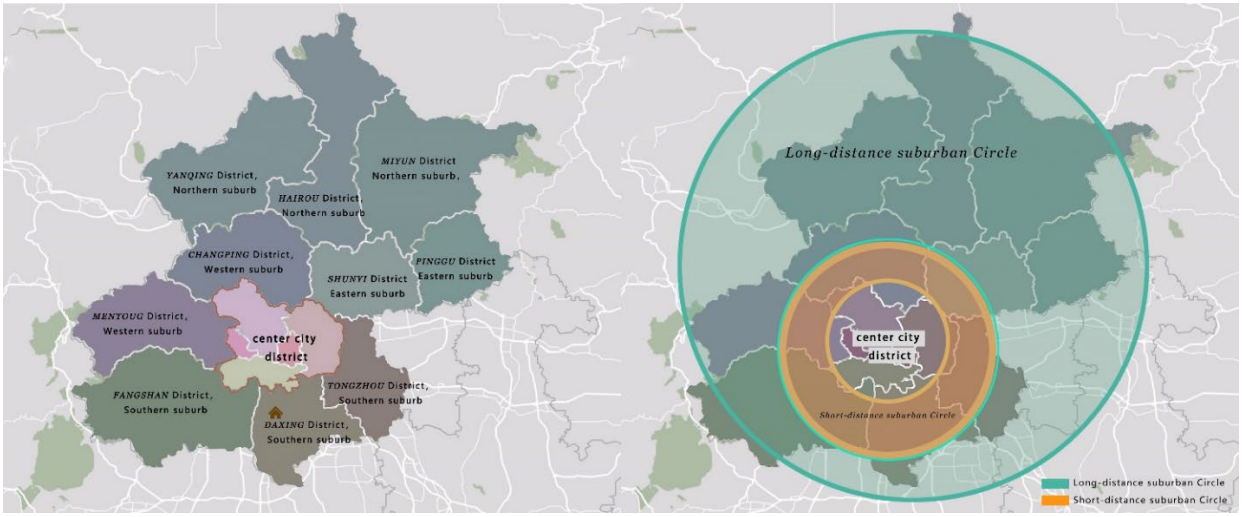


Figure 1. *Beijing Suburban Distribution and Concentric Layout (Drawn by the author)*

Overview of the Study Cases

Beijing, the capital of China, encompasses an expansive land area of 15,039 square kilometers, with approximately 91.3% of its expanse classified as suburban terrain [23]. The city's layout adheres to a concentric structure, revolving around the central urban core, and can be broadly segmented into three zones: "central city," "short-distance suburban," and "long-distance suburban" (**Figure 1**).

The "short-distance suburban circle," positioned at a distance of approximately 10-40 kilometers from the central city, assumes a pivotal role in facilitating large-scale industrial production, advanced technology development, and a spectrum of other functions. This region operates as a transitional nexus, bridging the urban and rural realms, marked by varying degrees of construction development, oscillating between urban and rural standards. Within this expansive domain, one encounters well-developed zones replete with robust infrastructure and a judiciously structured landscape, juxtaposed against less-developed sectors striving to synchronize with the pace of urbanization. It is worth noting that certain economically challenged region still await comprehensive urbanization initiatives to propel their development forward.

The "long-distance suburban circle" refers to the area located approximately 40 miles away from the central city of Beijing. Characterized by favorable natural conditions, picturesque landscapes, and a lesser impact from industrialization and urbanization, this region often serves as the urban populace's idyllic retreat – a veritable "backyard" for relaxation and rejuvenation. Given its distinct role in supporting the capital's development, this circle is entrusted with the crucial mission of preserving the ecological equilibrium. Certain areas even bear the designation of environmental conservation zones, resulting in a marked divergence in terms of modernization and construction levels when compared to the central urban areas [24, 25].

The development patterns of rural areas in the Short-distance and Long-distance suburban villages of Beijing exhibit differences, resulting in disparities in economic conditions, cultural levels, infrastructure, and consequently, divergent needs. Due to the efficient urbanization and high-quality construction requirements in Beijing, presently, rural communities in short-distance suburban villages are better equipped with outdoor environments and facilities for the older people, and the motivation of older people to engage in outdoor activities has experienced an increment, thus leading to a partial alleviation of their sense of isolation. However, the long-distance suburban villages affected by factors like distance and location, the built outdoor environment is inadequately designed to cater to the needs of older people [26]. Additionally, as urbanization in Beijing continues to progress, elderly individuals in the long-distance suburban villages gradually gain access to better urban living resources, leading to an increasing demand and concept for improved quality of life, fitness, health, and leisure activities. Consequently, the disparity between evolving mindset and reality often results in a stronger sense of loneliness among the older people in the far outskirts, pushing them to rely increasingly on conversations and gatherings with other elderly individuals in public spaces.

It's inescapable that both Short and Long-distance suburban villages encounter challenges in bridging the gap between physical aging and psychological solitude. They all yearn to live and retire in an environment suitable for aging. Therefore, when considering the shared needs of outdoor public spaces in suburban areas, it is essential to consider physiological, psychological, and social aspects for both groups.

Methodology

Methodology and Evaluation Process

The assessment described in this study incorporates the principles and methodologies of POE (Post-Occupancy Evaluation) to conduct a thorough evaluation of qualitative and quantitative indicators pertaining to the suitability of outdoor public spaces for older people in suburban villages of Beijing [27, 28]. The evaluation encompasses the following specific methods:

- Qualitative Analysis: The systematic collection and synthesis of information concerning the behaviors and usage patterns of older people within these spaces is accomplished through qualitative analysis. To achieve this objective, a combination of methodologies is employed, including behavioral observations, semi-structured interviews, and questionnaires. In addition, verbal satisfaction assessments are conducted to encourage older people to articulate their usage requirements and elicit relevant insights.
- Quantitative Analysis: The scientific Analytic Hierarchy Process (AHP) methodology forms the foundation of quantitative analysis [29, 30, 31]. This methodology allows us to capture the comparative judgments of experts, scholars, and researchers in related fields regarding the importance of evaluation factors. And the evaluation process as follow (**Figure 2**):

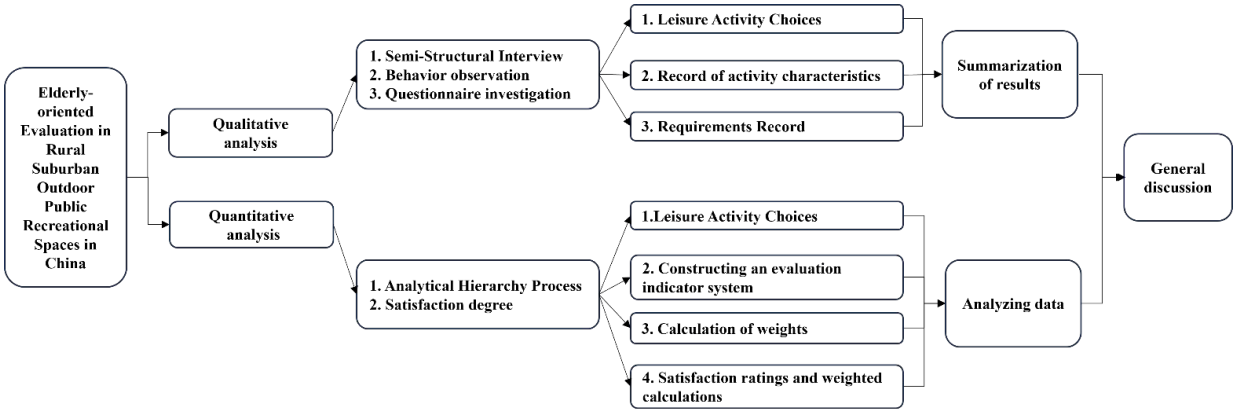


Figure 2. *Evaluation process (Drawn by the author)*

Qualitative Analysis Part of POE

The Qualitative Analysis part of POE utilized Semi-structured interviews and Behavioral observations.

Semi-structured Interviews

In order to target the acquisition of information from the semi-structured interviews, four broad categories of questions were created as follows:

- User Demographics: This segment focuses on gathering foundational information about the users, such as gender, age, residential proximity to the outdoor public space, etc.
- User Behavior Profile: This section explores users' behavioral patterns, including visit frequency, usage timeframes, intended purposes for use, duration of stay, etc.
- Subjective User Needs: Respondents are encouraged to express their subjective needs, highlighting any challenges they encounter during their usage of the space and offering proposals for potential improvements.
- Evaluation of Spatial Suitability for Aging: Respondents are presented with a range of indicators related to the space's suitability for aging individuals. Elderly residents in the village rate each indicator on a scale of 1 to 5, reflecting their assessment of the indicator's relevance and significance (Very satisfied: 5; Satisfied: 4; Average: 3; Dissatisfied: 2; Very Dissatisfied: 1).

Table 1. *Detailed Description of Data Sources (Drawn by the author)*

Data Type	Data Name	Data Source
Basic Spatial Data	Basic Overview	https://www.tianditu.gov.cn/
	Outdoor Public Space Functions Selection Data	Semi-structured Interviews, Behavioral Observations, Questionnaires
Target Audience-related data	Activity Characteristics and Usage Patterns Data of the Elderly	
	Subjective Needs and Opinions of the Elderly	Semi-structured Interviews, Questionnaires
	Evaluation Index Satisfaction Rating	

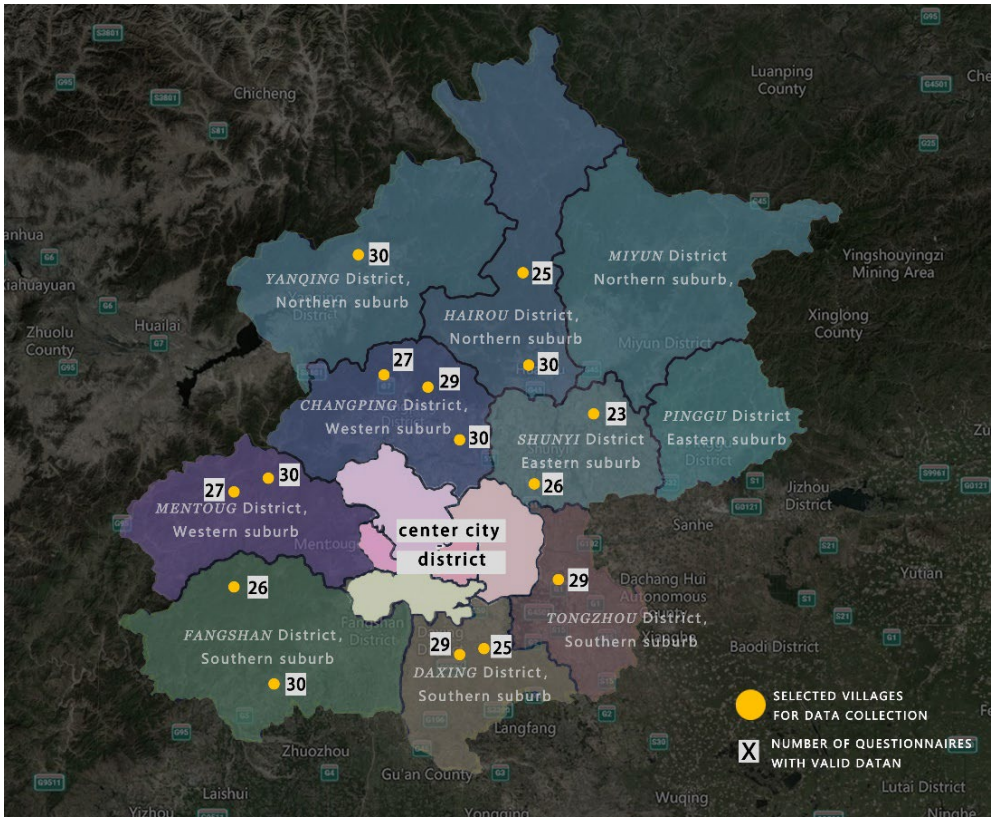


Figure 3. *Distribution of villages for data collection and number of valid questionnaires (Drawn by the author)*

Behavioral Observations

Behavioral observation focuses on determining the usage rate of each function of the public space by observing the behavior of the elderly. Therefore, the behavioral observation form was set up with six columns: *Village name* (To categorize data sources), *Season* (To determine seasonal characteristics), *Time* (To determine the time pattern of outdoor activities), *All Functions* (To determine what facilities are generally needed by the older people), *Behavioral activities of older people* (To determine the behavioral activity characteristics of the older people), *Leisure Activity Select* (To screen for "leisure activities" that can enhance the enthusiasm of elderly people for outdoor activities).

Data Sources and Collection

The evaluation targeted older people residing in rural villages employing a random sampling approach to select 15 villages in the suburban of Beijing for data collection (Half of long-distance and half of short-distance suburban). Data collection activities took place across all four seasons - spring, summer, fall, and winter - and encompassed visits to key gathering points for older people within these villages. These gathering areas included village squares, fitness activity areas, village entrances, and areas in front of private residences. The data collection process involved the observation and recording of various elements, including behavioral activities and usage patterns, subjective needs, opinions,

and preliminary satisfaction rating (**Table 1**); Additionally, with the invaluable assistance of the village committees, a total of 450 questionnaires were distributed to older people within the selected villages, and 416 valid questionnaires (The questionnaire was completed comprehensively, and there were no instances of perfunctory scoring, such as assigning the same score to all indicators.) were returned, with a validity rate of 92.4% (**Figure 3**).

Quantitative Analysis Part of POE

Constructing an Evaluation Indicator System

Utilizing the Analytic Hierarchy Process (AHP) methodology, we constructed the evaluation indicators. This process involved a thorough analysis of relevant literature sources [32, 33, 34, 35, 36] and enlisted the expertise of ten professionals to craft a comprehensive set of criteria. The standards governing this construction emphasized maintaining a balanced number of evaluation factors at each level, preventing redundancy or similarity among indicators within the same tier, and ensuring that factors across different levels did not contradict one another. Ultimately, the evaluation hierarchy comprised three distinct levels: the target level, the criteria layer (comprising 7 indicators), and the sub-criteria layer (comprising 21 elements), each thoughtfully designed to encompass multi-dimensional aspects.

The overarching goal is denoted as set X, with the set of evaluation indicators for the criteria layer delineated as follows: $X = (X_1, X_2, X_3, X_4, X_5)$

Further delineation establishes the set of evaluation indicators for the sub-criteria layer as follows: $X_1 = (Y_1, Y_2)$; $X_2 = (Y_3, Y_4, Y_5, Y_6)$; $X_3 = (Y_7, Y_8, Y_9)$; $X_4 = (Y_{10}, Y_{11}, Y_{12})$; $X_5 = (Y_{13}, Y_{14}, Y_{15})$; $X_6 = (Y_{16}, Y_{17}, Y_{18})$; $X_7 = (Y_{19}, Y_{20}, Y_{21})$;

The evaluation index system and evaluation criteria are established as follows (**Table 2**):

Table 2. *Evaluation Index Criteria at All Layers (Drawn by the author)*

Goal	Criteria Layer(X)	Sub-criteria Layer (Y)	Standard Interpretation of Evaluation Criteria
Elderly-oriented Evaluation of Outdoor Public Spaces Design in Suburban Villages of Beijing	X_1 Accessibility	Y_1 Accessibility of private residences to outdoor public spaces	The roads leading from homes to outdoor public spaces are well-maintained, providing convenient and direct access from homes to these spaces.
		Y_2 Accessibility to functional areas for internal activities	All functional areas are interconnected, ensuring a logical flow within the space.
	X_2 Security	Y_3 Adequate nighttime space lighting	Adequate nighttime lighting is in place to prevent any safety hazards.
		Y_4 Internal and external transportation security	Pedestrian and vehicular traffic are separated, and the ground is level for easy movement.
		Y_5 Safety in the use of various facilities	The facility operates within a reasonable range and is well-structured.
	X_3 Comfortableness	Y_6 Rational layout with separation of motion and static functions	The functional layout is sensible, avoiding conflicts between different areas.
		Y_7 Comfort during relaxing and socializing	There are sufficient seating facilities with comfortable and temperature-friendly materials.
		Y_8 Comfort during exercising	The material and operating range of the fitness facilities will not make the older people feel uncomfortable during the activity.

Table 2. *Cont.*

Goal	Criteria Layer(X)	Sub-criteria Layer (Y)	Standard Interpretation of Evaluation Criteria
Elderly-oriented Evaluation of Outdoor Public Spaces Design in Suburban Villages of Beijing	X_4 Identifiability	Y_9 External guidance	The facility provides clear guidance outside to direct older people to outdoor public spaces for activities.
		Y_{10} Internal guidance	The site interior features a transparent navigation system, explaining the functions of each area.
		Y_{11} Instructions for use of facilities	Fitness equipment includes clear and easily understandable instructions for seniors.
	X_5 Convenience	Y_{12} Convenience of location	Travel distances are suitable and accessible for villagers.
		Y_{13} Convenience of socializing	The facility is designed for both older people and children to engage in activities together conveniently.
		Y_{14} Convenience of intergenerational interaction	The facility is designed for both older people and children to engage in activities together conveniently.
		Y_{15} Convenience of facility operation	It is user-friendly, easy to operate, and suitable for all ages.
	X_6 Wellness	Y_{16} Rehabilitation function of fitness facilities	Facilities for rehabilitative health functions are available.
		Y_{17} Relaxing green landscape	The surrounding plants and scenery are well-matched, promoting physical and mental relaxation.
		Y_{18} Quiet and relaxing environment	There is no noise interference in the vicinity of the space.
	X_7 Aesthetics	Y_{19} Landscape aesthetics	Artificial facilities and the natural environment harmonize and complement each other.
		Y_{20} Design refinement	Attention is given to rigorous design details.
		Y_{21} Differentiated design styles	The landscape is distinctive and avoids homogenization.

Calculation of Weights

(1) Construction of Judgment Matrix and Preliminary Calculation

The judgment matrix forms a pivotal foundation for the weight calculation, characterized by the assignment of relative importance values through comparisons between elements, denoted as: X_{ij} $(i,j=1,2,\ldots,n)$, "i" and "j" represent specific elements within the criteria layer, and "n" signifies the total number of indicators. With the provided information, a judgment matrix is derived as follows: (1)

$$Y = (Y_{ij})_{n\times n} = \begin{bmatrix} Y_{11} & \cdots & Y_{1n} \\ \vdots & \ddots & \vdots \\ Y_{1n} & \cdots & Y_{nn} \end{bmatrix} \quad (1)$$

Weighting Questionnaire Utilizing the Saaty 1-9 Scale: To assign weights to the evaluation indicators, a weighting questionnaire was organized. The Saaty1-9 scale method [37] (**Table 3**) served as a guideline for both constructing the questionnaire and collecting data. The collected data were subsequently input into the "Yaahp" software, specifically designed for the Analytic Hierarchy Process (AHP). This software facilitated the comparison of indicator importance within the same level of the guideline layer and sub-criteria through pairwise assessments. These assessments yielded quantitative insights into the indicators' significance, aiding in the creation of judgment matrices.

Table 3. *Significance of Evaluation Criteria (Drawn by the author)*

Intensity of Relative Importance	Scale of Importance
Equal importance	1
Moderate importance of one Experience and judgment slightly favor one activity over another	3
Essential or strong importance	5
Demonstrated importance	7
Extreme importance	9
Intermediate values between the two adjacent judgments	2, 4, 6, 8
Reciprocals of the above nonzero numbers	Reciprocal for inverse comparison

(2) Calculation of Consistency Test

Indeed, variations in individuals' perceptions and the inherent diversity of the objective world can lead to differing expert opinions on various matters. Consequently, it is essential to ensure the scientific objectivity of the evaluation results and the rationality of the evaluation index judgment matrix. This is achieved when the Consistency Ratio $(\mathrm{CR}) < 0.1$. The calculation process is as follows, referencing equations (2), (3), (4), (5), and (6).

$Normalize\ each\ column\ of\ the\ matrix. i, j = l, 2, \ldots, n$:

$$Y_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{n} Y_{ij}} \tag{2}$$

$Horizontal\ Summation, i = l, 2, \ldots, n$:

$$\bar{W}_i = \sum_{j=1}^{n} \bar{Y}_{ij} \tag{3}$$

$Vector\ normalization, i = l, 2, \ldots, n$:

$$W_i = \frac{\bar{W}_i}{\sum_{j=1}^{n} \bar{W}_j} \tag{4}$$

$Calculate\ the\ maximum\ judgment\ matrix, i, j = l, 2, \ldots, n$:

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(YW)_i}{nW_i} \tag{5}$$

$Calculate\ the\ consistency\ CI;\ n represents\ the\ order\ of the\ judgment\ matrix$:

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \tag{6}$$

The ratio of the consistency indicator (CI) to the corresponding (RI) $(\textbf{Table 4})$ was defined as the random consistency ratio, (CR) formula as follows (7):

$$CR = \frac{CI}{RI} \tag{7}$$

Table 4. *Random Inconsistency Indices (RI) (Drawn by the author)*

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.52	0.89	1.12	1.23	1.36	1.41	1.46

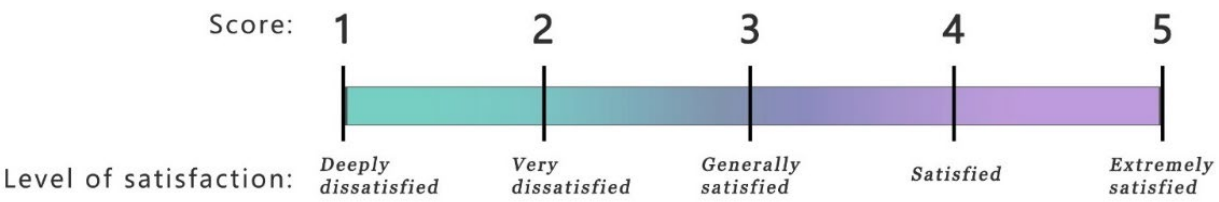


Figure 4. *Satisfaction Rating Scale (Drawn by the author)*

(3) Comprehensive Calculation of Evaluation Indicator Weights

Having performed the preliminary weight calculation for the previous evaluation indicators and successfully passing the consistency test, the comprehensive calculation of the outcomes for each sub-criteria layer can proceed. This formula for determining the total weight of each sub-criteria layer's weight value across all sub-criteria layers is as follows (8):

$$W_i = W_x \times W_y \tag{8}$$

Calculation of Satisfaction Scores

After establishing evaluation criteria and calculating weight values, the subsequent step involves assessing the satisfaction of older people with the current state of outdoor public spaces in suburban villages of Beijing. This necessitates collecting authentic and objective feedback and sentiments from older people utilizing these spaces. To accomplish this, the paper utilizes the Satisfaction Degree (SD) assessment method, a psychology-based approach that quantifies respondents' psychological feelings by assigning scores to their experiences.

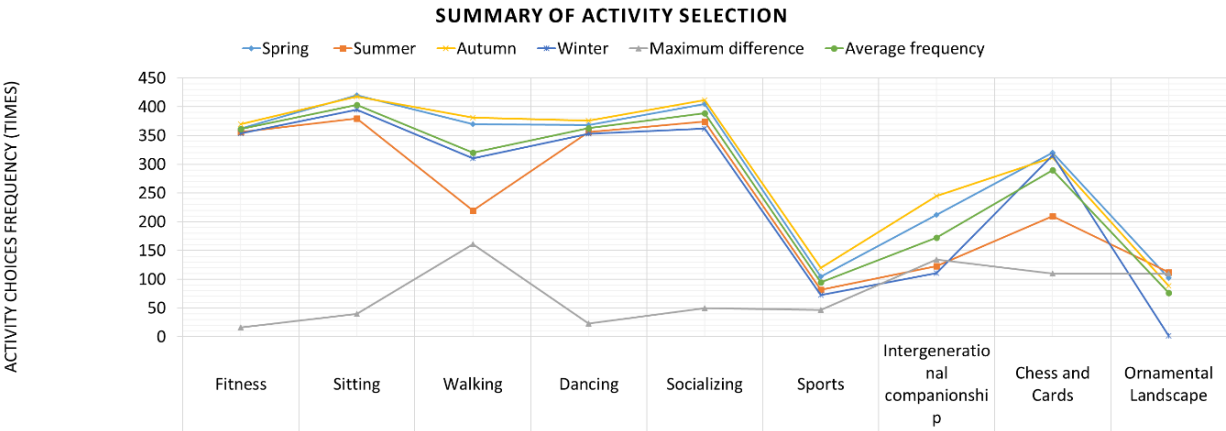
In this part, we scored the indicators of outdoor public space in the village based on older people' experience using these spaces. We utilized a Likert scale to assign scores ranging from 1 to 5 [38]. These scores corresponded to the five levels of satisfaction, from "Deeply dissatisfied" to "Very dissatisfied," "Generally satisfied," "Satisfied," and "Extremely satisfied," respectively (**Figure 4**).

Calculation of Final Scores of Criteria Layer Indicators based POE

Finally, to calculate the evaluation scores for the distribution of the seven indicators at the Criteria layer, a linear weighting calculation was employed. This calculate involved weighting the combined weight values of the indicators at the sub-criteria layer with the average satisfaction scores. the formula for this calculation is as follows:

$$z = \sum_{i=1}^{n} \bar{s}\, w_y \tag{9}$$

Table 5. *Summary of Activity Selection (Drawn by the author)*



	Fitness	Sitting	Walking	Dancing	Socializing	Sports	Intergenerational companionship	Chess and Cards	Ornamental Landscape
Spring	362	420	370	368	405	105	212	320	102
Summer	356	380	220	356	374	82	123	210	112
Autumn	370	418	381	376	412	120	245	312	89
Winter	354	395	310	353	362	73	111	316	2
Maximum difference	16	40	161	23	50	47	134	110	110
Average frequency	361.5	403.25	320.25	363.25	388.52	95.00	172.75	289.5	76.25

Results

Results of Qualitative Analysis

Functional Selection Usage Preferences

Analyzing the predilection for selecting functions within outdoor public spaces among the elderly population residing in Beijing's suburban villages serves as a pivotal approach for evaluating the appropriateness of the existing functions within these spaces. Consequently, four distinct datasets were procured, stratified in accordance with Beijing's seasonal climatic patterns [29] (**Table 5**). Among the four seasons, Walking exhibits the highest value (161) for the maximum difference in activity selection frequency, whereas Fitness has the lowest value (16). Sitting ranks first in the average frequency number of times it was selected, about 327 times higher than the last ranked Ornamental Landscape.

Common Requirements

Throughout our field research, we engaged in semi-structured interviews with senior members of the village community, delving into their daily requirements concerning outdoor public spaces. A comprehensive study of the underlying motivations for these needs was conducted (**Table 6**). Upon careful review and analysis, we discerned that the outdoor public space needs of elderly residents in Beijing's suburban villages primarily revolved around key aspects, notably "Safety," "Comfort," "Wellness," "Accessibility," and "Convenience."

Table 6. *Requirements Record Sheet (Drawn by the author)*

▪ Requirements	Reasons	Associated Properties
▪ Natural versus artificial lighting	1. Tall trees hampers sunlight exposure for older people. 2. Insufficient lighting compromises nighttime safety.	Comfortableness, Wellness, Safety
▪ Safety and comfort of fitness equipment	1. The fitness equipment has a risk of injuries. 2. The material is poorly insulated and not skin-friendly.	Comfortableness, Wellness, Safety
▪ The floor of the space is flat and open	1. Uneven walking and dancing surfaces pose a tripping hazard for older people. 2. Staircases are inconvenient for older people to navigate.	Safety, Accessibility
▪ Separation of dynamic and static spaces	1. Quiet conversations of seated individuals are disrupted by crowds dancing and singing.	Comfortableness, Wellness
▪ Adding seat layout types	1. Insufficient seating arrangements for various types of conversations (e.g., face-to-face, quiet discussions, group deliberations).	Comfortableness, Convenience
▪ Adding a roof to the lounge area	1. Adverse weather conditions, such as rain and snow, disrupt the user experience.	Comfortableness, Convenience

Results of Quantitative Analysis

Weight Values of Evaluation Indicator

(1) Results of Preliminary Calculation

Building upon the preceding *3.3.2 Calculation of Weights*, weight values for the 7 criteria layer indicators and the 21 sub-criteria layer indicators within their respective criterion layers have been calculated. The initial calculation results are presented in the following table (**Table 7**).

Table 7. *Weighted Values of Criteria Layer Index Judgment Matrix (Drawn by the author)*

Goal	Criteria layer(X)	Weighting values of the criteria layer (W_X)	Sub-criteria layer (Y)	Weighting values of the sub-criteria layer (W_Y)
Elderly-oriented Evaluation of Outdoor Public Spaces Design in Suburban Villages of Beijing	X_1 Accessibility	0.0441	Y_1 Accessibility of private residences to outdoor public spaces	0.2500
			Y_2 Accessibility to functional areas for internal activities	0.7500
	X_2 Security	0.2678	Y_3 Adequate nighttime space lighting	0.1429
			Y_4 Internal and external transportation security	0.4286
			Y_5 Safety in the use of various facilities	0.4286
	X_3 Comfortableness	0.1852	Y_6 Rational layout with separation of motion and static functions	0.2402
			Y_7 Comfort during relaxing and socializing	0.2098
			Y_8 Comfort during exercising	0.5499
	X_4 identifiability	0.1053	Y_9 External guidance	0.1365
			Y_{10} Internal guidance	0.2385
			Y_{11} Instructions for use of facilities	0.6250

Table 7. Cont.

Goal	Criteria layer(X)	Weighting values of the criteria layer (W_X)	Sub-criteria layer (Y)	Weighting values of the sub-criteria layer (W_Y)
Elderly-oriented Evaluation of Outdoor Public Spaces Design in Suburban Villages of Beijing	X_5 Convenience	0.1262	Y_{12} Convenience of location	0.1364
			Y_{13} Convenience of socializing	0.1364
			Y_{14} Convenience of intergenerational interaction	0.2322
			Y_{15} Convenience of facility operation	0.4950
	X_6 Wellness	0.2183	Y_{16} Rehabilitation function of fitness facilities	0.4286
			Y_{17} Relaxing green landscape	0.1429
			Y_{18} Quiet and relaxing environment	0.4286
	X_7 Aesthetics	0.0532	Y_{19} Landscape aesthetics	0.2493
			Y_{20} Design refinement	0.5936
			Y_{21} Differentiated design styles	0.1571

Table 8. Consistency Test Results (Drawn by the author)

	X	X_1	X_2	X_3	X_4	X_5	X_6	X_7
λ_{max}	7.2153	2.0000	3.0000	3.0183	3.0183	4.0606	3.0000	3.0536
RI	1.36	0.52	0.52	0.52	0.52	0.89	0.52	0.52
CI	0.036	0	0	0.009	0.009	0.020	0	0.027
CR	0.0264＜0.1	0＜0.1	0＜0.1	0.0173＜0.1	0.0173＜0.1	0.0227＜0.1	0＜0.1	0.0516＜0.1

(2) Results of Consistency Test

Following the calculations, the CR value of each judgment matrix within this study is less than 0.1 (**Table 8**). This demonstrates that the results align with the consistency requirements, affirming the reliability and validity of the analytical outcomes.

(3) Results of Comprehensive Calculation

The results of Comprehensive Calculation of Evaluation Indicator Weights are presented in the table below (**Table 9**).

Table 9. The Comprehensive Weight Value of All Layer Index Judgment Matrix (Drawn by the author)

Goal	Criteria layer(X)	Weighting values of the criteria layer (W_X)	Sub-criteria layer (Y)	Weighting values of the sub-criteria layer (W_Y)	Sub-criteria layer Comprehensive weight value (Wi)
Elderly-oriented Evaluation of Outdoor Public Spaces Design in Suburban Villages of Beijing	X_1 Accessibility	0.0441	Y_1 Accessibility of private residences to outdoor public spaces	0.2500	0.0110
			Y_2 Accessibility to functional areas for internal activities	0.7500	0.0331
	X_2 Security	0.2678	Y_3 Adequate nighttime space lighting	0.1429	0.0383
			Y_4 Internal and external transportation security	0.4286	0.1148
			Y_5 Safety in the use of various facilities	0.4286	0.1148

Table 9. *Cont.*

Goal	Criteria layer(X)	Weighting values of the criteria layer (W_X)	Sub-criteria layer (Y)	Weighting values of the sub-criteria layer (W_Y)	Sub-criteria layer Comprehensive weight value (Wi)
Elderly-oriented Evaluation of Outdoor Public Spaces Design in Suburban Villages of Beijing	X_3 Comfortableness	0.1852	Y_6 Rational layout with separation of motion and static functions	0.2402	0.0445
			Y_7 Comfort during relaxing and socializing	0.2098	0.0389
			Y_8 Comfort during exercising	0.5499	0.1018
	X_4 identifiability	0.1053	Y_9 External guidance	0.1365	0.0144
			Y_{10} Internal guidance	0.2385	0.0936
			Y_{11} Instructions for use of facilities	0.6250	0.0251
	X_5 Convenience	0.1262	Y_{12} Convenience of location	0.1364	0.0312
			Y_{13} Convenience of socializing	0.1364	0.0936
			Y_{14} Convenience of intergenerational interaction	0.2322	0.0658
			Y_{15} Convenience of facility operation	0.4950	0.0172
	X_6 Wellness	0.2183	Y_{16} Rehabilitation function of fitness facilities	0.4286	0.0293
			Y_{17} Relaxing green landscape	0.1429	0.0172
			Y_{18} Quiet and relaxing environment	0.4286	0.0625
	X_7 Aesthetics	0.0532	Y_{19} Landscape aesthetics	0.2493	0.0133
			Y_{20} Design refinement	0.5936	0.0316
			Y_{21} Differentiated design styles	0.1571	0.0083

***** The sub-criteria layer weight value reflects the weight assigned to an indicator within its corresponding criterion layer, e.g., the weight value of the indicator "Y_1Accessibility of private residences to outdoor public spaces" is 0.2500, indicating its weight within the criteria of "X_1 Accessibility" criterion. On the other hand, the sub-criteria layer composite weight value signifies the weight of an indicator within all the sub-criteria layer indicators (A total of 21 items). The larger the sub-criteria layer integrated weight value, the more significant the influence of the indicator on the adaptability of rural outdoor public space in the suburban villages of Beijing., Conversely, a smaller integrated weight value indicates a less significant influence.

As shown in the table above, The top five of Wi are Y_5 \ Y_4\ Y_8 \ Y_{13} \ Y_{10}, The bottom five are Y_{15} \ Y_9 \ Y_{19} \ Y_1 \ Y_{21} ; Both Y_4 and Y_5 share the top position in terms of Wi (0.1148), while Y_{21} ranks last (0.0083).

(4) Results of Satisfaction Scores

The survey was conducted in selected sample villages with the assistance of village committees and students. Various methods, such as oral interviews and on-site questionnaires, were employed. A total of 450 questionnaires were distributed, and 416 valid questionnaires were returned, resulting in an effective response rate of 92.4%. Subsequently, the average satisfaction ratings for each sub-criteria layer indicator ($\bar{S}$) were computed, and the results are presented in the table below (**Table 10**).

Table 10. *Average Satisfaction of Sub-criteria (Drawn by the author)*

Goal	Criteria layer(X)	Sub-criteria layer (Y)	Average satisfaction of sub-criteria ($\bar{S}$)
Elderly-oriented Evaluation of Outdoor Public Spaces Design in Suburban Villages of Beijing	X_1 Accessibility	Y_1 Accessibility of private residences to outdoor public spaces	2.025
		Y_2 Accessibility to functional areas for internal activities	2.413
	X_2 Security	Y_3 Adequate nighttime space lighting	2.775
		Y_4 Internal and external transportation security	2.050
		Y_5 Safety in the use of various facilities	1.880
	X_3 Comfortableness	Y_6 Rational layout with separation of motion and static functions	2.313
		Y_7 Comfort during relaxing and socializing	1.970
		Y_8 Comfort during exercising	1.948
	X_4 identifiability	Y_9 External guidance	2.350
		Y_{10} Internal guidance	2.120
		Y_{11} Instructions for use of facilities	1.988
	X_5 Convenience	Y_{12} Convenience of location	2.328
		Y_{13} Convenience of socializing	2.365
		Y_{14} Convenience of intergenerational interaction	2.410
		Y_{15} Convenience of facility operation	2.390
	X_6 Wellness	Y_{16} Rehabilitation function of fitness facilities	2.905
		Y_{17} Relaxing green landscape	2.640
		Y_{18} Quiet and relaxing environment	2.760
	X_7 Aesthetics	Y_{19} Landscape aesthetics	2.475
		Y_{20} Design refinement	2.660
		Y_{21} Differentiated design styles	1.905

As shown in the table above, The top five of $\bar{S}$ are $Y_{16} \setminus Y_3 \setminus Y_{18} \setminus Y_{20} \setminus Y_{17}$, The bottom five are $Y_{11} \setminus Y_7 \setminus Y_8 \setminus Y_{21} \setminus Y_5$; Y_{16} is the top position in terms of $\bar{S}(2.905)$, while Y_5 ranks last (1.88).

(5) Results of Final Scores for POE of Criteria Layer Indicators (Evaluation Indicator) (**Table 11**)

Table 11. *Final Scores for POE of Criteria Layer Indicators (Drawn by the author)*

Criteria layer(X)	Evaluation score (Z)
X_1 Accessibility	2.315
X_2 Security	1.724
X_3 Comfortableness	1.592
X_4 identifiability	2.691
X_5 Convenience	2.384
X_6 Wellness	2.807
X_7 Aesthetics	2.766
Average Comprehensive Evaluation Score	2.326

As shown in the table above, X_6 is the top position in terms of $Z(2.807)$, while X_3 ranks last (1.592).

Discussion

A comprehensive study was conducted on rural outdoor public spaces in suburban villages in Beijing, employing the POE approach and integrating both qualitative and quantitative evaluation results. The discussion yielded the following conclusions:

Characteristics of the Activities of Beijing's Elderly Groups in Suburban Villages

The Result indicates two regularities:

(1) The priorities of older residents in Beijing's suburban villages regarding outdoor public spaces revolve around factors like *Safety, Comfortableness, Wellness, Accessibility* and *Convenience*.

(2) Upon comparing all the functions available in the sample suburban villages of Beijing, it was observed that the following activities were presented in the outdoor public spaces: *Fitness*, *Sitting*, *Walking*, *Dancing*, *Socializing*, *Sports activities*, *Intergenerational play*, *Chess and cards*, and *Ornamental Landscape*. The top five activities with the highest average frequency of choices among older people were *Sitting, Socializing*, *Dancing*, *Fitness*, *and Walking*. In the overall ranking of the average frequency of activity choices, *Sitting* held the first positions consistently across all four seasons. Conversely, *Ornamental Landscape* being the least frequently chosen activity in all seasons.

(3) The usage of outdoor public spaces by older people exhibited a close relationship with the time of day and seasonal characteristics, as follows: (**Figure 5**). Among the four seasons, *Walking* is most affected by seasonal characteristics, while *Fitness* is least affected. Both extreme heat and extreme cold weather can discourage seniors from walking; however, *Fitness* remains an activity consistently chosen by seniors throughout the year.

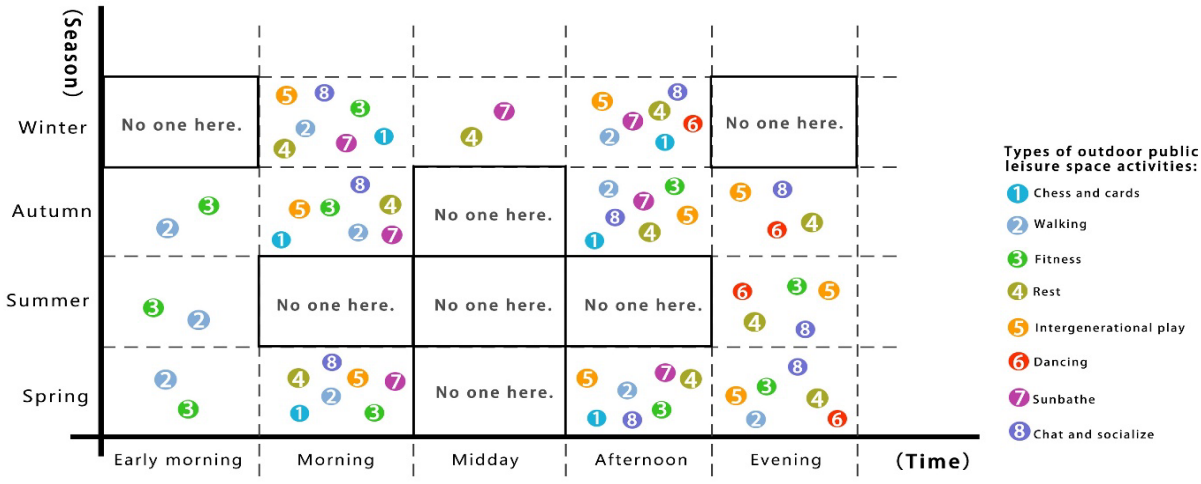


Figure 5. *Outdoor Public Space Activity Characterization (Drawn by the author)*

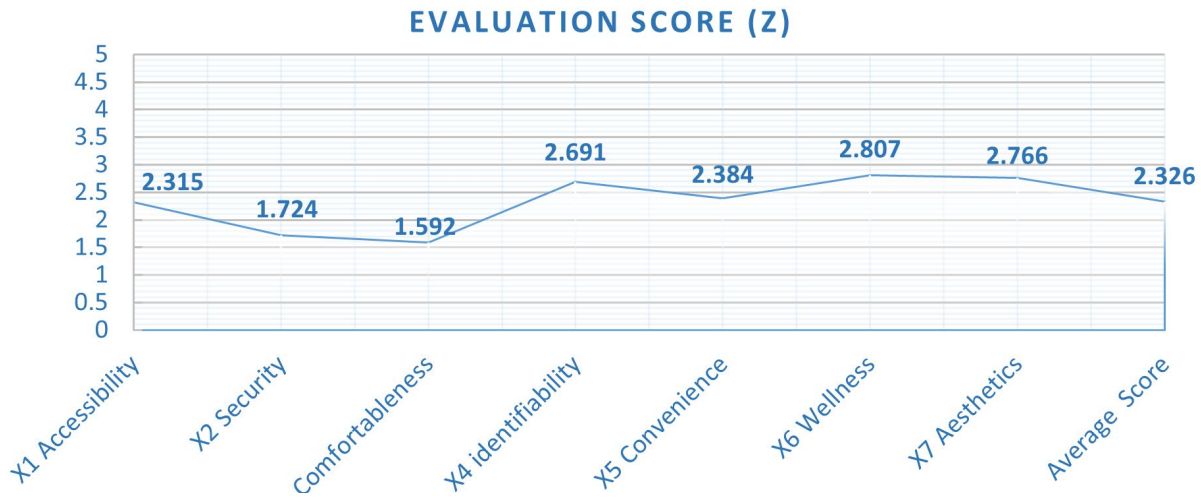


Figure 6. *Line chart of Final Scores (Drawn by the author)*

Therefore, the outdoor recreational activities of older people are greatly affected by Climate, Temperature, and Light. Suppose it is necessary to improve the enthusiasm of older people in outdoor activities, it is essential to improve the site's defenses against particular climates according to the actual situation and enhance the comfort of the whole day and year.

Key Issues for Outdoor Public Space in Suburban Villages

(1) Among the indicators in the criteria layer (X) of rural outdoor public space in suburban villages of Beijing, the top three in terms of weight are X_2 (Security), X_3 (Comfortableness), and X_6 (Wellness). In contrast, in the sub-criteria layer (Y), the top five in terms of significance are Y_4 (Internal and external transportation security), Y_5 (Safety in the use of various facilities), Y_8 (Comfort during sports and exercising), Y_{16} (Rehabilitation function of fitness facilities), Y_{18} (Quiet and relaxing environment). However, for several of the above indicators with high weight values had low satisfaction scores, leading to low final evaluation scores.

(2) The overall quantitative evaluation score (Z) for the suitability of outdoor public space in suburban villages of Beijing is 2.326 (out of 5), indicating that it falls within the lower-middle range, with considerable room for improvement. Notably, the low scores for "Safety for the elderly" and "Comfort of use" highlight the significance of prioritizing safety and overall experience for older people. Furthermore, the higher scores of "health and wellness" and "spatial appreciation" in the criteria layer may be influenced by the simple daily use of equipment by older people and their limited cognitive assessment of environmental conditions, which could lead to inflated satisfaction score (**Figure 6**).

Conclusion

This study focused on outdoor public spaces in suburban villages in China, with a specific case study in Beijing.

Through this comprehensive approach, the study aimed to provide insights into the current

state of outdoor public spaces in suburban villages and highlight areas that require improvement. Ultimately, this research contributes to the enhancement of age-friendly environments in these rural settings.

Through the comprehensive assessment of outdoor public space in suburban villages of Beijing has identified specific issues and root causes related to inadequate aging-friendliness in rural areas on the outskirts of Beijing, Derived the content of Characteristics of the Activities of Beijing's Elderly Groups in Suburban Villages and Key issues for Outdoor Public Space in Suburban Villages. The three main recommendations derived from above research are as follows:

(1) Optimization of outdoor public spaces for older people in suburban villages should prioritize safety enhancements and improvements in comfort for rest, relaxation, socialization, and fitness activities. This approach is considered the most efficient and effective means of boosting older people motivation to engage in outdoor activities and improving their physical and mental well-being; Simultaneously, in order to mitigate the impact of extreme weather on the motivation of the elderly to spend time outdoors, it is recommended to establish a spatial structure comprising grids, enclosures, and coverings.

(2) Consideration of the unique characteristics of each suburban village is crucial. Different villages have distinct social structures, resource bases, aging levels, Climatic characteristics and other variables. Therefore, in future research of a similar kind, the optimization of age-friendliness should be based on local evaluation results to avoid applying demand data from older people in other suburban villages, preventing potential optimization bias and resource wastage.

(3) Village committees and governments should establish a regular evaluation mechanism. This mechanism should include evaluations during the early stages of village planning, as well as periodic assessments during and after construction. Regular evaluations can help identify problems, implement improvements, and promote the sustainable development of rural areas.

In conclusion, this study aims to provide a comprehensive assessment of the suitability of outdoor public spaces in suburban villages for aging populations through the POE approach. The results shed light on the challenges surrounding the aging appropriateness of these spaces and offer a nuanced perspective. However, it is important to recognize that creating age-friendly rural environments involves multiple dimensions, including economic, policy, and cultural aspects. To comprehensively address this complex matter, future research should adopt a macroscopic approach that considers a broader range of factors. Additionally, the geographical expanse of China, with its diverse village types and regional variations, limits the scope of this study, potentially missing out on a complete understanding of challenges and opportunities in different rural areas. Future investigations should prioritize collaborative efforts with researchers from diverse professional backgrounds, enabling a multidimensional approach to consolidate findings, incorporate a wider array of variables, and refine aging optimization methodologies. Ultimately, these endeavors aim to significantly improve the quality of life for elderly residents in suburban villages and all rural settings in the coming years.

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Conceptualization, F.D. and C.L.; Data curation, F.D. and Y.Z.; Formal analysis, F.D.; Investigation, F.D. and Y.Z.; Methodology, F.D.; Project administration, F.D.; Resources, F.D. and C.L.; Software, F.D.; Supervision, F.D. and Y.Z. and C.L.; Validation, F.D. and J.Z.; Visualization, F.D.; Writing - original draft, F.D.; Writing - review & editing, F.D. and C.L. and J.Z. All authors have read and agreed to the published version of the manuscript.

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