

Article

A Study on the Design of Living Spaces for Rural Tourism-Based Elderly Housing Driven by User Needs

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Abstract

To improve the user perception of design decisions for living spaces in rural tourism-based elderly housing scientifically, a design approach is proposed from the perspective of user needs. This approach establishes an innovative model for the design of living spaces in rural tourism-based elderly housing by integrating the Kano model, the Analytic Hierarchy Process (AHP), and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). Firstly, the KJ method is used to extract the raw user needs, and after data cleaning, the Kano model is applied to categorize the attributes of these initial needs. Subsequently, the AHP method is used to construct a hierarchical model of user needs, enabling the calculation of the weight values of needs across different levels. User needs with higher weight values are integrated to create the design, and three design schemes are proposed for comparative analysis. Finally, the TOPSIS method is used to comprehensively evaluate the three design schemes derived from the user needs items identified by the Kano model and AHP method, thereby validating the feasibility of each design scheme. Experimental results show that the user needs-driven living space, constructed using the Kano model, AHP method, and TOPSIS method, transforms subjective concepts into specific design parameters through both qualitative and quantitative methods. This approach not only effectively addresses user needs but also provides solid theoretical support for the design of living spaces in rural tourism-based elderly housing.

Keywords: user needs; integrated model; rural tourism-based elderly housing; living space



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1. Introduction

The issue of population aging is gradually evolving into an increasingly severe challenge for social development. As shown in Figure 1, according to data released by the National Bureau of Statistics [1], China's population aged 60 and over reached approximately 310 million in 2024 and is projected to surpass 400 million by 2033. This demographic trend meets the international criteria for a deeply aged society. However, the concurrent rise in economic development and the expectations of the elderly has created increasing pressure on the current elderly care system, which struggles to accommodate the diverse needs of the aging population. As shown in Figure 2, the number of tourists aged 60 and above in China peaked in 2019. Although the COVID-19 pandemic caused a three-year decline in

travel, this group has shown a marked resurgence in travel activity beginning in 2024, reflecting a strong rebound [2]. In this context, a new model of elderly housing that integrates both tourism and long-term living—known as “rural tourism-based elderly housing”—has emerged as a promising alternative to traditional institutional care. This model responds to shifting demographic trends and evolving lifestyle preferences among older adults, offering both social engagement and environmental renewal through extended stays in rural settings. This model combines elderly care, housing, and tourism, aligning with the strategy of rural revitalization, fostering long-term consumption potential, and holding dual significance for both elderly care services and rural revitalization. It addresses the challenges of inadequate elderly care resources and facilities, while promoting high-quality economic development in urban and rural areas. The rural tourism-based elderly care model differs from traditional tourism as it emphasizes long-term residence.

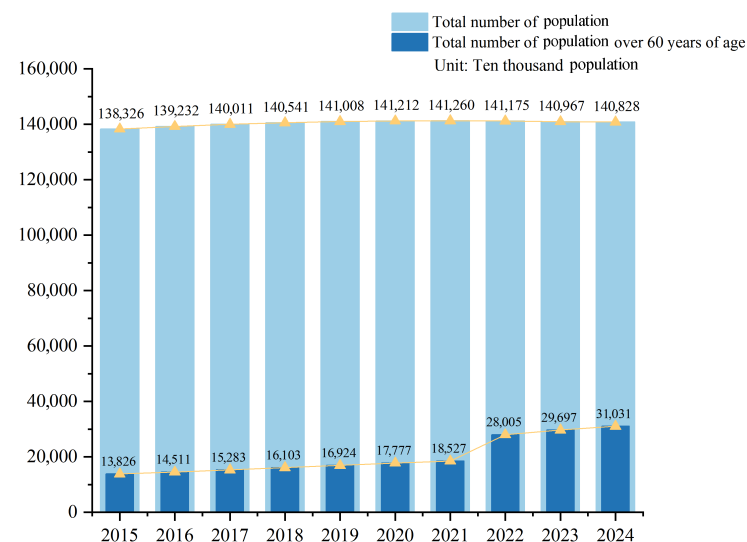


Figure 1. China’s population aged 60 and over, and total population statistics for the last 10 years.

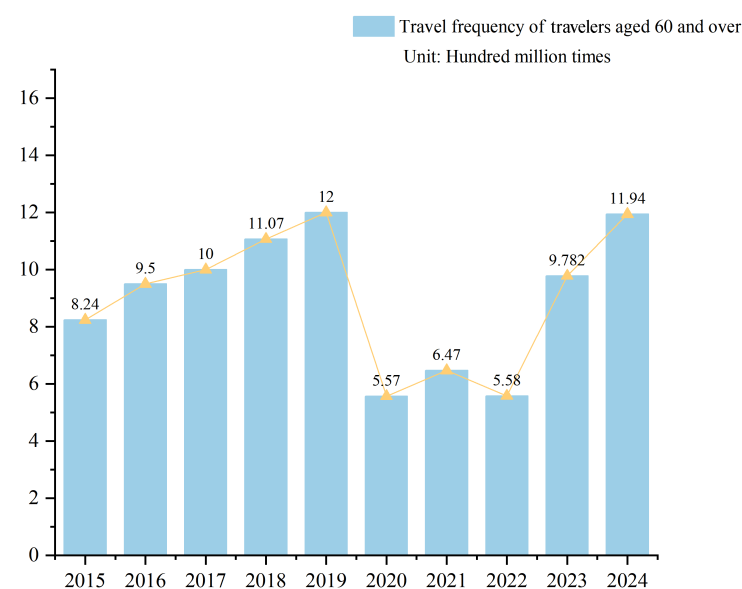


Figure 2. Number of travelers aged 60 and above in China.

The design of living spaces for tourism-based elderly housing is a new model of elderly care that integrates tourism, housing, and wellness, distinct from traditional elderly care institutions. It achieves a functional cross-border integration. The concept of tourism-based

elderly housing has its origins in the academic discussions surrounding “second homes” and “long-term tourism.” As early as the late 20th century, European scholars began to systematically investigate the development and policy implications of second residences. These dwellings, typically owned by middle- and high-income groups, not only reflect shifts in lifestyle preferences but also exert considerable influence on local economies, land use patterns, and community structures. In many European countries, second homes have increasingly served as destinations for elderly migration, a trend that closely parallels the objectives of tourism-based elderly housing development in China [3,4]. In the Chinese context, the concept was first introduced by Cheng Yong in 2009, referring to a form of non-primary, non-permanent residence intended for purposes such as leisure, wellness, and tourism. In recent years, the acceleration of population aging and the growing demand for “seasonal migration” among the elderly have positioned tourism-based elderly housing as a representative model of China’s version of the second residence. According to current literature on tourism-based building spaces, four major trends are observed: (1) focus on the physical comfort of architectural spaces, where studies have focused on optimizing lighting design to ensure a comfortable residential environment, improving photovoltaic systems in rural dwellings to enhance energy efficiency, and examining approaches to evaluating thermal comfort in such buildings [5–7]; (2) emphasis on the locality of architectural design, transforming traditional rural homes into tourism reception facilities through a shared model, achieving a balance between cultural heritage and community welfare, and promoting cultural transmission and tourism experiences through emotion-driven design [8,9]; (3) focus on the sustainability of buildings, reducing energy demand and environmental impact in rural tourism buildings through the use of natural materials, and forming multidimensional collaborative governance through stakeholder collaboration [10,11]; (4) exploration of human-centered spatial design, adopting an ecological wisdom perspective to offer new insights into rural tourism-oriented residential spaces, addressing mental health and architectural design from an interdisciplinary perspective, or influencing users’ emotional experiences through facility configuration [12,13].

Although some institutions have proposed guidelines for rural tourism-based buildings, most focus on structural safety and ecological protection or target the general population. Research specifically addressing the needs of elderly groups remains insufficient. The reason why many elderly people tend to choose tourism-based elderly care is mainly due to the more comprehensive elderly care facilities in the target areas [14]. By integrating traditional housing renovation with tourism functions, the project’s appeal to the elderly population is enhanced [15]. Alternatively, space adaptation for the elderly is used to improve environmental suitability, enhancing the elderly group’s experience and behavior patterns, further optimizing their subjective feelings, comfort, and autonomy. Additionally, comprehensive analyses of the applicability and accessibility of rural elderly housing are carried out through methods such as spatial evaluation, and the concept of universal design is applied to break traditional visual stereotypes of “barrier-free facilities” [16–18]. Furthermore, there are studies that combine tourism-based elderly care with healthcare, forming a “medical-residential-hotel” triadic spatial framework in the context of healthy aging [19,20]. Recent studies have shown that the application of smart technologies can achieve higher levels of inclusivity and sustainability, effectively promoting the seasonal migration needs of the elderly population [21].

Currently, research on the spatial design and transformation of rural tourism-based elderly care buildings primarily relies on qualitative studies, with a notable lack of quantitative research on the relationship between age-friendly design and elderly preferences. With the advancement of technology and the evolving needs of the elderly, their environmental demands are becoming increasingly diversified and profound. Due to the lack

of quantitative research, current challenges in the development of rural tourism-based elderly housing spaces include ambiguous user demands, unreasonable weighting, and severe design homogenization. Therefore, to accurately categorize user needs, effectively extract user need weights, and scientifically propose design schemes that enhance the reliability and advancement of user needs in rural tourism-based elderly housing spaces, a user needs-driven design methodology is proposed. This approach integrates the Kano model, the Analytic Hierarchy Process (AHP), and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) model to optimize the design of living spaces for rural tourism-based elderly housing. The study is divided into several parts: firstly, the KJ method is used to summarize the current status of tourism-based elderly housing spaces and identify the demand indicators of elderly users. Secondly, the Kano model is used to classify user needs to evaluate their importance. Thirdly, AHP constructs a hierarchical analysis model for living spaces, creating a judgment matrix to accurately calculate the weights between levels. Finally, based on the data results, design schemes are generated, and the TOPSIS model is used to evaluate the design schemes, validating the rationality and feasibility of the design model. The Kano/AHP/TOPSIS hybrid model was developed as a flexible and generalizable methodology capable of being tailored to diverse regional contexts and user demographics. Its adaptability allows for the accommodation of varying design requirements across different settings and population groups.

2. Literature Review: User Needs-Driven Architectural Space Design Methods

The user-centered design concept emphasizes prioritizing and addressing users' actual needs in the design process. Particularly in spatial design, it is essential to deeply understand the living habits, behavioral characteristics, and physiological as well as psychological changes of the elderly population to ensure the practicality, comfort, and accessibility of the design solutions.

In recent years, several user-driven design models have emerged, such as QFD (Quality Function Deployment), UCD (User-Centered Design), Kano (Kano Model), AD (Axiomatic Design), AHP (Analytic Hierarchy Process), and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution). The core of QFD lies in converting users' needs into substitute quality characteristics to determine the design standards of the product. Scholars such as Yesim Sireli have integrated the classification results of the Kano model into the "importance" column of QFD, constructing a "House of Quality" matrix, and optimizing the design of beer glasses based on the QFD analysis results [22]. UCD is a design methodology that focuses on users' needs, preferences, constraints, and environment at every stage of product design and development. Scholars such as Hans-Jörg have combined UCD with immersive virtual environments to optimize spatial layouts, improving the design's applicability and user satisfaction [23]. The Kano model is a qualitative research method. In user needs-driven design, the Kano model effectively addresses user needs, enhances design sustainability, and assists in design analysis and decision-making. Pei-Hsuan Lee et al. identified 17 sustainable features of customized housing and employed the Kano model to analyze age-related differences in demands and preferences for these features. Their work offers a systematic approach to integrating user-driven requirements and sustainability into the design of mass-customized housing [24]. Ming-Shih Chen et al. adopted the Kano model, combined with Importance-Performance Analysis (IPA) and Analysis of Variance (ANOVA), to systematically evaluate the regional attraction factors of an arts district [25]. Huimin Lu et al. employed the Kano model to categorize the design requirements of both tourists and experts and further assessed the relative importance of different requirement types. Their study aimed to meet the expectations and experiential

needs of tourists [26]. AD is a scientific design method that starts from user needs, clarifies functional requirements, and converts them into design parameters to improve design efficiency and quality while reducing randomness and iterations. Leonard D. Albano et al. applied the axiomatic design method to analyze and optimize the structural framework design of an innovative mechanical parking system [27]. AHP is primarily used for calculating the weight values of user needs. Ipek Yaralioglu et al. used the AHP method to analyze collected data and determine the priorities of public space standards, showing that the sustainable design of public spaces should focus on physical, social, economic, and administrative dimensions [28]. Congxiang Tian et al. applied AHP, combining expert evaluation and field surveys, to construct a quantitative indicator system for building spaces and performed comprehensive evaluations of the spaces to identify existing issues and propose corresponding optimization suggestions [29]. TOPSIS is an efficient method for the comprehensive analysis and rating of multiple architectural space designs. Asmaa Eldiasty et al. combined spatial syntax analysis with TOPSIS's multi-criteria decision-making model to evaluate the street network structure of the Rosetta Historical Center and the advantages and disadvantages of different market relocation schemes [30]. Lu Peng proposed an HF-TODIM-TOPSIS method to more accurately reflect decision-makers' preferences and uncertainties in evaluating the interior design quality of public spaces [31].

In summary, the Kano model enables the precise categorization of user needs by assessing their impact on user satisfaction, effectively distinguishing between must-be, one-dimensional, attractive, indifferent, and reverse requirements. The Analytic Hierarchy Process (AHP) facilitates the decomposition of complex decision-making structures and quantifies subjective judgments, thereby ranking these need types and guiding the generation of design solutions accordingly. TOPSIS, as a robust multi-criteria decision-making tool, allows for the objective evaluation and ranking of alternative design proposals. The application of the Kano model, AHP, and TOPSIS has become increasingly mature in the design domain. Each method contributes distinct strengths—need classification, priority analysis, and decision evaluation, respectively—and their integration yields a synergistic framework that enhances the effectiveness of the entire design process. By combining these three approaches, it is possible to ensure both the comprehensiveness and precision of design outcomes. The integration of Kano, AHP, and TOPSIS not only introduces a systematic and reliable approach to design but also establishes a complete methodological flow from user need identification to final scheme selection.

Within the scope of architectural space design, the application of user-driven model methods in design practice is relatively limited, as this approach is more commonly employed in the field of industrial design. Rural residential elderly care architecture differs significantly from traditional vacation housing, particularly in terms of functionality, sustainability, demand orientation, and age-friendly design. Currently, rural vacation architecture mainly takes the form of homestays, wellness centers, and self-built residential houses. However, these structures generally lack specialized considerations and adaptive planning tailored to the elderly population. Against this backdrop, the present study adopted an integrated Kano/AHP/TOPSIS approach to conduct an in-depth exploration of living space design in rural tourism-based elderly housing.

3. Recommendations and Methods

3.1. Construction of the Integrated KANO/AHP/TOPSIS Method for Designing Living Spaces in Tourism-Based Elderly Housing

Through the integration of the Kano, AHP, and TOPSIS models, user needs and expectations can be systematically identified and categorized using the Kano model, while the AHP method enables the prioritization of these needs by quantifying their relative

importance across multiple criteria. TOPSIS further provides a robust and structured approach to evaluating alternative design proposals. The combined use of these three methods ensures a user-centered, multi-criteria decision-making process, ultimately selecting the design solution that most effectively aligns with user needs. This study applies the AHP method to determine the user needs weights in the Kano model, effectively solving the problem of comprehensive ranking of Kano model demand indicators. By combining AHP/TOPSIS with the Kano model, it compensates for the limitations of the Kano model in evaluating design solutions for living spaces in rural tourism-based elderly housing. Therefore, the integrated approach of the Kano, AHP, and TOPSIS models offers advantages over other architectural space design methods, including a precise understanding of user needs, rapid analysis of user needs weights, objective evaluation of design solutions, and a complete and closed design process. Currently, no scholars in China have adopted this approach to study the design of living spaces in rural tourism-based elderly housing. Based on this, the approach of this study is to integrate the Kano, AHP, and TOPSIS models to explore design factors that have a significant impact on users, design living space solutions for rural tourism-based elderly housing, and evaluate the design solutions to verify the rationality of the Kano/AHP/TOPSIS hybrid model. The research framework for the design and evaluation of living spaces in rural tourism-based elderly housing, based on the integrated KANO/AHP/TOPSIS model, is illustrated in Figure 3. This study comprises four key stages. In the first stage, user demand indicators are identified based on the current conditions of tourism-based elderly housing environments. The KJ method is then employed to develop the questionnaire tool. This method involves the systematic collection of qualitative data—such as textual descriptions, verbal expressions, and visual materials—related to the research topic. These data are subsequently arranged into affinity diagrams using card-based grouping, allowing for the precise extraction and hierarchical structuring of elderly users' needs. Second, the Kano model is applied to classify elderly user needs indicators and their expected levels of demand, and the AHP model is used to establish a demand indicator analysis matrix to determine the overall weight values of different demand indicators. Third, the results of the Kano and AHP models are compared and analyzed, and the AHP model's results are used to adjust the indicators selected by the Kano model, thus identifying the high-quality design factors for rural tourism-based elderly housing living spaces. Fourth, based on the design factors, design solutions are created and the design solutions evaluated using the AHP/TOPSIS model to verify the rationality and feasibility of the design model.

3.2. User Needs Analysis for Living Spaces in Tourism-Based Elderly Housing Based on the KANO Model

As shown in Figure 4, the Kano model classifies user needs into five distinct categories: Must-be (M), One-dimensional (O), Attractive (A), Indifferent (I), and Reverse (R). The core of the Kano model is to provide theoretical support for the user needs of living spaces in rural tourism-based elderly housing through the use of a questionnaire survey and data analysis. When conducting such a questionnaire survey to assess the user needs for living spaces in rural tourism-based elderly housing, it is essential to design both positively and negatively worded questions. Respondents were asked to select from five options, with corresponding scores of 5, 4, 3, 2, and 1 points. Based on the questionnaire data, the user demand attributes for living space indicators in rural tourism-based elderly housing can be classified using the table of Kano evaluation (Table 1).

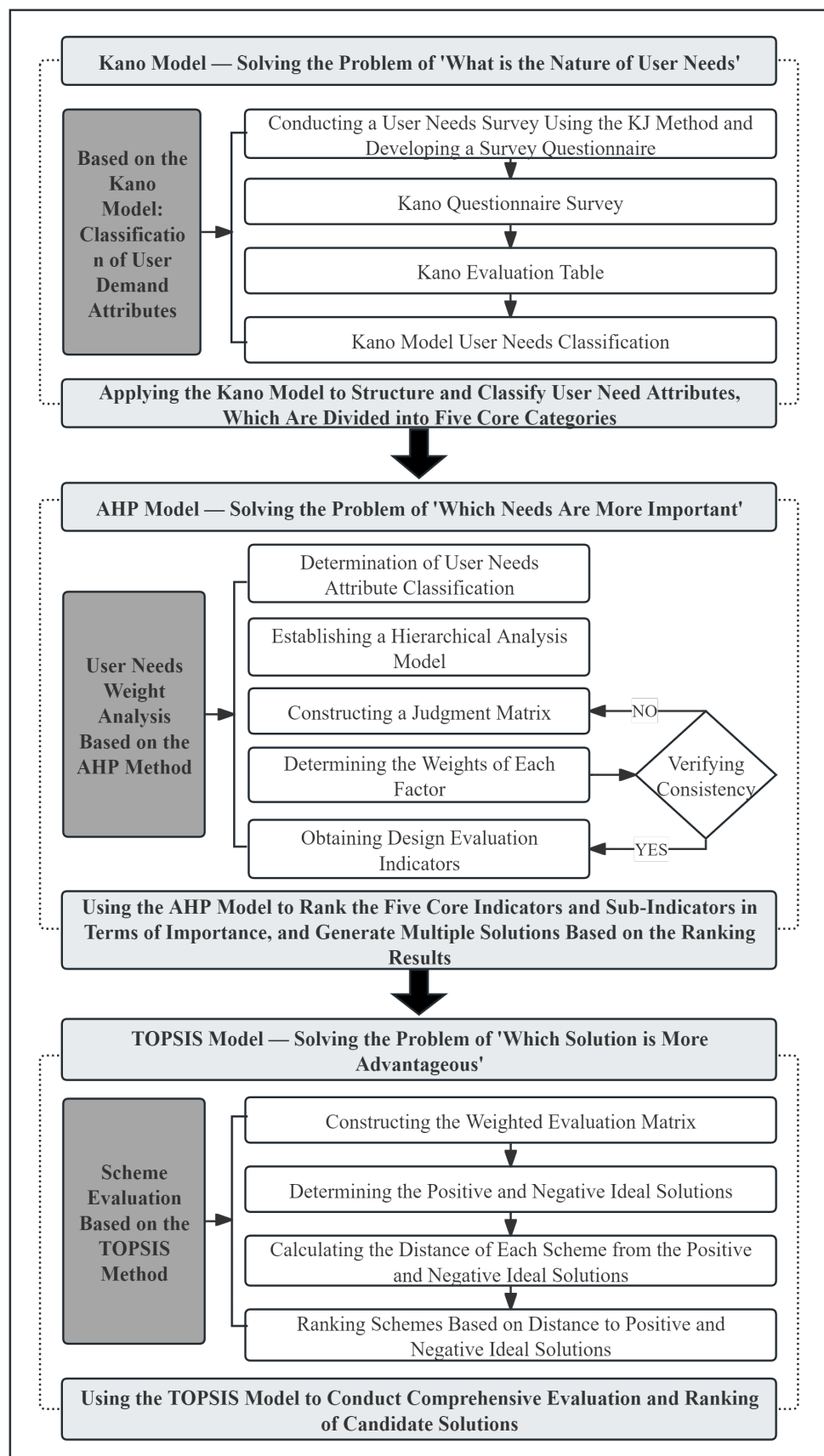


Figure 3. Research framework based on the KANO/AHP/TOPSIS hybrid model.

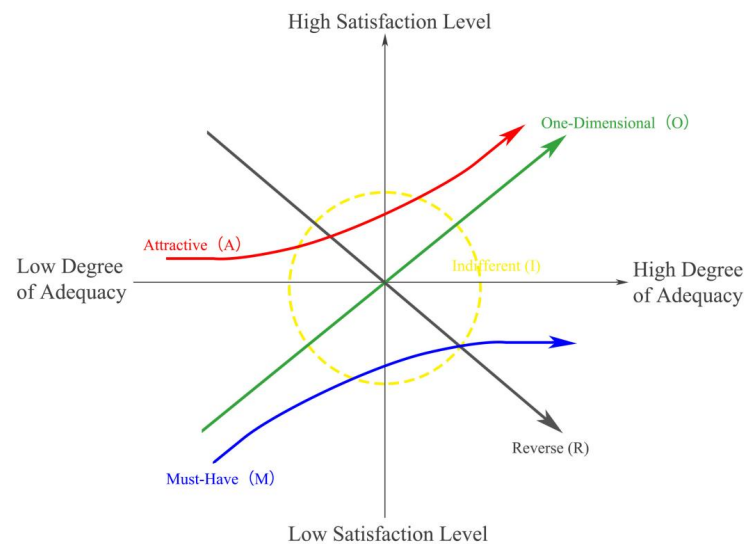


Figure 4. Kano model model analysis.

Table 1. Kano model quality type evaluation.

Functional Requirements	Scale	Reverse Question (Not Providing This Function)				
		Satisfied (5 Points)	As It Should Be (4 Points)	Indifferent (3 Points)	Acceptable (2 Points)	Dissatisfied (1 Point)
Positive Question (Providing This Function)	Satisfied (5 Points)	Q	A	A	A	O
	As It Should Be (4 Points)	R	I	I	I	M
	Indifferent (3 Points)	R	I	I	I	M
	Acceptable (2 Points)	R	I	I	I	M
	Dissatisfied (1 Point)	R	R	R	R	Q

Note: M: Must-be Requirement, O: One-dimensional Requirement, A: Attractive Requirement, I: Indifferent Requirement, R: Reverse Requirement, Q: Questionable Response.

3.3. Hierarchical Analysis Model and Demand Weight Analysis for Living Spaces in Tourism-Based Elderly Housing Based on AHP

The Analytic Hierarchy Process (AHP) is used to establish design indicators for living spaces in rural tourism-based elderly housing. This method operates by decomposing design elements and user needs into a hierarchical structure, followed by calculating the relative weights through both quantitative and qualitative analyses. Based on the user need categories identified via the Kano model, a hierarchical model is then constructed according to the principle of dominance relationships in AHP, as illustrated in Figure 5.

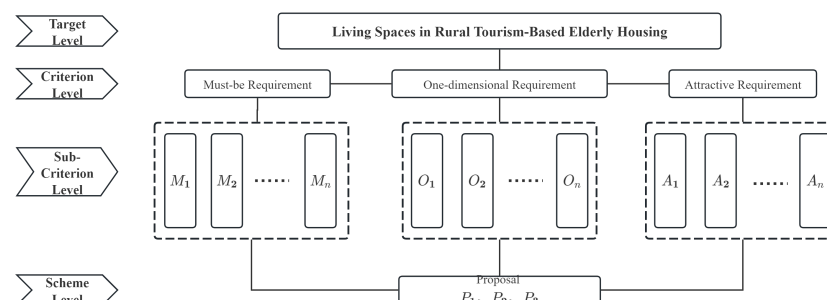


Figure 5. Hierarchical model of the AHP method.

The Analytic Hierarchy Process (AHP) serves as a methodological basis for selecting design indicators in the context of living spaces for rural tourism-based elderly housing.

Its core principle lies in decomposing the evaluation criteria into a hierarchical structure and deriving the overall weights of each indicator through a combination of qualitative and quantitative analyses. The implementation process consists of two main steps. First, the AHP judgment matrix is constructed. A 1–9-point scale, as defined in the table of the standard AHP scale, is used to express the relative importance between evaluation indicators of living space design, forming the judgment matrix X . Second, the validity of the judgment matrix is assessed through a consistency check. The Consistency Ratio (CR) is calculated to evaluate whether the matrix meets the required level of consistency. If the CR value is less than or equal to 0.1, the matrix passes the consistency test. The CR is calculated as shown in the following equations:

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

$$CR = \frac{CI}{RI} \quad (2)$$

3.4. Optimization Analysis of Design Evaluation for Living Spaces in Tourism-Based Elderly Housing Based on TOPSIS

The TOPSIS model primarily normalizes the data to form a standardized matrix and calculates the distances between the evaluation object and both the positive and negative ideal solutions to evaluate the alternatives. If the evaluation object is closest to the positive ideal solution and farthest from the negative ideal solution, it is considered the best alternative; conversely, if it is closer to the negative ideal solution, it is considered the worst. However, there is no complete and specific methodological framework for each objective, and the weight values are often influenced by the decision maker's subjective judgment, compromising objectivity. Therefore, combining AHP and TOPSIS ensures that the evaluation results are more objective. As illustrated in Figure 6, TOPSIS involves seven standard steps for evaluating and ranking the design alternatives.

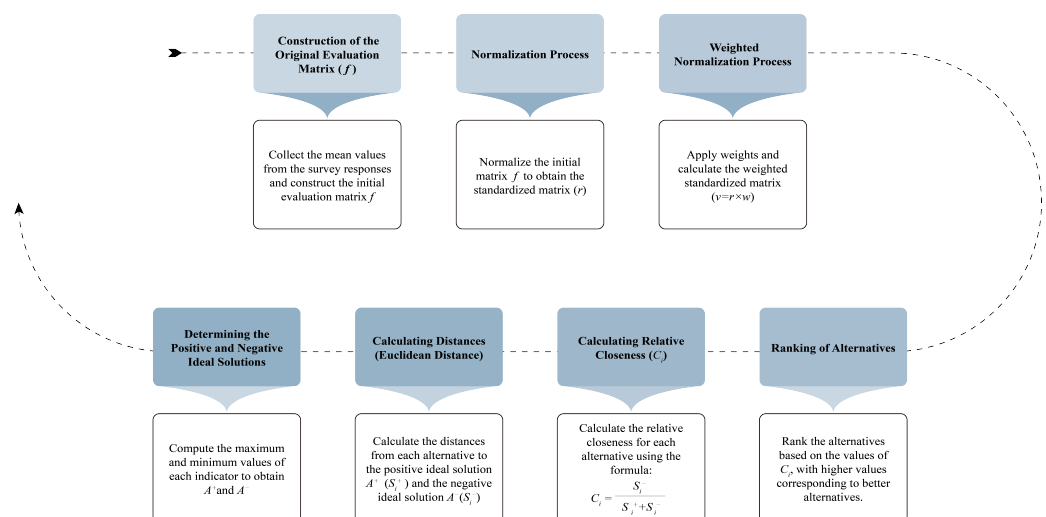


Figure 6. TOPSIS step flowchart.

4. Results and Discussion

4.1. User Needs-Driven Design Practice: A Case Study of Living Spaces in Tourism-Based Elderly Housing in Qianlianghu Town

Qianlianghu Town, abundant in natural resources and adjacent to Dongting Lake, boasts a wealth of natural resources and a unique fishing and hunting culture, attracting a large number of seasonal migratory birds each winter, forming a rare natural landscape. Qianlianghu Town is promoting the integration of the culture and tourism industries,

taking the opportunity of hosting the Hunan Provincial Tourism Development Conference to develop Specialty Lodging (such as Tinglan Courtyard), accelerating the integration of culture, tourism, and rural revitalization, so as to create a “demonstration area for the integration of agriculture, culture, and tourism” (with Liumen Gate and Caishang Lake as the core). This includes the construction of supporting facilities such as a food street, guesthouses, bird-watching camps, and a crayfish demonstration base. However, as illustrated in Figure 7, the tourism-based elderly care industry remains insufficiently developed. The current service system primarily depends on the senior home located at the Fenlukou junction as the core institution, supplemented by self-constructed rural residences serving as elderly housing. Therefore, to enhance the tourism industry in Qianlianghu Town and improve the elderly care infrastructure, the KANO/AHP/TOPSIS hybrid model is introduced to provide a complete design solution for the living spaces of tourism-based elderly housing in Qianlianghu Town, Junshan District, by Dongting Lake. Through the design practice in Qianlianghu Town, this study explores the design model and innovative pathways for rural tourism-based elderly housing, combining the specific needs of the region and providing theoretical support and practical guidance for future tourism-based elderly housing design in other rural areas.

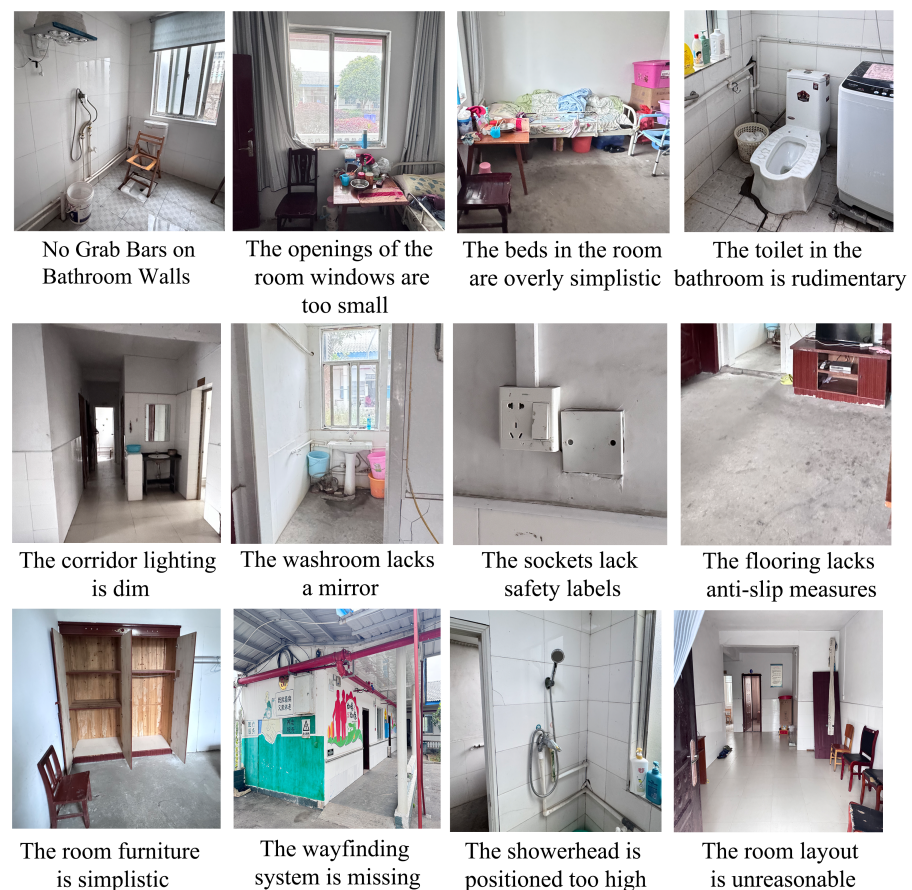


Figure 7. Current status of certain spatial sites in Qianlianghu Town.

4.2. Acquisition and Classification of User Needs for Living Spaces in Tourism-Based Elderly Housing in Qianlianghu Town

4.2.1. Acquisition of User Needs for Living Spaces in Tourism-Based Elderly Housing in Qianlianghu Town

To address the challenges of age-friendliness and sustainability in existing tourism-based elderly housing spaces, the KJ method was employed to collect user needs and develop an indicator system. Data were obtained through a comprehensive approach

involving literature review, policy analysis, user interviews, and expert consultations. A total of 63 individuals participated in the study, including elderly users, instructors, medical staff, and caregivers (such as family members and support staff) from Yueyang City University for the Elderly—of whom 53 were elderly respondents. During the interviews, participants were guided to describe their needs concerning the living spaces of tourism-based elderly housing in Qianlianghu Town, Junshan District, along the shores of Dongting Lake. The qualitative information gathered through interviews and summarized from the literature was then organized and synthesized, resulting in the identification of 20 categories of user demand indicators, as presented in Table 2. The KJ method enables the efficient and objective extraction of diverse user needs and arranges them in an organized and logical manner, thereby significantly enhancing the feasibility of applying the Kano model.

Table 2. User demand indicators.

Sufficient natural lighting and artificial illumination systems	Barrier-free accessibility throughout the home
Comfortable temperature levels	Equipped with a way finding system
Interior design aligned with local characteristics	User-friendly internal facilities
Use of environmentally friendly materials for decoration	Well-planned and efficient circulation paths within interior spaces
Pre-designed assistive tools tailored to user behavioral patterns	Customizable smart furniture throughout the home
Flexible spatial layout	Provision of entertainment facilities
Adaptability of spaces to accommodate future changes in population size	Large open-air balconies with scenic views
Handrails along all movement pathways	Dedicated spaces for hosting and social interaction
Fully integrated home sensor systems	Emergency call system installation
Slip-resistant treatment for all flooring	Spacious bathroom areas

4.2.2. Classification of User Needs for Living Spaces in Tourism-Based Elderly Housing in Qianlianghu Town

Based on the 20 indicators and influencing factors identified through the KJ method survey, the survey structure was incorporated into the Kano model to develop the Kano questionnaire. This questionnaire aimed to classify the demand attributes of the indicator system and influencing factors. For each design factor, respondents answered both positive and negative questions based on their personal experiences, selecting one of the five options: Satisfied, Expected, Indifferent, Acceptable, or Unsatisfied. The questionnaire was randomly distributed among students at Yueyang City University for the Elderly, with 210 questionnaires issued. After excluding invalid questionnaires (those completed in less than 60 s), 202 valid responses were collected, yielding a response rate of 96.19%. The age of respondents mainly ranged from 60 to 75 years, and overall, the selected sample demonstrated high representativeness and typicality, adequately reflecting the characteristics of the study population. According to the Table of Kano Model Quality Type Evaluation, the demand attributes of living spaces for tourism-based elderly housing in Qianlianghu Town, Junshan District, along the shores of Dongting Lake, were determined based on the survey group. Finally, based on the Table of Kano Model Quality Type Evaluation, a statistical analysis was performed on the user demand items for living spaces in tourism-based elderly housing, as identified through the Kano questionnaire conducted in Qianlianghu Town, Junshan District, along the shores of Dongting Lake. After categorizing and aggregating the attribute types for each item, the table of Kano result analysis was compiled, as presented in Table 3.

Table 3. Kano model results analysis.

User Needs	A	O	M	I	R	Q	Demand Attributes
M1 Sufficient natural lighting and artificial illumination systems	24	61	69	19	5	24	Must-Be (M)
M2 Comfortable temperature levels	23	66	68	21	2	22	
M3 Use of environmentally friendly materials for decoration	22	54	75	26	4	21	
M4 Handrails along all movement pathways	35	37	66	41	4	19	
M5 Slip-resistant treatment for all flooring	23	51	85	21	4	18	
M6 User-friendly internal facilities	35	40	63	41	3	20	
M7 Well-planned and efficient circulation paths within interior spaces	34	54	56	37	5	16	
M8 Emergency call system installation	23	61	64	34	4	16	
O1 Pre-designed assistive tools tailored to user behavioral patterns	26	55	41	41	4	35	Attractive (O)
O2 Adaptability of spaces to accommodate future changes in population size	46	53	41	38	4	20	
O3 Barrier-free accessibility throughout the home	40	51	49	35	6	21	
O4 Equipped with a way finding system	48	51	36	43	4	20	
O5 Spacious bathroom areas	41	68	38	36	4	15	
A1 Interior design aligned with local characteristics	61	33	36	47	5	20	One-Dimensional (A)
A2 Flexible spatial layout	52	45	43	35	2	25	
A3 Fully integrated home sensor systems	72	40	23	44	3	20	
A4 Customizable smart furniture throughout the home	86	35	16	43	4	18	
A5 Large open-air balconies with scenic views	88	28	15	46	6	19	
I1 Provision of entertainment facilities	60	28	19	70	7	18	Indifferent (I)
I2 Dedicated spaces for hosting and social interaction	48	28	32	73	4	17	

4.3. Solving the User Needs Weights for Living Spaces in Tourism-Based Elderly Housing in Qianlianghu Town

4.3.1. Construction of the Hierarchical Analysis (AHP) Model for Living Spaces in Tourism-Based Elderly Housing in Qianlianghu Town

As illustrated in Figure 8, an Analytic Hierarchy Process (AHP) model was constructed focusing on the design of living spaces in tourism-based elderly housing in Qianlianghu Town, Junshan District, along the shores of Dongting Lake. The model follows a hierarchical structure composed of three levels: the goal layer, the criteria layer, and the sub-criteria layer. The goal layer is defined as the living space of elderly housing in Qianlianghu Town; the criteria layer includes must-be, one-dimensional, and attractive attributes; and the sub-criteria layer consists of the specific user needs categorized under each attribute type.

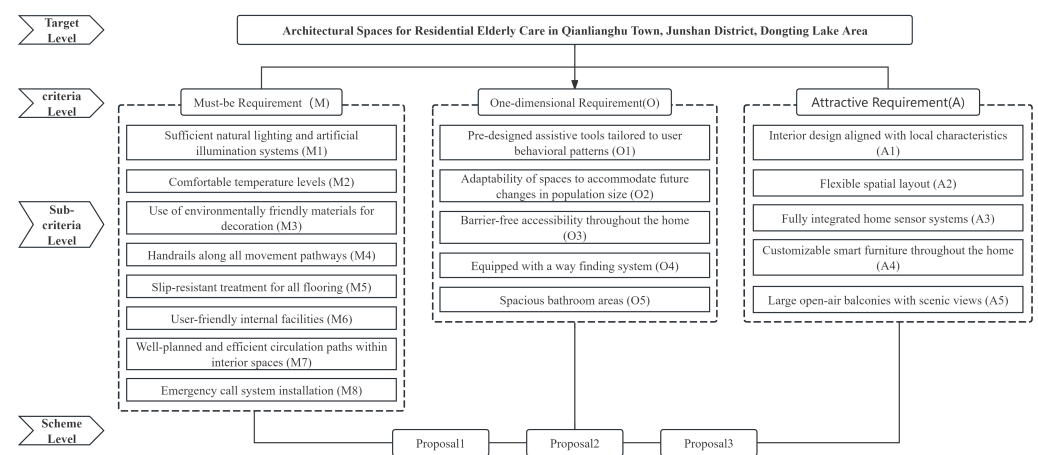


Figure 8. Analytic Hierarchy Process (AHP) model.

4.3.2. Construction of the Judgment Matrix and Calculation of User Needs Weights for Living Spaces in Tourism-Based Elderly Housing in Qianlianghu Town

The weight values of each level were calculated based on the relative importance relationships between all the hierarchical factors. To ensure the objectivity of the weight values assigned to each criterion in the AHP model, we invited five graduate students majoring in environmental design, five professional living space designers, and several scholars in related fields to participate in the evaluation process. The weights were determined using the geometric mean method and subsequently normalized. Thereafter, a consistency check was performed by calculating the Consistency Ratio (CR) of the judgment matrix. The detailed calculation process is presented below.

(1) Calculation of the Product of Scale Values for Each Level:

$$M_i = \prod_{j=1}^m b_{ij} \quad (i = 1, 2, \dots, 3) \quad (3)$$

(b_{ij} represents the demand indicator in the i -th row and j -th column; m represents the number of demand indicators).

(2) Geometric Mean of the Product of Scale Values for Each Level

$$a_i = \sqrt[m]{M_i} \quad (i = 1, 2, \dots, 3) \quad (4)$$

(3) Calculation of Relative Weights

$$W_i = \frac{a_i}{\sum_{i=1}^m a_i} \quad (5)$$

(4) Calculation of the Maximum Eigenvalue

$$\lambda_{\max} = \frac{1}{n} \sum_{i=1}^n \frac{B_{W_i}}{W_i} \quad (6)$$

(5) Consistency Test of Results

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (7)$$

$$CR = \frac{CI}{RI} \quad (8)$$

(n represents the order of the evaluation scale in the judgment matrix, with corresponding numerical values for each order; RI is the average random consistency index; CR is the consistency ratio).

Based on the weight values presented in Tables 4–7, the criteria layer was ranked in order of importance as follows: Must-be needs (M) > One-dimensional needs (O) > Attractive needs (A).

Table 4. Weight of criteria layer indicators.

X	M	O	A	Weight Value
M	1	1	2	0.41
O	1	1	1	0.32
A	1/2	1	1	0.26

Table 5. Weight of essential demand indicators.

M	M1	M2	M3	M4	M5	M6	M7	M8	Weight Value
M1	1	2	1	1	2	1	1/2	1	0.13
M2	1/2	1	1	2	2	1	2	2	0.15
M3	1	1	1	1/4	1	1	2	1	0.11
M4	1	1/2	4	1	2	2	1/2	2	0.16
M5	1/2	1/2	1	1/2	1	1	1/2	1/3	0.71
M6	1	1	1	1/2	1	1	2	2	0.12
M7	2	1/2	1/2	2	2	1/2	1	1	0.12
M8	1	1/2	1	1/2	3	1/2	1	1	0.12

Table 6. Weight of expected demand indicators.

0	01	02	03	04	05	Weight Value
01	1	2	1	2	1	0.25
02	1/2	1	1/2	2	1	0.172
03	1	2	1	1	1	0.22
04	1/2	1/2	1	1	2	0.18
05	1	1	1	1/2	1	0.173

Table 7. Weight of attractive demand indicators.

A	A1	A2	A3	A4	A5	Weight Value
A1	1	2	2	2	1	0.29
A2	1/2	1	1	1	1	0.16
A3	1/2	1	1	1	1/2	0.14
A4	1/2	1	1	1	2	0.19
A5	1	1	2	1/2	1	0.20

Within the sub-criteria layers, the priority rankings were as follows:

- For Must-be needs: $M5 > M4 > M2 > M1 > M6 = M7 = M8 > M3$
- For One-dimensional needs: $O1 > O3 > O4 > O5 > O2$
- For Attractive needs: $A1 > A5 > A4 > A2 > A3$

where “>” indicates higher relative importance.

The visualized results of these rankings are illustrated in Figure 9.

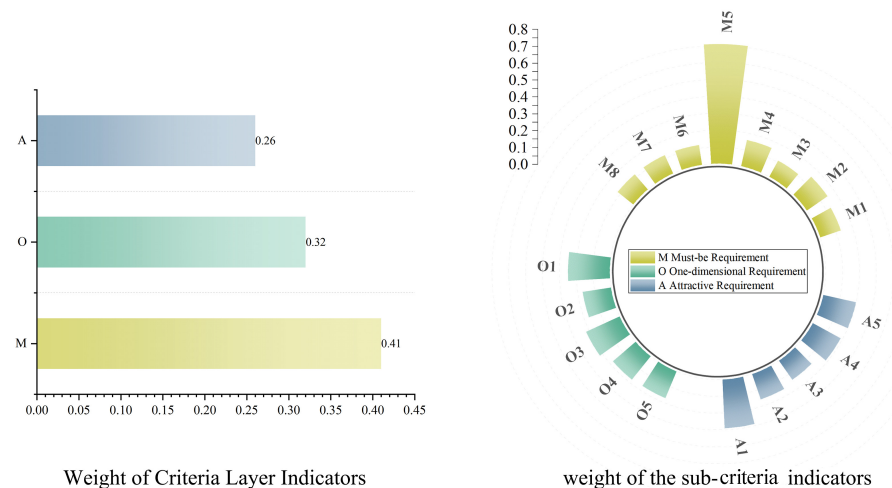


Figure 9. Analytic Hierarchy Process (AHP) model.

As shown in Table 8, the Consistency Ratio (CR) of the goal layer is 0.052, while the CR values of the sub-criteria layers are 0.096, 0.076, and 0.049, respectively. According to the standard threshold ($CR \leq 0.1$), all the calculated CR values meet the consistency requirement.

Table 8. Consistency test results.

	X	M	O	A
$\lambda_{\max}$	3.054	8.943	5.342	5.221
CI	0.027	0.135	0.086	0.055
RI	0.520	1.410	1.120	1.120
CR	0.052	0.096	0.076	0.049

4.4. AHP-Based Evaluation of Living Space Design for Tourism-Oriented Elderly Housing in Qianlianghu Town

Firstly, based on the characteristics of the Kano model, the two design factors categorized as Indifferent (I) needs were excluded from further analysis. The research focused specifically on exploring the design factors under the Must-be (M), One-dimensional (O), and Attractive (A) categories.

Secondly, according to the AHP computation and statistical results illustrated in Figure 10, the top five overall priority scores were assigned to the following design elements:

- M5: Slip-resistant treatment for all flooring;
- A1: Interior design aligned with local characteristics;
- O1: Pre-designed assistive tools based on user behavioral actions;
- O3: Barrier-free accessibility throughout the home;
- A4: Customizable smart furniture throughout the home.

These five elements serve as the primary design basis for the living spaces of tourism-based elderly housing in Qianlianghu Town. Their rankings based on AHP weights range

from 1st through 5th. In the Kano model, their rankings within their respective categories are as follows: M5 (1st in M), A1 (4th in A), O1 (2nd in O), O3 (3rd in O), and A4 (2nd in A).

This alignment indicates that high-priority elements are consistently emphasized across both evaluation models, supporting their significance in guiding design decisions. Therefore, the relative importance of these design factors should be carefully considered in the spatial design process.

In summary, the living space design of tourism-based elderly housing in Qianlianghu Town should prioritize safety performance, intelligent features, and aesthetic considerations.

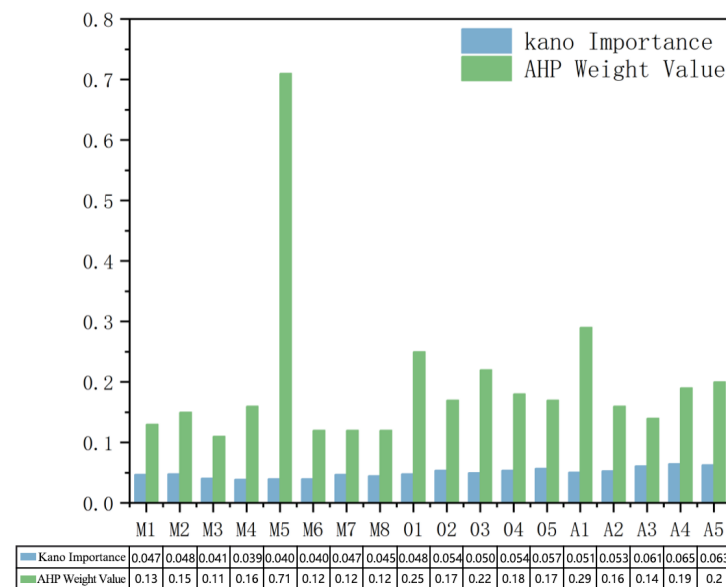


Figure 10. Comparison of Kano model importance and AHP weight value.

4.5. Design of Living Space Solutions for Tourism-Based Elderly Housing in Qianlianghu Town

In the design process of living spaces for tourism-based elderly housing in Qianlianghu Town, it is essential to not only address must-be requirements but also to fully incorporate the five key design elements previously identified—M5, A1, O1, O3, and A4. Accordingly, three design proposals were developed, all complying with national standards such as the “Code for Barrier-Free Design” and the “Code for Design of Hotel Buildings” issued by the Ministry of Housing and Urban-Rural Development.

Proposal 1 (Figure 11) prioritizes safety performance, with a focus on slip-resistant measures (M5) and barrier-free accessibility (O3). An effective slip-resistant strategy helps prevent falls and improves both comfort and confidence for elderly users. Based on field research and behavioral pattern analysis, the minimum required Slip Resistance Value (SRV) in major activity zones—including bedrooms, living rooms, and corridors—should not fall below SRV 45 under both dry and wet conditions. Suitable flooring includes materials with textured surfaces such as micro-roughened engineered wood, matte glazed ceramic tiles, or slip-resistant vinyl, which strike a balance between safety and homeliness. Transitions between rooms must be level to eliminate tripping hazards, and contrasting visual strips (30%–50% luminance difference) are recommended to aid visually impaired users in recognizing spatial boundaries. To accommodate common rural environmental challenges such as muddy or damp conditions, all floor materials should receive waterproof, easy-to-clean coatings to preserve safety and aesthetics over time. A fully barrier-free environment should integrate four core components: circulation space, elevation transitions, openings, and functional fixtures. Indoor passageways should maintain a minimum width of 900 mm, with main corridors no less than 1200 mm. Elevation changes must not exceed 5 mm, and any slopes should adhere to a maximum gradient of 1:12, complemented

by contrasting tactile warning strips. Doorways must have a minimum clear width of 850 mm, favoring flat-sliding or threshold-free designs. All switches and sockets should be mounted at a height between 450 and 1200 mm from the floor, featuring high-contrast visual and tactile indicators. Furniture layout should maintain a turning radius of at least 1500 mm, and key areas such as bathrooms, bedrooms, and kitchens must reserve at least two locations for grab bars. Lighting systems should include both primary and auxiliary sources, incorporating voice or motion activation; minimum illumination levels should reach 150 lx in general zones and 300 lx in bathrooms. All materials should be durable, water-resistant, and easy to clean, while supporting smart systems such as fall detection alarms and bedside sensor lighting—ultimately providing a seamless, accessible experience from entrance to bedside. To enhance furniture safety, all edges should be rounded to reduce injury risk during accidental collisions—especially in emergency scenarios. Corridors should eliminate thresholds, minimize elevation changes, and maintain unobstructed circulation paths to optimize spatial flow.

Architectural Renderings



Floor Plan

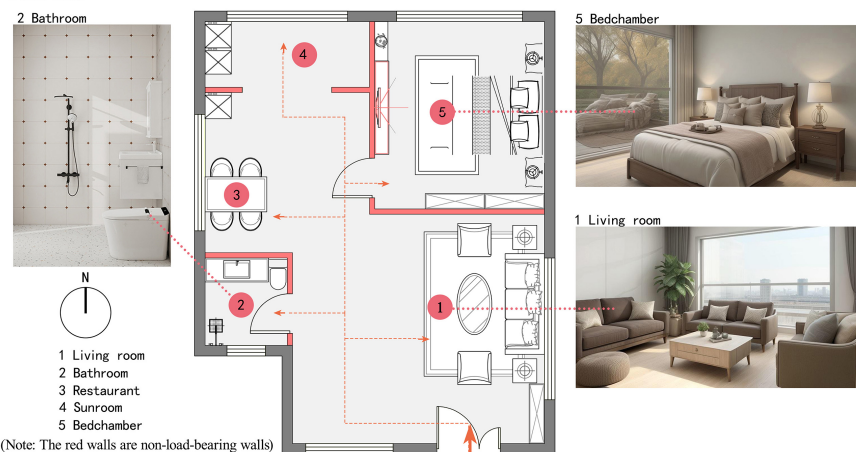


Figure 11. Proposal 1.

Proposal 2 (Figure 12) emphasizes the intelligent features of the living space (A4, O1), with the objective of achieving seamless integration of digital and smart technologies throughout the home. A comprehensive system of smart furniture and sensor is introduced, tailored to the behavioral characteristics of elderly users. The core furniture items—such as beds, sofas, and dining chairs—are designed to maintain seat heights within a range of 420–480 mm, with bed height set at 480 mm (including mattress) and equipped with adjustable lift bases (range: 350–550 mm). This supports ease of standing, wheelchair compatibility, and nursing care. Infrared or pressure sensors (response time < 1.5 s) are embedded into furniture to enable active services such as automatic night lighting and prolonged sitting alerts, enabled via wireless communication modules. Regarding user interface, control panels should be positioned within reachable zones (750–1000 mm) and support multimodal interaction, including voice commands, touchscreens, and remote controls to accommodate varying user abilities. Functionally, an integrated approach is

adopted—for example, intelligent bedside tables and sofa armrests combining storage, assistance in standing up, lighting control, and health monitoring. These components are interconnected via low-power Bluetooth or Wi-Fi to the overall smart system, including fall detection and environmental sensing. During the early design stage, it is critical to incorporate behavior-responsive assistive tools based on path analysis and movement tracking of elderly users' daily activities (e.g., getting up, walking, reaching). Key measures include the following:

- Oldable cushioned support bars (height 650–750 mm, length ≤ 300 mm) pre-installed beside beds, sofas, and toilets.
- Handrails or embedded grab bars (width 40–50 mm, height 850 mm) installed along bedsides, doorways, and long corridors.
- Pull-down shelves or motorized lift rails (operating force < 15 N) installed in high kitchen cabinets and wardrobes for easy one-handed retrieval.
- Pressure mats or IMU sensors embedded in commonly used seats (response time < 1.0 s), linked to trigger lighting or emergency calls.
- Low-position motion-sensing LED light strips (mounted at 200–300 mm height, sensing range 1.2–1.8 m, illuminance 20–30 lx) installed along nighttime routes such as from the bed to the bathroom.

Architectural Renderings



Floor Plan

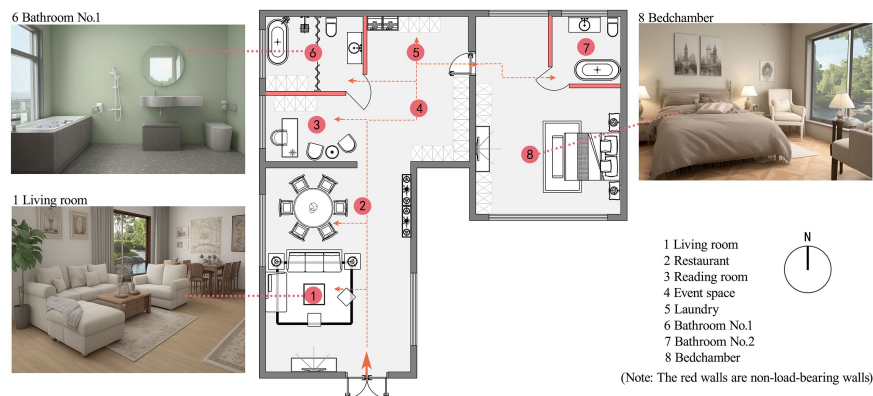
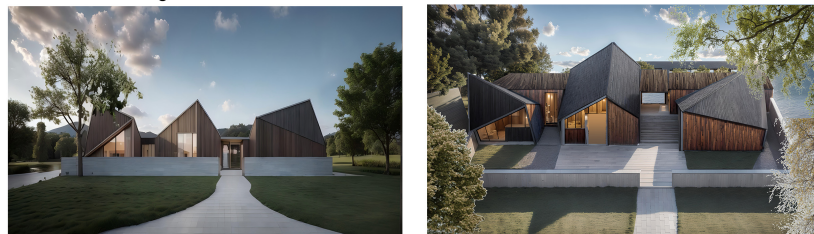


Figure 12. Proposal 2.

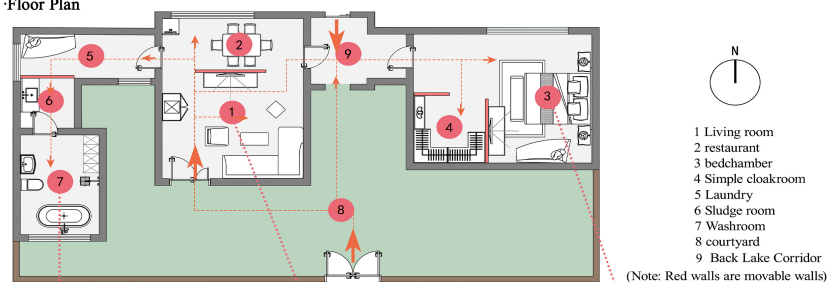
Additionally, non-contact modules such as millimeter-wave radar or 3D infrared cameras are deployed to detect abnormal behaviors (e.g., falls, immobility, frequent nocturnal activity) with an accuracy rate exceeding 99% and a false alarm rate below 1%, ensuring real-time alerts to caregivers. While intelligent features are the primary focus, the design also ensures safety and comfort. The layout maintains barrier-free accessibility and includes pre-designed assistive tools such as toilet support frames, grabbers, and walkers. From a comfort perspective, lighting and thermal control are emphasized. Indoor illumination should range between 300 and 500 lx, and large windows are strategically placed to maximize natural daylight exposure.

Proposal 3 (Figure 13) prioritizes aesthetic appeal and cultural resonance (A1) by adopting a modified Xiang-style architectural approach. The design preserves the essence of traditional courtyard configurations while introducing flexible interior partitions composed of lightweight wood panels and sliding wall systems. This strategy allows for adaptive spatial zoning tailored to elderly users' needs. To cultivate a warm and culturally familiar living atmosphere that fosters a sense of psychological comfort and memory for rural elderly residents, the interior design deeply integrates local cultural elements with traditional aesthetics. Based on field investigations conducted in Qianlianghu Town, a palette of soft, neutral tones—such as beige, light brown, pale yellow, and earthy white—is recommended to establish a tranquil spatial tone. Traditional residential features are reinterpreted through modern abstraction, using linear elements (30–80 mm in width) along ceiling edges, furniture detailing, and wall panels. This follows a “culturally inspired but non-retro” design philosophy that respects tradition without reverting to nostalgia. Walls are best adorned with non-glossy canvas prints or embroidered textiles, which help reduce visual fatigue and enhance the tactile warmth of the space. Ambient lighting should incorporate flexible, diffused sources hidden within wooden grilles or sheer curtains. Warm white light (color temperature 2700–3500 K) is preferred, and lamp designs may draw inspiration from local lanterns or weaving crafts. To create a multi-sensory experience that connects residents to place and memory, localized decorative artifacts such as handcrafted sachets and ceramic incense burners are recommended. In addition, a controllable background audio system may be installed to play ambient sounds such as Dongting fishing songs, birdsong, or wind chimes—natural audio samples that enhance immersion and psychological well-being. This aesthetic-focused scheme aims not only to satisfy visual comfort and cultural affinity but also to reinforce the emotional bond between elderly users and their living environment, ultimately supporting aging-in-place with dignity and familiarity.

Architectural Renderings



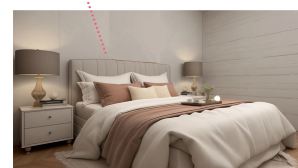
Floor Plan



7 Washroom



1 Living room



3 bedchamber

Figure 13. Proposal 3.

4.6. Design Evaluation of Living Spaces in Rural Tourism-Based Elderly Housing in Qianlianghu Town Based on TOPSIS

To ensure the objectivity of the selection process and mitigate bias arising from the subjective judgment of decision-makers, it is necessary to scientifically determine the priority ranking of each design proposal. The 18 sub-criteria from the hierarchical analysis model are used as evaluation indicators in the TOPSIS decision-making method, with all 18 sub-criteria classified as positive indicators. For the TOPSIS evaluation, 30 industry experts in living space design are invited to score the three design proposals based on these indicators. The TOPSIS evaluation involved 30 professional experts specializing in residential space design, who were invited to rate the three proposed design schemes based on the previously identified criteria. As shown in Table 9, a 7-point Likert scale was used for scoring. The collected scores were then normalized to obtain the initial decision matrix F.

Table 9. Initial evaluation matrix.

Evaluation Criteria	Proposal 1	Proposal 2	Proposal 3
FM1	4.15	4.25	4.02
FM2	4.05	4.11	4.07
FM3	4.13	4.06	4.09
FM4	4.30	4.42	3.82
FM5	4.25	4.31	4.07
FM6	3.82	4.21	4.05
FM7	4.01	4.13	3.98
FM8	3.25	4.17	3.95
FO1	3.41	4.08	4.09
FO2	3.50	4.16	2.67
FO3	4.25	4.12	3.86
FO4	3.35	4.03	3.98
FO5	3.10	4.25	4.12
FA1	3.15	3.76	4.53
FA2	4.14	4.27	4.17
FA3	4.13	4.02	3.86
FA4	3.25	4.14	3.83
FA5	4.38	3.42	4.29

Based on the five steps of the TOPSIS algorithm, the positive and negative ideal solutions and relative closeness for the three proposals are derived.

(1): Normalize the initial evaluation matrix to obtain the standardized matrix R_{ij} :

$$R_{ij} = \frac{f_{ij}}{\sum_{i=1}^m f_{ij}^2} \quad (i = 1, 2, \dots, m; j = 1, 2, \dots, n)$$

(2): Calculate the weighted standardized matrix u_{ij} based on the target weights of each evaluation indicator:

$$u_{ij} = W_j R_{ij} \quad (i = 1, 2, \dots, m; j = 1, 2, \dots, n)$$

where W_j represents the weight.

(3): Derive the positive ideal solution (A^*) and the negative ideal solution (A^-):

$$M_j^+ = \max\{u_{1j}, u_{2j}, \dots, u_{nj}\} \quad (j = 1, 2, \dots, m)$$

$$M_j^- = \min\{u_{1j}, u_{2j}, \dots, u_{nj}\} \quad (j = 1, 2, \dots, m)$$

Then,

$$A^* = (M_1^+, M_2^+, \dots, M_m^+)$$

$$A^- = (M_1^-, M_2^-, \dots, M_m^-)$$

(4): Use the Euclidean distance formula to calculate the distance of each proposal from the ideal solutions. The distance to the positive ideal solution is denoted as (S_i^+) , and the distance to the negative ideal solution is denoted as (S_i^-) :

$$S_i^+ = \sqrt{\sum_{j=1}^n (u_{ij} - u_j^+)^2} \quad (i = 1, 2, \dots, m)$$

$$S_i^- = \sqrt{\sum_{j=1}^n (u_{ij} - u_j^-)^2} \quad (i = 1, 2, \dots, m)$$

(5): Calculate the relative closeness (C_i) of each proposal to the ideal solution:

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-} \quad (i = 1, 2, \dots, m)$$

According to the comparative analysis shown in Table 10, the relative closeness values of the three schemes are ranked as follows: Scheme 2 > Scheme 1 > Scheme 3. This result indicates that among the three living space design proposals for tourism-based elderly housing in Qianlianghu Town, developed using the integrated KANO/AHP/TOPSIS model, Scheme 2 is the optimal solution.

Table 10. Positive and negative ideal solutions and relative closeness.

	Positive Ideal Solution	Negative Ideal Solution	Relative Closeness	Ranking
Proposal 1	3.231	1.456	0.311	3
Proposal 2	1.596	2.868	0.642	1
Proposal 3	1.775	3.073	0.634	2

To further optimize Scheme 2, computer-aided techniques were employed to integrate a multi-source intelligent sensing system into the living space of Qianlianghu Town, as illustrated in Figure 14. This system was designed to comprehensively enhance both proactive safety and daily convenience for elderly residents in tourism-based housing.

The intelligent system consists of three main types of sensors:

1. Infrastructure sensors (marked in black), deployed at critical utility nodes such as water, electricity, and gas pipelines, are designed for energy consumption monitoring and leakage detection.

2. Environmental sensors (marked in blue), installed in central ceiling areas and key interior zones, monitor temperature, humidity, air quality, and smoke levels to ensure environmental safety.

3. Smart furniture and object-sensing modules (marked in green), embedded in mattresses, chair surfaces, and mobility aids, track behavioral patterns such as the frequency of sitting and standing and the duration of nighttime out-of-bed activity. These features enable real-time detection of fall risks and health-related conditions.

In the bathroom area, the layout is divided into three functional zones: hygiene, bathing, and grooming. The grooming counter is typically positioned at a height of 700–900 mm to accommodate wheelchair users, and safety grab bars are installed around

the countertop for support. In addition, smart toilets are equipped with side-mounted handrails to assist movement. The bathing zone provides a turning space with a minimum diameter of 1500 mm to support large-body movements, and the showerhead is installed at a lower height than standard to allow for seated bathing.

In terms of deployment strategy, the system adheres to three key principles:

- Barrier-free coordination, such as maintaining a 500 mm clearance in wheelchair-accessible areas;
- Maintainability, ensuring devices are installed within visible and reachable zones;
- Responsive feedback, using multi-modal identification such as pressure + infrared sensing for precise behavior recognition.

Collectively, this forms a smart elderly living space driven by a “perception–response” paradigm. The design not only addresses the operational reliability and energy efficiency required for rural environments but also serves as a practical prototype for future intelligent upgrades of elderly housing in rural areas.

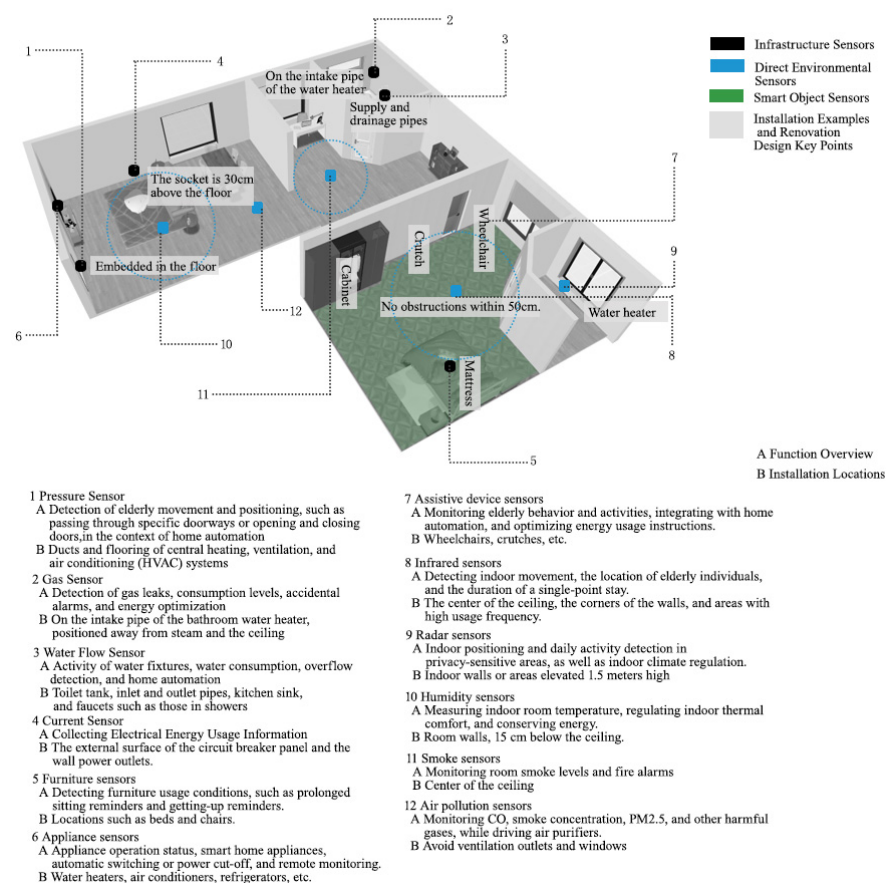


Figure 14. Layout of whole-house smart devices.

5. Conclusions

The rural tourism-based elderly care model demonstrates a high degree of modernity and has the potential to act as a catalyst for rural revitalization through localized, scalable interventions. With the continuous improvement of living standards, the elderly population has developed increasingly diverse and hierarchical demands for the design of living spaces in such rural settings—particularly in terms of safety, intelligence, comfort, and aesthetics. In response to these evolving needs, this study adopts a hybrid Kano/AHP/TOPSIS model to guide the design of living spaces for elderly-oriented tourism housing in Qianlianghu Town. The approach considers not only the specific requirements of elderly users but also

incorporates the professional insights of designers and domain experts, making it applicable to similar types of tourism-based housing projects. Building upon a thorough review of the Kano model, Analytic Hierarchy Process (AHP), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and the relevant literature on rural tourism architecture, a comprehensive decision-making framework was constructed. Five key design factors were identified: full-floor slip-resistant treatment, locally adapted interior decoration, behavior-responsive assistive tools, barrier-free accessibility, and customized smart furniture systems. Based on these factors, three design schemes with distinct emphases were developed. The TOPSIS was then employed to evaluate and rank these schemes, ultimately identifying the optimal solution. This study not only enhances the scientific and systematic nature of rural tourism-based elderly housing design but also provides an operable theoretical model and practical methodology for optimizing similar architectural spaces. Looking ahead, the Kano/AHP/TOPSIS hybrid model can serve as an effective tool for analyzing the diversity of elderly housing design needs across different geographic and cultural contexts. By conducting similar design studies in varied geographic and cultural environments, the adaptability and universality of design solutions can be further refined and expanded.

Author Contributions: H.L. designed the study. All authors were involved in the analysis of the results and the collection of data. J.Z. collected user demand data. Y.L. wrote the first draft of the manuscript. Y.Z. and H.C. carefully reviewed the manuscript. All authors have read and agreed to the published version of the manuscript.

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