A Multi-Method Co-Design Framework for Elder–Cat Shared Furniture: Enhancing Feline Enrichment and Elderly Well-Being

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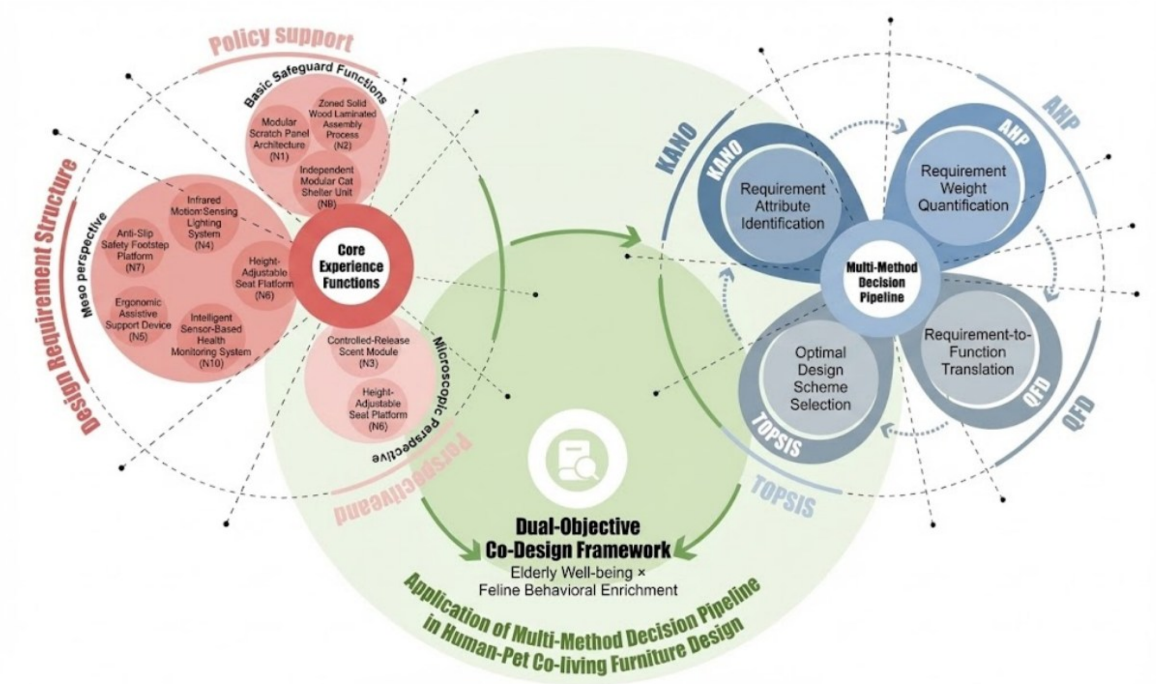
GRAPHICAL ABSTRACT



A Multi-Method Co-Design Framework for Elder–Cat Shared Furniture: Enhancing Feline Enrichment and Elderly Well-Being

Bing Liu,[a] and Yingxian Tu,[b,*]

Against the background of population aging and the growing demand for human–pet co-living, this study proposes a dual-objective co-design framework for older adults and domestic cats and applies it to the development of an intelligent human–cat interactive chair. To address the animal-centered bias and lack of age-friendly functions in existing pet furniture, the study integrates the Kano model, AHP, QFD, and TOPSIS to establish a structured design decision-making pathway. Based on surveys of 98 older adults and behavioral analysis of 30 domestic cats, 11 core functional requirements were identified. AHP results showed that the replaceable scratching layer and composite natural wood structure accounted for 42.9% of the total weight, while QFD mapping yielded 14 design features, with modular scratching structure, quick-release scratching board slot, and natural wood segmented assembly receiving the highest scores. TOPSIS evaluation indicated that Option B achieved the optimal closeness coefficient (Ci = 0.741). The results demonstrate that integrating feline behavior stimulation with assistive functions for older adults enhances feline activity and user safety, and the proposed Kano–AHP–QFD–TOPSIS framework provides methodological support for cross-species co-design of shared furniture.

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Keywords: Human–pet co-living; Age-friendly design; Multi-actor co-design; Emotional interaction; Kano–AHP–QFD–TOPSIS

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INTRODUCTION

With the continued acceleration of global population aging, many countries have promoted “aging in place” strategies that aim to support older adults in maintaining independent living within familiar home environments (Birnbaum *et al.* 1984). How to effectively improve physical and psychological well-being under conditions of limited caregiving resources has become a critical challenge that requires urgent attention (Shin and Sok 2012). Existing interventions generally emphasize two key factors: support for daily activities and emotional companionship. As one of the most frequently used pieces of furniture for older adults, chairs play a significant role in influencing sit-to-stand ability, muscle function, and physical recovery through their ergonomic structure (Blackler *et al.* 2018). However, mainstream chair designs are still largely developed within a single-user–ergonomics paradigm, showing limited responsiveness to older adults’ emotional needs and multidimensional interaction requirements. At the same time, pet-assisted companionship has gained increasing importance in recent research on elderly well-being (Northrope *et al.*

2025). A substantial body of evidence indicates that pet ownership not only strengthens social connections and provides emotional support, but also increases participation in daily activities (Reniers *et al.* 2023). In particular, domestic cats are often preferred by older adults due to their high level of independence, relatively low caregiving demands, and strong adaptability to indoor environments (Enmarker *et al.* 2015). This sustained human–pet relationship is inherently reciprocal in nature (Hardie *et al.* 2023). Accordingly, the systematic integration of pet interaction elements into elderly living spaces has been recognized as an important direction for promoting overall physical and psychological well-being.

Traditional furniture, which is primarily designed for single users, often fails to accommodate differences between humans and pets in behavioral patterns, emotional needs, and usage purposes, thereby limiting the quality of human–pet interaction and emotional bonding. Most existing pet furniture designs merely add basic pet-related functions while neglecting older adults' operational convenience, emotional experience, and interaction needs. In addition, there is still a lack of systematic design frameworks specifically targeting shared furniture for human–pet co-living. Previous studies have shown that supporting cats' natural behaviors can reduce anxiety and aggressive behavior (Han and Witzman 2023). Other research has focused on feline enrichment strategies, such as olfactory stimulation, vertical activity pathways, and video-based hunting activities, to enhance exploration and emotional stability (Houser and Vitale 2022). These approaches attempt to integrate cat-dominant behavioral patterns into furniture design. However, current human–pet shared furniture design often overlooks the unique identity and functional needs of older adults (Zafriana *et al.* 2024). In addition, current designs often provide limited consideration of interaction experience and emotional bonding between humans and pets (Menor-Campos *et al.* 2024). In domestic co-living environments, humans and cats function as co-present agents with overlapping spatial usage and frequent interaction. Improving chair structures through age-friendly design can enhance sit-to-stand performance and perceived safety (Valipoor *et al.* 2018). At the same time, it is essential to fully consider feline functional needs and human–pet interaction functions.

Based on the above research gaps, this study proposes a Dual-Objective Co-Design Framework for human–cat co-living scenarios, targeting older adults and domestic cats. The framework innovatively integrates two core objectives: age-friendly physical support and emotional companionship for older adults, and the stimulation of cats' natural behaviors and social needs. On this basis, an intelligent human–cat shared furniture prototype with multimodal interaction capabilities is developed. In terms of research approach, the study takes feline behavior stimulation and older adults' needs for safety support, emotional interaction, and well-being enhancement as dual focal points. These requirements are systematically addressed through a multi-method decision-making pathway. First, the KANO model is employed to identify basic, expected, and attractive requirements for both human and cat users. Subsequently, the Analytic Hierarchy Process (AHP) is applied to quantify functional weights and construct a weighted decision matrix. The identified user requirements are then precisely mapped to technical function modules through Quality Function Deployment (QFD), forming a traceable design linkage and generating three design alternatives with differentiated structures and functions. Finally, the optimal solution is selected using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), achieving a scientific and verifiable design optimization process. In terms of contributions, this study proposes a systematic dual-objective co-design paradigm for cross-species shared furniture, helping bridge the gap between age-friendly design and animal behavior-oriented research. It also demonstrates how multi-method integration can support the engineering implementation of product functions. The findings provide a transferable theoretical foundation and practical design pathway for the future development of intelligent age-friendly living environments and human‑pet interactive systems.

LITERATURE REVIEW

Age-friendly Furniture and Human Factors Engineering

This study adopts a human‑pet‑environment interaction perspective to systematically review existing research on age-friendly furniture design, feline behavior stimulation, and shared living environments. This perspective emphasizes the interdependent relationships between human users, companion animals, and the physical environment, providing a coherent analytical lens for identifying current research gaps.

Supportive interior environment design plays a critical role in older adults' physical health and well-being. Adults aged 65 years and above spend significantly more time indoors than other age groups, with an average daily indoor duration of approximately 19.5 h (Oswald and Wahl 2004; Brasche and Bischof 2005). From a human‑environment interaction perspective, a synthesis of recent studies on elderly care facilities and intelligent interactive technologies suggests that effective pathways to improving elderly well-being include the coordinated application of age-friendly interior environment design and digital intervention tools. Traditional research has focused on functional optimization of elderly living spaces, such as living rooms, bathrooms, dining areas, and entrance zones, to meet older adults' psychological, physiological, and behavioral needs (Yun 2024). In addition, Cubukcuoglu *et al.* (2023) further emphasized that indoor physical factors—including lighting, acoustics, air quality, and thermal conditions—have significant effects on older adults' autonomy, self-care ability, and quality of life. Optimizing these environmental conditions can help reduce disease risk and feelings of insecurity, enhance physical and mental vitality, and improve care quality, thereby exerting a positive impact on elderly well-being. Artificial intelligence systems represented by conversational agents have also been shown to effectively alleviate loneliness, cognitive decline, and digital exclusion at the psychological level by providing emotional companionship and health support (Alessa and Al-Khalifa 2023). Current trends are gradually moving toward integrating intelligent interactive technologies into age-friendly environment design, enabling comprehensive improvements in elderly well-being from physical space to emotional support. However, although current age-friendly environments emphasize spatial and technological integration, they often overlook the experiential impact of chair design, despite chairs being among the most frequently used products by older adults.

Among various household components, chairs serve as one of the most frequently used pieces of furniture for older adults and carry core human–furniture support functions. Most older adults spend a large proportion of their daytime seated on chairs, and the structural comfort, support performance, and interaction safety of chairs have a direct impact on the maintenance of physical function (Matsuo *et al.* 2017). Human–chair interaction is influenced not only by differences in body dimensions, but also significantly depends on the functional type of the chair and the specific needs of the target user group (Valipoor *et al.* 2018). Well-designed age-friendly chairs typically consider factors such as foot force distribution, seat height, and the installation angle of armrests (Matsuo *et al.*

2017). These design considerations help reduce pressure on the feet during standing movements and alleviate musculoskeletal discomfort (Vink and Hallbeck 2012). Armrests are particularly important for assisting users in standing up, as they reduce trunk flexion as well as hip and knee joint moments (Nemoto and Ogawa 2006). Non-concave seats (flat or slightly forward-tilted surfaces) further facilitate standing movements among older adults. Jeyasurya *et al.* confirmed that seating devices with stand-assist functions are more beneficial for rehabilitation, and that adjustable support devices, such as lift chairs, lifting cushions, powered standing devices, armrests, and standing frames, demonstrate higher effectiveness (Jeyasurya *et al.* 2013). In addition to functional performance, material design also directly influences user experience and perceived comfort.

Compared with metal materials, wood has lower thermal conductivity and does not become excessively cold in winter or overheated in summer. For older adults with weaker circulatory systems and higher sensitivity to temperature changes, wooden armrests and seating surfaces provide a more stable and comfortable thermal perception (Zhang *et al.* 2025). At the same time, wood, as a natural material, serves as a key design element for enhancing emotional experience among older adults (L. Li *et al.* 2025). The presence of solid wood in indoor environments has been shown to significantly reduce stress levels and improve indoor air quality, with these perceptions arising from both the visual and tactile properties of wood (Mamić and Domljan 2023; Zhuan 2023). Wooden materials can enhance positive emotions and reduce negative emotions, thereby contributing to improved emotional health (Kumpulainen *et al.* 2024). In addition to being favored for their visual and psychological qualities, wood also offers favorable material properties, including lower weight and good cushioning performance (Kwak and Choi 2025). Wood treated with antibacterial processes can resist corrosion and inhibit mold growth. As a result, contemporary furniture design for older adults widely adopts wood as part of mixed-material design strategies.

Feline Behavior Stimulation Strategies

Cats’ natural behavioral needs, such as climbing, scratching, sniffing, and chasing, and the constraints imposed on these behaviors in indoor environments, have become a central issue in improving the quality of human–pet interaction. Existing indoor feline behavior stimulation designs generally follow three main approaches: (1) behavior stimulation approaches, which enhance cats’ exploratory behavior and activity levels through hunting simulations, dynamic visual stimuli, and olfactory stimulation (Strickler and Shull 2014; Shreve *et al.* 2017); (2) behavior management approaches, which address potentially destructive behaviors, such as scratching of furniture, which can be addressed through scratching boards and behavior redirection strategies (Rossi *et al.* 2023); and (3) spatial coordination approaches, which rely on intelligent devices to guide behavior and alleviate anxiety, but are predominantly cat-centered and lack systematic consideration of operational convenience and interactive participation for human users, particularly older adults (Han and Witzman 2023). In response to these limitations, the design framework proposed in this study treats climbing, scratching, sniffing, and interactive feedback as core inputs on the feline side, while defining operational convenience, safety support, and emotional interaction as key requirements on the older adult user side, thereby constructing a dual-objective design pathway for human–pet co-living that addresses the structural gaps in both theoretical logic and practical implementation within existing cross-species shared furniture research.

Research Gaps in Human–Pet Co-living Furniture

With the shrinking of household structures and the increasing number of older adults living alone, the role of pets in providing emotional support and social connection for the elderly has become increasingly prominent. Previous studies indicate that animal companionship can effectively alleviate loneliness, depression, and social isolation, and that human–pet relationships are gradually shifting from emotional comfort–oriented interactions toward a deep co-living model characterized by high overlap in daily routines and spatial use (Applebaum *et al.* 2021; Kretzler *et al.* 2022). However, compared with the growing dependence of older adults on pets, systematic research on multi-species furniture remains significantly underdeveloped. These gaps can be understood at three levels: theoretical, methodological, and application. At the theoretical level, existing designs tend to focus either on animal behavioral welfare or on ergonomic safety for older adults, with the two remaining largely separated in both theory and methodology (Obradović *et al.* 2020). Although recent multi-species co-living studies emphasize design concepts centered on shared spaces between humans and non-human agents, most remain at the architectural or environmental scale and offer limited guidance for structural and functional integration at the furniture level (Saeidi 2023). At the methodological level, there is still a lack of pathways for systematically translating dual-user requirements into structured design decisions and engineering-oriented parameters. At the application level, within the field of furniture design, there is still a lack of co-design approaches capable of simultaneously supporting cats' natural behavior stimulation and older human adults' needs for safety, convenience, and emotional companionship.

Throughout human history, human–pet symbiotic relationships have remained one of the most stable forms of cross-species interaction and constitute an important resource for physical and mental health. Existing research has demonstrated that pet ownership produces positive effects across multiple physiological and psychological dimensions, including improved cardiovascular function, stabilized blood pressure, reduced risk of coronary heart disease, and enhanced rehabilitation outcomes (Headey 1999; Allen *et al.* 2001). Positive human–pet interactions are also significantly associated with higher subjective well-being (Chopik *et al.* 2025), and qualitative studies further indicate that pets are regarded by older adults as family members and key sources of emotional support (Reniers *et al.* 2023). Among companion animals, cats have become the primary companions in urban elderly households due to their high level of independence, low caregiving demands, and strong adaptability to indoor environments (Franck *et al.* 2022). As population aging and household miniaturization continue to accelerate, relationships between older adults and pet cats are transitioning from one-directional emotional comfort toward a deep co-living model that emphasizes spatial sharing, behavioral interaction, and functional coordination. Consequently, a significant gap remains in current human–pet co-living research, as a dual-subject co-design framework capable of simultaneously addressing cats' behavioral needs and older adults' physical and psychological requirements has yet to be established. This theoretical gap constitutes the key driving force behind the development of the human–cat dual-objective co-design approach proposed in this study.

Multi-method Collaborative Product Design and Decision-Making Pathway

To systematically address the design requirements of both human and feline users, this study constructs a multi-method collaborative pathway composed of KANO–AHP–QFD–TOPSIS, forming a complete decision-making chain from requirement identification to optimal solution selection. First, the Kano model, proposed by Noriaki Kano as a user requirement classification tool, is capable of revealing the non-linear relationship between user requirements and satisfaction, and has been successfully applied in furniture design optimization (Kapuria *et al.* 2020). The study by Wu *et al.* further demonstrates that the Kano model can translate subjective preferences into clearly defined requirement indicators (M. Li and Zhang 2021) integrating Kano Model, AHP, and QFD methods for new product development based on text mining, intuitionistic fuzzy sets, and customers satisfaction.

Based on this approach, the present study identifies basic, expected, and attractive requirements for both human and cat users. Second, AHP, as a weight quantification method under multi-criteria conditions (Pant *et al.* 2022), enables the determination of requirement priorities through pairwise comparison. Lu *et al.* (1994) confirmed its reliability in evaluating the importance of customer requirements. It is therefore employed to determine the weight distribution of each requirement. After obtaining weighted requirements, QFD is applied to systematically transform user requirements into technical functions. As a user-oriented quality tool proposed by Akao Corporation, QFD has shown strong performance in eco-design and sustainable product development (Büyüközkan and Berkol 2011), and is effective in handling requirement ambiguity. The study by Varolgunes *et al.* (2021) indicates that the combination of QFD and AHP can support the derivation of optimal design solutions. Accordingly, the present study constructs a requirement–technology matrix to ensure traceability of the design logic. Finally, TOPSIS is employed for the comprehensive evaluation of multiple design alternatives. Based on the relative distances to the positive ideal solution and the negative ideal solution, TOPSIS selects the optimal option among three prototypes through steps including normalization, weighting, distance calculation, and ranking (Kuo 2017). It should be noted that each method has inherent limitations, such as the potential subjectivity in AHP weighting and the possibility of cumulative bias across sequential decision-making steps. However, the integration of these methods allows for a complementary process in which qualitative user requirements are progressively translated into quantitative design decisions, thereby reducing the limitations of any single method and enhancing overall robustness. In summary, the Kano model is responsible for requirement identification, AHP performs weight quantification, QFD establishes the requirement–technology mapping, and TOPSIS enables solution selection. Together, these methods form a progressive collaborative design chain that provides systematic methodological support for scientific decision-making in the design of age-friendly human–cat interactive chairs.

METHOD

Research Methodology

For multi-role and multi-objective co-living product design requirements, as illustrated in Fig. 1, this study integrates the Kano model, AHP, QFD, and TOPSIS to construct a closed-loop design pathway of "requirement identification–weight determination–function transformation–solution evaluation." This framework can be understood as a sequential process from input (user requirements), to processing (Kano－AHP－QFD integration), and finally to output (TOPSIS-based solution evaluation). This pathway effectively supports the systematic integration of two core objectives, namely feline behavior stimulation and elderly well-being.

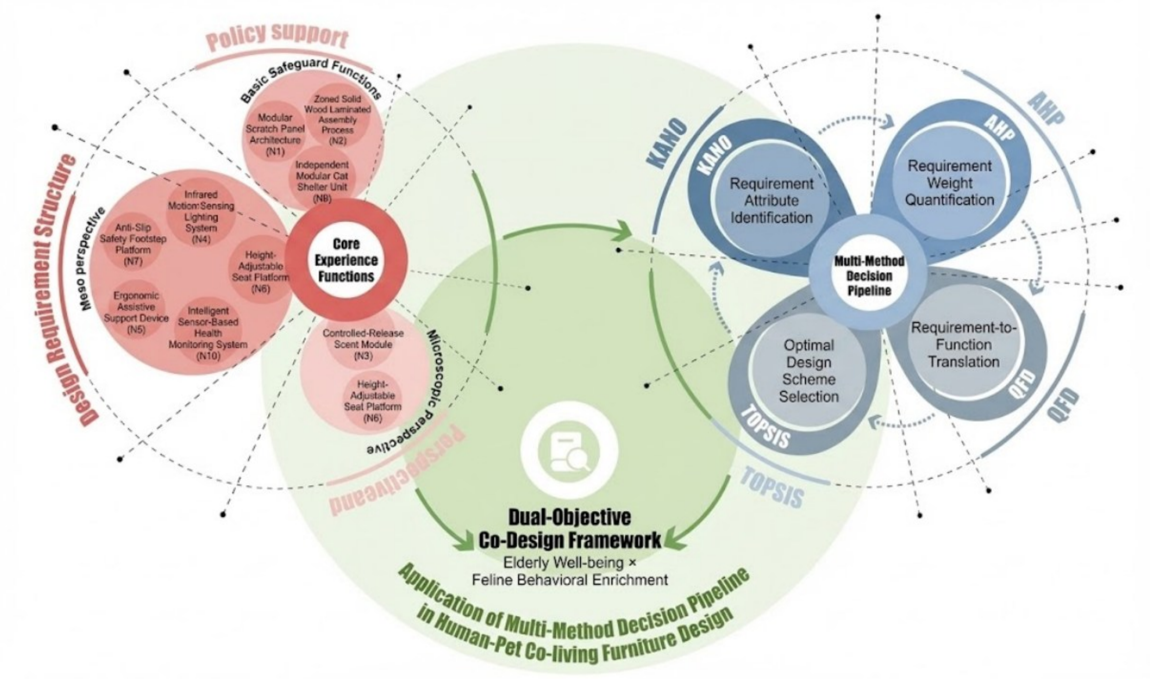

Fig. 1. Framework of the literature review

The scientific validity and applicability of this pathway have been supported by previous studies. M. Li and Zhang (2021) employed the Kano model to identify user requirements for shoe-changing chairs for older adults and further combined AHP and QFD to rank the relative importance of design elements, providing new research insights for the development of age-friendly furniture. (Z. Liu *et al.* 2024) proposed a user-requirement-driven evaluation method in research on mother–infant-friendly product design by integrating the Kano model, AHP, and QFD to systematically identify the multi-level needs of mothers and infants and effectively translate them into implementable product design elements. Taking a breastfeeding chair as a case study, their research verified the effectiveness of the three-method integrated pathway in optimizing user experience and enhancing usage intention, offering a structured design process reference for user-centered product development and providing methodological support for the construction of the co-design pathway in human–pet co-living contexts addressed in this study.

Construction of the Kano Model

Data collection

Based on a cross-species co-living design framework, this study adopts a dual-user modeling strategy to identify functional requirements for the intelligent human–cat interactive chair, defining older adults and domestically kept cats as two distinct user groups. Feline behavior data were collected through a combination of owner interviews and on-site observation. A total of 30 adult domestic cats (15 females and 15 males) were selected as observation subjects. The sample was recruited through voluntary participation from urban households, and inclusion criteria required that the cats were healthy, indoor-kept, and had lived with their owners for an extended period. The Fe-BARQ (Feline Behavior Assessment and Research Questionnaire) was used as an indirect owner-reported assessment tool to capture cats' behavioral tendencies in daily environments. In addition, continuous seven-day behavioral observation logs and fixed-point video recordings were collected, as shown in Table 1, to quantitatively code typical in-home behaviors such as climbing, scratching, resting, sniffing, and interaction. Behavioral categorization was based on predefined behavior types derived from common indoor feline activity patterns. The coding process considered both the frequency and duration of each behavior to reflect behavioral intensity and preference. To ensure consistency, all observation data were cross-checked by multiple members of the research team using unified coding criteria. Through cross-analysis of multi-source data, core feline behavior stimulation patterns in indoor furniture environments were identified and mapped to older adult functional expectations.

Table 1. Quantitative Coding of Feline Behaviors

Behavior Code	Behavior Name	Behavior Definition	Recording Unit	Example Criteria	Notes (Design Function Mapping)
B01	Climbing	All four limbs leave the ground as the cat jumps upward and attaches to a structure higher than shoulder level.	B01	Climbing	All four limbs leave the ground as the cat jumps upward and attaches to a structure higher than shoulder level.
B02	Scratching	Front paws remain in contact with a surface for ⩾1 s with repeated scratching motion.	B02	Scratching	Front paws remain in contact with a surface for ⩾1 s with repeated scratching motion.
B03	Sniffing	Nose tip within <2 cm of target surface for ⩾0.5 s	B03	Sniffing	Nose tip within <2 cm of target surface for ⩾0.5 s
B04	Resting	Lying posture with body in contact with surface, motionless for >30 s	B04	Resting	Lying posture with body in contact with surface, motionless for >30 s
B05	Human interaction	Active approach, rubbing, vocalizing, or jumping onto older adult's lap	B05	Human interaction	Active approach, rubbing, vocalizing, or jumping onto older adult's lap
B06	Alert solitude	Stationary posture with ear or head movement, tail flicking, sustained gazing	B06	Alert solitude	Stationary posture with ear or head movement, tail flicking, sustained gazing
B07	Catnip response	Rolling, licking, biting, or rubbing after scent exposure	B07	Catnip response	Rolling, licking, biting, or rubbing after scent exposure

In the process of collecting requirements from older adults, the research team recruited a total of 120 participants aged between 65 and 75 years. Data were mainly collected through two methods: semi-structured in-depth interviews and structured questionnaire surveys. The questionnaire combined a five-point Likert scale with open-ended questions, focusing on key design dimensions, such as sit-to-stand support, operational convenience, emotional companionship, and pet interaction, to systematically collect older adults' functional expectations and attitude evaluations toward shared pet furniture. A total of 120 questionnaires were distributed, and 98 valid questionnaires were returned. While the sample provides relevant user insights, it may reflect a certain degree of selection bias toward more active and pet-friendly older adults. As shown in Table 2, from the perspective of dual users (older adults and cats), the research team identified 11 preliminary requirement elements, including a replaceable scratching layer, modular cat shelter unit, catnip scent module, interactive light feedback, embedded assistive armrests, height-adjustable seat surface, anti-slip foot platform, composite structure of cypress/white oak/birch wood, health monitoring function, and feeding and hydration module. These requirements were subsequently introduced into the Kano model questionnaire classification process, serving as the basis for subsequent AHP weight calculation and QFD function transformation.

Table 2. User Requirement Classification Table

Function Category	User Requirement	Code
Feline behavior stimulation and interaction functions	Replaceable scratching layer	N1
	Composite structure of cypress / white oak / birch wood	N2
	Catnip scent module	N3
	Interactive light feedback	N4
Elderly assistive and age-friendly functions	Embedded assistive armrests	N5
	Height-adjustable seat surface	N6
	Anti-slip foot platform	N7
Human－pet emotional resonance and calming functions	Removable and washable seat cover	N8
	Modular cat shelter unit	N9
Intelligent monitoring and care reminder functions	Health monitoring function	N10
	Feeding and hydration module	N11

Data analysis

To reveal how different types of requirements influence user satisfaction, the Kano model was applied to classify user quality requirements identified at the early design stage into distinct attribute categories, including Must-be attributes (M), One-dimensional attributes (O), Attractive attributes (A), Indifferent attributes (I), Reverse attributes (R), and Questionable attributes (Q). Subsequently, the Better–Worse coefficient method was used to analyze each functional requirement by calculating its satisfaction coefficient and dissatisfaction coefficient. The specific values were calculated using the equations proposed by Zhao and Chen (2021), as shown in Eqs. 1 and 2:

$$\text{Better}_i = \frac{A_i + O_i}{A_i + O_i + M_i + I_i} \tag{1}$$

$$\text{Worse}_i = -\frac{O_i + M_i}{A_i + O_i + M_i + I_i} \tag{2}$$

The classification of user requirement attributes and the corresponding satisfaction coefficients are shown in Table 3. The functional features of the intelligent human–cat interactive chair exhibit stratified attribute characteristics in users' perceptions. Mandatory attributes (M), including N1 (replaceable scratching layer), N2 (composite structure of cypress/white oak/birch wood), N7 (anti-slip foot platform), and N9 (modular cat shelter unit), present the largest absolute values of the Worse coefficient, clearly reflecting users' high dependency on these fundamental functions and their zero-tolerance attitude toward their absence. That is, the absence of any of these functions leads to a significant decrease in user satisfaction, while their presence is regarded merely as a basic requirement and does not result in a notable increase in satisfaction. One-dimensional attributes (O), namely N3 (catnip scent module) and N6 (height-adjustable seat surface), are characterized by both high Better and high Worse coefficients, indicating that users are highly sensitive to these functions. Their presence can significantly enhance the user experience, whereas their absence generates strong dissatisfaction, making them core experiential elements in product design and iteration. Attractive attributes (A), including N4 (interactive light feedback), N5 (embedded assistive armrests), and N10 (health monitoring function), mainly demonstrate high Better coefficients and relatively low Worse coefficients, suggesting that these functions provide emotional value-added effects. Such features contribute to enhanced market appeal and stronger emotional attachment to the product. In contrast, indifferent attributes (I), namely N8 (removable and washable seat cover) and N11 (feeding and hydration module), show no significant impact on user satisfaction regardless of whether they are present, and are therefore recommended as optional configurations or low-priority development items. Overall, N1 to N11 reflect a diversified distribution of user needs across basic support functions, core experiential functions, and emotional value-added functions, providing a solid empirical basis for the scientific optimization and precise positioning of intelligent age-friendly pet furniture.

Table 3. User Requirement Attributes and Satisfaction Coefficients

Function / Service	A	O	M	I	R	Q	Attribute	Better	Worse
N1 and N1.1	17.71%	29.17%	29.17%	23.96%	0.00%	0.00%	M	46.88%	-58.33%
N2 and N2.1	14.58%	25.00%	50.00%	10.42%	0.00%	0.00%	M	39.58%	-75.00%
N3 and N3.1	19.79%	41.67%	12.50%	25.00%	0.00%	1.04%	O	62.11%	-54.74%
N4 and N4.1	32.29%	28.13%	13.54%	26.04%	0.00%	0.00%	A	60.42%	-41.67%
N5 and N5.1	43.75%	15.63%	12.50%	28.13%	0.00%	0.00%	A	59.38%	-28.13%
N6 and N6.1	15.63%	38.54%	12.50%	29.17%	4.17%	0.00%	O	56.52%	-53.26%
N7 and N7.1	14.58%	21.88%	44.79%	18.75%	0.00%	0.00%	M	36.46%	-66.67%
N8 and N8.1	15.63%	6.25%	12.50%	65.63%	0.00%	0.00%	I	21.88%	-18.75%
N9 and N9.1	10.42%	14.58%	42.71%	31.25%	0.00%	1.04%	M	25.26%	-57.89%
N10 and N10.1	36.46%	20.83%	18.75%	22.92%	1.04%	0.00%	A	57.89%	-40.00%
N11 and N11.1	32.29%	9.38%	11.46%	46.88%	0.00%	0.00%	I	41.67%	-20.83%
Note: A: Attractive attribute, O: One-dimensional attribute, M: Must-be attribute, I: Indifferent attribute, R: Reverse attribute, Q: Questionable attribute									

The distribution map of the Better–Worse coefficients provides both quantitative and intuitive decision support for evaluating user perception sensitivity and development priority of each function. As shown in Fig. 2, performance-type functions are mainly concentrated in the first quadrant, characterized by "high satisfaction gain and high dissatisfaction when absent," indicating their central role in user experience and their importance as key targets for functional innovation and optimization. Attractive functions are distributed in the second quadrant, reflecting "high satisfaction bonus and low dissatisfaction risk," and represent the strategic direction for emotional value enhancement and brand differentiation. Must-be functions, including the modular cat shelter unit (N9), are located in the fourth quadrant, highlighting their role as "basic and indispensable requirements," which must be prioritized in design and manufacturing to ensure proper configuration and quality, so as to avoid sharp declines in user satisfaction caused by functional absence. Indifferent functions (such as N8 and N11) appear in the third quadrant and show limited influence on user experience; therefore, their development priority can be appropriately reduced or addressed through optional configurations to meet the needs of specific user groups. Overall, the dual-coefficient Better–Worse analysis effectively reveals the multidimensional attribute structure of user requirements and provides solid theoretical support and data evidence for the functional allocation, innovation direction, and market segmentation strategy of intelligent age-friendly pet furniture.

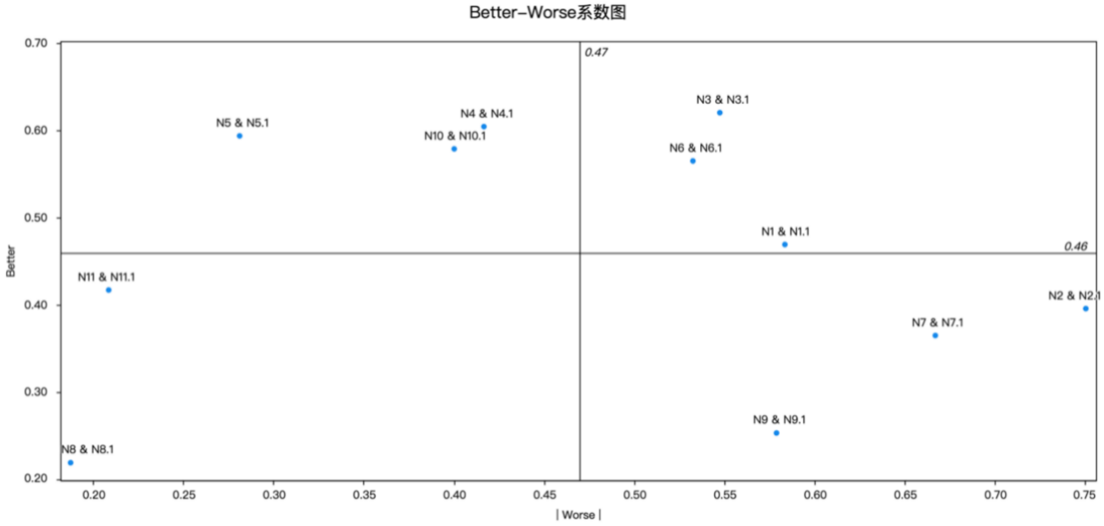

Fig. 2. Better–worse coefficient diagram

Construction of the Kano Model

To further clarify the functional priorities in the design of the cat chair, this study introduces AHP to quantitatively evaluate the importance of different categories of requirements based on the user requirement attributes identified through the Kano model. Through constructing a judgment matrix and calculating normalized weights, AHP enables effective comparison of the relative priorities among different design elements, thereby complementing and refining the results obtained from the Kano model (Y. Liu *et al.* 2020). Because of its systematic structure, objectivity, and operational convenience in addressing multi-criteria decision-making problems, AHP has been widely applied in recent years in the field of product design and development. In the functional priority evaluation of the cat chair in this study, N8 (removable and washable seat cover) and N11 (feeding and hydration module) were classified as Indifferent (I) attributes by the Kano model, with both their Better and Worse coefficients remaining at relatively low levels, indicating that users exhibited very limited perceptual sensitivity and subjective expectations toward these two functions. This suggests that whether such functions are included or not has no significant impact on improving overall user satisfaction or increasing the risk of dissatisfaction. Therefore, in the subsequent construction of the AHP judgment matrix and weight modeling, N8 and N11 were rationally excluded, and only the must-be, one-dimensional, and attractive functions that exert substantial driving effects on user satisfaction were retained, providing a solid data foundation and theoretical basis for scientifically optimizing design decisions. Based on these criteria, a hierarchical structure model was established, as shown in Table 4.

Table 4. AHP Hierarchical Structure Design

Goal Level	Criteria Level	Alternative Level
Optimal user satisfaction design of the intelligent human–cat interactive chair	C1 Basic support functions (must-be attributes, M)	N1, N2, N7, N9
	C2 Core experience functions (one-dimensional attributes, O)	N3, N6
	C3 Emotional add-on functions (attractive attributes, A)	N4, N5, N10

To ensure the scientific rigor and diversity of weight allocation, this study organized an expert panel consisting of six members, including three experienced pet furniture designers, two professors in the field of furniture design, and one long-term actual user representative. The expert panel adopted the 9-point scale method proposed by Darko *et al.* (2019) to conduct pairwise comparisons of all major requirement indicators, systematically evaluating the relative importance of each indicator with respect to the objective of optimizing user satisfaction. Although the number of experts is relatively limited, all participants possess relevant domain expertise. Previous studies have demonstrated that small but specialized expert panels can provide reliable results in AHP-based evaluations, particularly in design-oriented decision-making contexts. Each pairwise comparison was independently scored by the six experts, after which the arithmetic mean method was applied to average the comparison scores and form the final judgment matrix. The eigenvector derived from this matrix represents the weight value of each functional item. In this study, a 9 × 9 AHP judgment matrix was constructed for the nine key functional indicators of the intelligent human–cat interactive chair (N1–N2–N3–N4–N5–N6–N7–N9–N10), enabling a systematic quantitative comparison of the relative importance of each function in achieving optimal user satisfaction. As shown in Table 5, the judgment matrix strictly follows the methodological principles of AHP, with diagonal elements equal to 1 and reciprocal relationships maintained among the remaining elements, while the expert evaluations reflect the relative priority of each function with respect to the overall design objective.

Table 5. AHP Input Data

	N1	N2	N3	N4	N5	N6	N7	N9	N10
N1	1	2	3	4	5	3	2	3	5
N2	1/2	1	2	3	4	2	2	2	4
N3	1/3	1/2	1	1	2	1	1/2	1	2
N4	1/4	1/3	1	1	1	1	1/2	1	1
N5	1/5	1/4	1/2	1	1	1/2	1/3	1/2	1

Using the eigenvector method, the weights of each functional requirement were calculated, as shown in Table 6. The results indicate that N1 (replaceable scratching layer) and N2 (composite structure of cypress/white oak/birch wood) have significantly higher weights than the other functions, reflecting the strong emphasis placed by experts and users on basic support functions (must-be attributes). Functions, such as N7 (anti-slip foot platform) and N9 (modular cat shelter unit) also exhibit relatively high weights, indicating their important role in improving user satisfaction in terms of safety and structural adaptability. The weights of one-dimensional attributes and attractive attributes are comparatively lower, while indifferent attributes were eliminated during the preliminary stage of the AHP model.

Table 6. Results of AHP Hierarchical Analysis

Item	Eigenvector	Weight	Maximum Eigenvalue	CI Value
N1	2.161	24.007%	9.387	0.048
N2	1.698	18.864%		
N3	0.852	9.471%		
N4	0.588	6.532%		
N5	0.479	5.322%		
N6	0.684	7.597%		
N7	1.217	13.525%		
N9	0.852	9.468%		
N10	0.469	5.213%		

To ensure the scientific validity of weight allocation, this study conducted a consistency test of the judgment matrix following the standard AHP procedure. As shown in Tables 7 and 8, by calculating the maximum eigenvalue (9.387) and the consistency index (CI = 0.048), and in combination with the random consistency index (RI = 1.460) corresponding to a ninth-order judgment matrix, the consistency ratio (CR) was obtained as 0.033. This value is significantly lower than the commonly accepted threshold of 0.1, indicating that the judgment matrix demonstrates good consistency and that the derived weight results are reliable. Overall, the AHP analysis not only quantifies the priority of each functional requirement in optimizing user satisfaction, but also provides a solid quantitative foundation for subsequent QFD-based design decisions and multi-scheme optimization.

Table 7. Random Consistency Index (RI) Values

Order (n)	3	4	5	6	7	8	9	10	11
RI value	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52
Order (n)	12	13	14	15	17	18	19	20	21
RI value	1.54	1.56	1.58	1.59	1.6064	1.6133	1.6207	1.6292	1.6358
Order (n)	22	23	24	25	26	27	28	29	
RI value	1.6403	1.6462	1.6497	1.6556	1.6587	1.6631	1.6670	1.6693	

Table 8. Consistency Test Results

Maximum Eigenvalue	CI value	RI value	CR value	Consistency Result
9.387	0.048	1.460	0.033	Passed

Through the systematic comparison and weighted calculation of functional indicators for the intelligent human–cat interactive chair using the AHP method, the composite ranking of the target hierarchy was obtained as follows: N1 > N2 > N7 > N9 > N3 > N6 > N4 > N5 > N10. The results indicate that users place the strongest emphasis on fundamental support and safety-related functions of the product, such as the replaceable scratching layer, removable and washable seat cover, anti-slip foot platform, and composite wood structure. This finding clearly reflects that efficient space utilization, structural stability, and ease of maintenance are primary concerns in the design of age-friendly pet furniture. With the diversification of contemporary interior aesthetics and lifestyles, users' expectations for the integration of functionality and visual appeal continue to increase, and material quality and craftsmanship details have become important considerations for product differentiation.

Furthermore, functions ranking relatively high in the AHP results also include experiential and health-related attributes, such as the catnip scent module and the height-adjustable seat surface. This suggests that, after basic requirements are satisfied, users increasingly focus on ergonomics, comfort, and health-promoting effects of furniture. This trend aligns with broader societal concerns regarding the quality of life and psychological well-being of older adults. However, in practical design processes, trade-offs and conflicts may arise among different functional indicators in terms of technical feasibility and resource allocation. Therefore, the next stage of the study will systematically introduce the QFD method to further decompose and transform core user requirements through the WHAT–HOW matrix, clarify the contribution relationships between design elements and overall performance, and achieve an accurate mapping from user value to technical implementation. This approach aims to establish a solid foundation for the innovative optimization and high-quality realization of intelligent age-friendly pet furniture.

Construction of the QFD Model

In this study, the user requirement weights of the cat chair derived through the AHP method provide a quantitative basis for the subsequent QFD process. These weights serve as an important reference for analyzing the relationships between user requirements and design functions, and facilitate a scientific evaluation of the contribution of each design function to satisfying user needs. During the QFD phase, the core requirements of older adults and cats are first systematically translated into specific design functions through the WHAT–HOW matrix. Subsequently, by combining the AHP-derived weights with the QFD relationship matrix, each design function is assigned a weighted score, where higher scores indicate a higher priority in contributing to the improvement of user satisfaction. As shown in Table 9, this approach not only clarifies the mapping relationships between user requirements and design functions, but also provides solid theoretical and data support for the subsequent selection of optimized solutions and the rational allocation of design resources, thereby enhancing user satisfaction and market competitiveness of intelligent age-friendly pet furniture.

To effectively translate user requirements into specific design parameters, this study adopts the QFD approach to construct a House of Quality model. Based on the key user requirements and design function items identified through the preceding Kano and AHP analyses, an expert panel was formed consisting of five industrial design experts with experience in pet furniture design and three pet behavior consultants with more than two years of experience in cat ownership.

Table 9. Transformation of User Requirement Summaries into Design Functions

Code	Requirement Item	Requirement Description	Design Function
N1	Replaceable scratching layer	Scratching area designed for frequent feline scratching behavior; modular structure allows quick replacement	Modular scratching structure F1
			Quick-release scratching board slot F2
N2	Cypress / white oak / birch composite structure	Natural wood composite structure supporting durability and sensory comfort	Natural wood segmented assembly process F3
N3	Olfactory stimulation	Scent-based stimulation to encourage feline exploration	Replaceable scent pouch structure F4
N4	Night-time guidance	Lighting assistance for safe night-time use	Infrared sensor lighting system F5
N5	Sit-to-stand assistance	Support for posture change and balance	Ergonomic assistive support device F6
N6	Height adaptability	Adjustment to different sitting and climbing needs	Height-adjustable seat structure F7
			Multi-level lifting and locking system F8
			Sloped auxiliary climbing edge structure F9
N7	Safety support	Prevention of slipping and falling	Anti-slip safety foot platform F10
N9	Independent resting space	Dedicated resting area for cats	Independent modular cat shelter structure F11
			Quick-release / magnetic connection system F12
N10	Health monitoring	Monitoring of basic health-related indicators	Intelligent health sensing system F13

This panel systematically evaluated the relationships between user requirements and design functions. In the constructed requirement–function relationship matrix, correlation strength was classified into three levels: weak, moderate, and strong, denoted by the symbols △, □, and ■, and assigned corresponding scores of 1, 3, and 5, respectively (Sakao 2007). If a design function had no direct relationship with a given requirement, the corresponding cell was left blank.

Table 10. Summary of House of Quality (HoQ) Evaluation Scores

User's Requirement		Design Function													
Requirement	Weight	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
N1	24.0072%	■	■					△	□						
N2	18.8640%		■	■			△								
N3	9.4712%			■											
N4	6.5321%				■										
N5	5.3221%					■									
N6	7.5973%						■	□			■	■			
N7	13.5252%	△					□	■					■		
N9	9.4684%								■	■				■	
N10	5.2128%														■

To enhance objectivity, the matrix incorporated the AHP-derived relative weights of user requirements, enabling a quantitative scoring mechanism based on the product of correlation strength and user weight.

The total score of each design function is calculated using the following weighted cumulative formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \tag{3}$$

Table 11. Ranking of Design Function Weights

Rank	Design Function Code	Design Function Name	Primary Related Requirement	Total Score (Fi)	Priority Level
1	F1	Modular Scratch Panel Architecture	N1	1.20	Level 1
2	F2	Quick-Release Scratch Panel Slot System	N1	1.15	Level 1
3	F3	Zoned Solid Wood Laminated Assembly Process	N2	1.10	Level 1
4	F4	Controlled-Release Scent Module	N3	0.95	Level 2
5	F5	Replaceable Scent Sachet Structure	N3	0.90	Level 2
6	F6	Infrared Motion-Sensing Lighting System	N4	0.88	Level 2
7	F7	Ergonomic Assistive Support Device	N5	0.85	Level 2
8	F8	Height-Adjustable Seat Platform	N6	0.80	Level 2
9	F9	Multi-Level Lift-and-Lock Mechanism	N6	0.75	Level 2
10	F10	Ramp-Integrated Assisted Climbing Edge	N6	0.68	Level 2
11	F11	Anti-Slip Safety Footstep Platform	N7	0.65	Level 2
12	F12	Independent Modular Cat Shelter Unit	N9	0.63	Level 2
13	F13	Quick-Release / Magnetic Modular Coupling System	N9	0.61	Level 2
14	F14	Intelligent Sensor-Based Health Monitoring System	N10	0.52	Level 2

In this formulation, Fi represents the final total score of the i-th design function, R_{ij} denotes the correlation score between the i-th design function and the j-th user requirement (with assigned values of 1, 3, or 5), and W_j represents the AHP weight of the j-th user requirement. Taking the modular scratching structure as an example, its score is calculated by adding the products of the weights of all related user requirements and their corresponding correlation values of 1, 3, or 5, depending on whether the relationship is weak, moderate, or strong. After calculating the scores for all design functions, the results are ranked from highest to lowest and classified into three priority levels: Level I (score > 1), Level II (score between 0.5 and 1), and Level III (score < 0.5). This hierarchical classification helps clarify the core directions for subsequent product optimization and development, ensuring that limited design resources are prioritized toward key functional modules associated with high-weight requirements, thereby systematically enhancing the overall user satisfaction and market adaptability of intelligent human–cat shared furniture.

RESULTS AND DISCUSSION

Research Findings

To efficiently translate user requirements into implementable design solutions, a hybrid design workflow was developed by integrating large language models (LLMs) and diffusion-based image generation models into the QFD analysis process. This approach aimed to improve the semantic accuracy and functional coverage of early-stage design outputs (Chen *et al.* 2024). The eleven key design attributes identified during the QFD phase, along with their corresponding priority weights, were used as core semantic inputs. These elements were integrated into a triadic semantic unit composed of functional attributes, usage scenarios, and human–cat interaction behaviors to generate design prompts.

Fig. 3. Dataset of human–pet interactive chairs

Through a continuous iterative process, multiple candidate prototypes were produced, ultimately forming a preliminary dataset of design solutions (Fig. 3). Based on criteria including functional coverage, semantic alignment, and design completeness, three highly matched solutions were selected from this dataset. Quantitative evaluation and ranking were then conducted using TOPSIS, a multi-attribute decision-making method based on proximity to the ideal solution. Three alternative human–cat interactive chair designs were selected (Figs. 4 through 6): Option A (basic type), Option B (balanced type), and Option C (intelligent type).

During the TOPSIS decision-making process, the construction of the original decision matrix served as the foundation for the quantitative comparison of multiple design alternatives. First, an evaluation panel composed of experts with backgrounds in design, engineering, and user experience was organized to independently and objectively score three alternative design schemes—A (basic type), B (balanced type), and C (intelligent type)—across six predefined core evaluation criteria, namely structural stability, feline behavior stimulation, operational convenience for older adults, intelligence of health monitoring, material sustainability, and manufacturing cost. The scoring method adopted either a 1 to 10 rating scale or a five-point Likert scale, with scores assigned based on each scheme's actual performance and level of innovation with respect to each criterion.

Fig. 4. Chair for Pets – Option 1

Fig. 5. Chair for Pets – Option 2

Fig. 6. Chair for Pets – Option 3

On this basis, all expert scores were aggregated using weighted averaging or consistency testing to eliminate individual subjective bias, thereby forming a standardized original decision matrix. Each element x_{ij} in the matrix represents the comprehensive score of the i-th scheme under the j-th evaluation criterion. This matrix not only comprehensively reflects performance differences among the schemes across all criteria, but also provides a solid data foundation for subsequent normalization and multi-attribute optimization.

Table 12. Original Decision Matrix of Design Alternatives

Scheme	Structural Stability	Feline Behavior Stimulation	Operational Convenience for Older Adults	Health Monitoring Intelligence	Material Sustainability	Manufacturing Cost
A	8	6	8	4	7	8
B	9	8	7	8	9	6
C	7	9	9	9	8	4

Normalization of Evaluation Indicators

To eliminate the influence of differing dimensions and value ranges among evaluation criteria and to ensure comparability across attributes, normalization of the original decision matrix is required. The purpose of normalization is to standardize the scores of each scheme under each criterion into the same interval, thereby avoiding weight imbalance caused by differences in units or scales. Specifically, for benefit-type indicators (*i.e.*, indicators for which higher scores indicate better performance), the vector normalization method is adopted, as shown in the following Eq. 4,

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \tag{4}$$

where x_{ij} denotes the original score of the iii-th scheme under the jjj-th criterion, nnn represents the number of schemes, and r_{ij} is the normalized value. For cost-type indicators (*i.e.*, indicators for which lower scores indicate better performance), such as manufacturing cost, inverse or reverse normalization methods are often applied, as expressed by Eq. 5:

$$r_{ij} = \frac{1}{x_{ij}} \tag{5}$$

After completing the normalization process, the normalized decision matrix must be weighted according to the relative importance of each evaluation criterion. The weights of the criteria are determined based on the results of the preceding AHP and QFD analyses, ensuring that weight allocation accurately reflects core user requirements and expert consensus. Specifically, each normalized value r_{ij} is multiplied by its corresponding weight w_j to obtain the weighted normalized decision matrix v_{ij}, as shown in the following Eq. 6,

$$v_{ij} = w_j \cdot r_{ij} \tag{6}$$

where v_{ij} represents the weighted normalized score of the i-th scheme under the j-th criterion, and w_j denotes the weight of the j-th criterion. This step not only preserves the advantages of normalization but also incorporates the influence of each criterion on the overall decision, thereby ensuring the scientific validity and rationality of the decision results. The weighted normalized decision matrix provides a robust data foundation for subsequent distance calculations to the ideal solutions (PIS/NIS) and for the final scheme selection, enabling comprehensive performance evaluation of multiple schemes under multiple attributes and weights.

After obtaining the weighted normalized decision matrix, the positive ideal solution (PIS) and negative ideal solution (NIS) are first determined according to the attribute type of each criterion (benefit-type or cost-type). The PIS represents the theoretically optimal performance across all criteria, while the NIS corresponds to the worst performance. Specifically, for benefit-type indicators, the PIS is defined as the maximum value of each column, and the NIS is defined as the minimum value; for cost-type indicators, the PIS is the minimum value of each column, and the NIS is the maximum value. The PIS is denoted as $v^+ = (v_1^+, v_2^+, \ldots, v_m^+)$, and the NIS is denoted as $v^- = (v_1^-, v_2^-, \ldots, v_m^-)$. Subsequently, the Euclidean distances between each scheme and the PIS, as well as the NIS, are calculated as Eq. 7,

$$S_i^+ = \sqrt{\sum_{j=1}^{m}(v_{ij} - v_j^+)^2}, \quad S_i^- = \sqrt{\sum_{j=1}^{m}(v_{ij} - v_j^-)^2} \tag{7}$$

where S_i^+ represents the distance between the i-th -th scheme and the positive ideal solution, and s_i^- represents the distance between the i-th scheme and the negative ideal solution. This approach enables a comprehensive assessment of each scheme's proximity to both optimal and worst-case performance levels, providing a quantitative basis for final selection.

After obtaining the Euclidean distances between each scheme and both the positive and negative ideal solutions, the closeness coefficient (Closeness Coefficient, CiC_iCi) is further calculated using the following Eq. 8:

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-} \tag{8}$$

Table 13. TOPSIS Decision Results

Plan	S_i^+	S_i^-	C_i	Rank
A	0.164	0.076	0.317	3
B	0.057	0.163	0.741	1
C	0.104	0.122	0.540	2

The calculation results indicate that Scheme B (balanced type) exhibited the shortest distance to the positive ideal solution and the longest distance to the negative ideal solution across all evaluation criteria, achieving a closeness coefficient of 0.741 and demonstrating the best overall performance. Scheme A and Scheme C show closeness coefficients of 0.317 and 0.540, respectively, indicating relatively lower performance. These schemes may therefore be considered as alternative options for subsequent optimization or for development targeting segmented markets.

DISCUSSION

Based on the systematic analysis using the Kano–AHP–QFD framework, the results indicate that older users' furniture requirements continue to exhibit a structural pattern centered on safety, stability, and ergonomic support. Among these, the replaceable scratching layer (N1), natural composite wood structure (N2), and anti-slip foot platform (N7) were classified as "must-be attributes" and received the highest weights in the AHP analysis. This finding is consistent with conclusions from previous age-friendly furniture studies, which emphasize safety as the primary quality criterion of functional furniture (Strickler and Shull 2014). At the same time, cats' preferences for high-frequency behaviors, such as climbing, scratching, and sniffing, in indoor environments are also consistent with observations reported in animal behavior studies (Pageat *et al.* 2010; Franck *et al.* 2022), further supporting the scientific validity of the behavioral coding and requirement interpretation adopted in this study. Overall, the hierarchical structure of requirements identified in this study shows a high degree of consistency with previous research at both the physiological and behavioral levels, supporting the reliability of the dual-subject modeling approach. This pattern indicates that safety-oriented attributes function as baseline requirements for user acceptance, while interaction- and enrichment-related features primarily serve as value-added elements that enhance user engagement rather than replace fundamental support functions.

Differences, Conflicts, and Theoretical Contributions

Previous studies have often addressed human and pet requirements separately, focusing either on older adults' physical function and safety or on feline behavior enrichment strategies, while lacking systematic analysis of spatial sharing, emotional linkage, and behavioral coupling between the two. The dual-subject requirement model proposed in this study reveals that older adults' "safety–convenience–emotional needs" and cats' "climbing–scratching–exploration needs" can be coordinated through structural and functional mapping, rather than being treated as parallel and independent design tasks. For example, the integration of modular scratching structures with supportive seating elements enables simultaneous fulfillment of feline activity needs and elderly usability requirements within a shared spatial unit. This also suggests that, in practical design, priority should be given to integrated functional modules that simultaneously support safety and interaction, rather than treating these aspects as separate or sequential design considerations. More importantly, prior research on age-friendly furniture has rarely examined the role of "emotional support" or "human–pet interactive behavior" at the furniture level. Through incorporating attractive attributes, such as interactive lighting, health monitoring, and catnip modules, into the requirement hierarchy, this study extends the theoretical boundary of age-friendly furniture from physical support toward emotional support and cross-species interaction media. These findings help address a key theoretical gap in multispecies co-living design research, namely the lack of an engineering-oriented dual-subject framework.

Methodological and Cross-Disciplinary Contributions

The primary methodological contribution of this study lies in constructing a closed-loop, traceable cross-species furniture design pathway by integrating Kano, AHP, QFD, and TOPSIS. Unlike conventional product development processes that rely mainly on experiential judgment or single-method evaluation, this study uses the Kano model to identify requirement sensitivity attributes, AHP to extract functional weights, QFD to establish requirement–technology mapping matrices, and TOPSIS to complete comprehensive evaluation of multiple design alternatives. This approach enables full-path quantitative decision-making from "requirements → functions → technologies → optimal solution." Similar integrated methodologies have been validated in age-friendly furniture design and mother–infant product design, but have not yet been applied to cross-species co-living furniture. Through extending this approach to a human–pet dual-subject context, this study not only broadens the application scope of multi-method integration in design research, but also provides a transferable theoretical framework and engineering pathway for interdisciplinary design of intelligent furniture, human–pet interaction systems, and elderly care products.

However, several limitations should be acknowledged. First, the sample size of older adult participants and expert evaluators is relatively limited, which may affect the generalizability of the findings. Second, the behavioral observations of cats were conducted in controlled domestic environments, which may not fully capture variations across different living contexts. In addition, the study focused on short-term behavioral and preference data, while long-term interaction effects were not examined. Future research could expand the sample size and incorporate longitudinal data to further validate and refine the proposed framework.

CONCLUSIONS

1. This study proposed and validated a dual-objective, multi-method collaborative design framework for human–pet co-living furniture, specifically targeting the shared living scenarios of older adults and domestic cats. Through integrating the Kano model, Analytic Hierarchy Process (AHP), Quality Function Deployment (QFD), and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), a systematic

and traceable decision-making pathway from user requirement identification to optimal design selection was established.

2. Based on empirical data collected from 98 older adult users and behavioral observations of 30 domestic cats, the Kano model identified four must-be attributes, including the replaceable scratching layer (N1) and the natural composite wood structure (N2). The absence of these functions resulted in a substantial decrease in user satisfaction, indicating their indispensable role in human–cat shared furniture design.
3. The AHP analysis further quantified the relative importance of key functional requirements and confirmed that the replaceable scratching layer and composite natural wood structure accounted for a combined weight of 42.9%, highlighting users' strong emphasis on structural safety, material quality, and fundamental behavioral support for both humans and cats.
4. Through QFD-based requirement–function mapping, 14 design functions were derived, among which the modular scratching structure, quick-release scratching board slot, and segmented natural wood assembly process (F1 to F3) achieved the highest overall utility scores. These functions were identified as the most critical contributors to satisfying dual-user requirements.
5. TOPSIS-based multi-attribute evaluation of three alternative design schemes demonstrated that the balanced-type solution (Option B) achieved the highest closeness coefficient (Ci = 0.741), indicating superior overall performance in terms of structural stability, feline behavior stimulation, operational convenience for older adults, material sustainability, and cost balance.
6. Overall, the findings empirically demonstrate that integrating feline natural behavior stimulation with age-friendly assistive functions can simultaneously enhance feline activity and improve perceived safety and well-being among older adults. The proposed Kano–AHP–QFD–TOPSIS framework provides a generalizable methodological reference for cross-species co-design and offers practical value for the development of intelligent human–pet shared furniture systems.

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