

Research on Age-Friendly Kitchen Cabinet Design Based on the Kano-QFD-FBS Model

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In home-based elder care, kitchen cabinets serve a critical function in the daily lives of older adults. However, most cabinets currently available in the Chinese furniture market are designed for young and middle-aged users, neglecting the specific requirements of the elderly population. To improve user satisfaction with age-friendly kitchen cabinet products, this study proposed a conceptual design method based on the Kano-QFD-FBS integration model. First, customer requirements were identified through behavioral observation and in-depth interviews, then systematically categorized and prioritized using the Kano model. Subsequently, Quality Function Deployment (QFD) was employed to translate customer requirements into actionable design requirements. Finally, the seven key design elements derived from this process were incorporated into the Function-Behavior-Structure (FBS) model to determine the product's structural components. This integrated approach enables a precise mapping from customer requirements to design elements, facilitating the development of age-friendly kitchen cabinet concepts. The study demonstrates the feasibility and effectiveness of the Kano-QFD-FBS model in age-friendly design research, providing valuable guidance and innovative perspectives for age-friendly kitchen design in China.

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INTRODUCTION

As China's population ages, enhancing quality of life and ensuring well-being for the elderly has become a major societal concern (Lin 2024). According to the latest National Bureau of Statistics data, China's population aged 60+ reached 22.0% by the end of 2024, while the population aged 65+ accounted for 15.6%. It is anticipated that China will face significant eldercare challenges in the foreseeable future (Xie and Lin 2022). The 2025 Government Work Report issued by China's State Council explicitly proposed to actively address population aging and to enhance institutional frameworks for eldercare service development and related industries. This policy indicated the Chinese government's strategic emphasis on responding to demographic aging challenges. China's current eldercare system operates under a "9073" model: approximately 90% of seniors primarily receive family-supported home care, 7% utilize community-based care services, and the remaining 3% are accommodated in institutional care facilities (Xu 2024). Consequently, home-based care has become the predominant model in contemporary China.

The growing adoption of home-based eldercare has led to rising demand for furniture designed for older users. This demographic change is encouraging furniture manufacturers to develop more age-adaptive designs (Cheng *et al.* 2022). In home-based eldercare, kitchen cabinets play a vital role in seniors' daily lives and significantly impact their care experience (Lin 2024). The design of these cabinets affects not only cooking efficiency for older users but also their safety and comfort during use (Zhang *et al.* 2025). Age-related declines in physical and cognitive abilities pose significant challenges in kitchen cabinet use, particularly due to deteriorating motor and cognitive functions that impair daily usability. In terms of motor function, older adults often experience muscle atrophy, reduced strength, and declining motor control, resulting in stiffness and limb weakness. As a result, retrieving items from lower base cabinets frequently requires excessive bending or squatting, elevating fall risks. Similarly, accessing items in upper wall cabinets often necessitates standing on stools or stretching by tiptoeing and raising arms, which can be physically strenuous and unsafe. These actions can cause physical discomfort and create potential safety risks. Regarding cognitive function, older adults often experience slower reaction times, reduced attention spans, and impaired memory. Consequently, while cooking, they may frequently forget steps in a recipe or omit ingredients. Additionally, memory decline can result in difficulty recalling the storage locations of kitchen utensils and ingredients. However, current cabinet design in the market predominantly focuses on younger demographics while neglecting the specific needs of elderly users (Lin 2024). Furthermore, while marketed as customizable, most commercial cabinets are essentially standardized products with similar designs, making them poorly suited to accommodate the specific requirements of aging users (Song *et al.* 2022).

Current research on kitchen cabinet design has explored various aspects of this field. For example, Zhang *et al.* (2021) conducted an ergonomic study examining multiple cabinet design parameters including dimensional specifications, functional features, intended user demographics, spatial arrangements, material selections, and color applications. Deng *et al.* (2022) incorporated interaction concepts with Affordance Theory to establish a systematic framework of cabinet design elements, ultimately identifying key user-centered design considerations. Similarly, Lin and Xu (2016) implemented flexible design principles for home products, developing an integrated kitchen cabinet concept that combines cooking, cleaning, and storage functions to meet the needs of small-space living. These studies have conducted in-depth investigations and evaluations of kitchen cabinet design from various perspectives, including ergonomics, user experience, and multifunctional integration. However, research focusing specifically on age-friendly kitchen cabinet design remains limited. This gap is particularly notable given the current trends of population aging and the growing preference for home-based eldercare solutions. Kitchen cabinets represent one of the most frequently used furniture systems in home-based elderly care, as older adults typically spend substantial time performing kitchen tasks including food washing, meal preparation, and cooking. Therefore, this study employed survey methods, in-depth interviews, and behavioral observations to investigate older adults' physical and psychological requirements, with the goal of establishing design guidelines and proposing innovative solutions for age-friendly cabinet design.

In product design research, the Kano model and Quality Function Deployment (QFD) have been widely adopted as theoretical frameworks for design optimization. Liu and Wang (2022) employed the Kano model to categorize and analyze the quality attributes of interactive aging-friendly products, subsequently developing an evaluation system for aging-friendly product-services. Similarly, Li *et al.* (2023) used Kano analysis to prioritize

health-related needs in smart home systems for older adults, establishing a valuable reference for design element prioritization. Kirgizov and Kwak (2022) developed an innovative approach that quantifies the Kano model and integrates it with QFD, enabling systematic analysis of user requirements through satisfaction-requirement relationship quantification. This method effectively identifies previously neglected quality attributes in product design. Wang *et al.* (2024) constructed Kano and QFD models to create modular entrance cabinet designs that better accommodate users' lifestyle requirements, significantly improving user satisfaction and product engagement. Similarly, Li and Ye (2023) applied Kano-QFD integration to prioritize design elements for smart public facilities, resulting in designs that more effectively meet public preferences. These cases confirm that combining Kano and QFD models successfully identifies customer requirements and translates them into specific design requirements and product features. The Function-Behavior-Structure (FBS) model provides a systematic framework for analyzing the relationships between a product's functions, behaviors, and structural components. Researchers have effectively applied this model in design studies, as demonstrated by Gu *et al.* (2025), who used the FBS framework to examine user interaction with reading products, yielding valuable design strategies for optimizing children's library spaces. The FBS model's ability to convert functional requirements into structural solutions makes it particularly valuable for guiding product development. Therefore, this paper aims to conduct innovative design research for age-friendly cabinets by integrating the Kano model, QFD model, and FBS model.

EXPERIMENTAL

Research Methodology

The Kano model

The Kano Model is a qualitative methodology for identifying and categorizing customer requirements (CRs) (Li and Shi 2024). This model analyzes the correlation between product attributes and customer satisfaction (CS), thereby enabling more precise requirement specification and streamlined product development processes (Chen *et al.* 2019; Dou *et al.* 2019; Wu *et al.* 2023; Zhou and Wang 2023). The Kano model categorizes CRs into six distinct types, which are explained as follows (Wu *et al.* 2025):

(1) Attractive (A): Features that generate significant satisfaction when implemented but do not cause dissatisfaction when omitted.

(2) One-Dimensional (O): Features that produce satisfaction when present and dissatisfaction when not present.

(3) Indifferent (I): Features that have negligible impact on user satisfaction regardless of their presence.

(4) Must-be (M): Essential features representing minimum product requirements whose absence causes dissatisfaction.

(5) Reverse (R): Features that negatively affect satisfaction when included.

(6) Questionable (Q): Features indicating potential issues with the Kano questionnaire design or respondent understanding (Karakurt and Cebi 2025).

The QFD model

Quality Function Deployment (QFD) is a systematic methodology for ensuring that product design and production processes are driven by CRs (Moskowitz and Kim 1997).

Its primary function is to accurately translate the user's subjective needs into definitive design and production requirements. This study primarily focused on the initial phase of the QFD, which involves translating CRs into design requirements (DRs), alternatively termed technical characteristics (Chan and Wu 2005). The implementation of this phase comprises four key steps: (1) Identification of CRs, including their relative weight values; (2) Determination of corresponding DRs necessary for product fulfillment; (3) Establishment of a correlation matrix mapping CRs to DRs, with quantified relationship strengths; (4) Computational analysis of DRs' importance ranking to validate alignment with primary user needs in the final design (Wang *et al.* 2025).

The FBS method

The Function-Behavior-Structure (FBS) model, initially developed by Gero in 1990, provides a systematic framework for conceptual design by mapping relationships between three core domains: Function (F), Behavior (B), and Structure (S) (Gero 1990). The three fundamental elements in the FBS model are defined as follows:

(1) Function (F): The design objectives derived from user requirements. In this study, these objectives are specifically derived through QFD analysis.

(2) Behavior (B): The expected user behaviors analyzed for the design object to achieve its design objectives (Chen *et al.* 2021).

(3) Structure (S): The structural elements involved in product design. For this research, it refers to the structure derived from mapping user operational behaviors.

Research framework

This study applied an integrated Kano-QFD-FBS model to the design process of age-friendly kitchen cabinets. The process comprises four sequential phases: requirements extraction and classification, customer requirements hierarchical classification, design requirements transformation, and function-behavior-structure mapping to structural elements (Fig. 1).

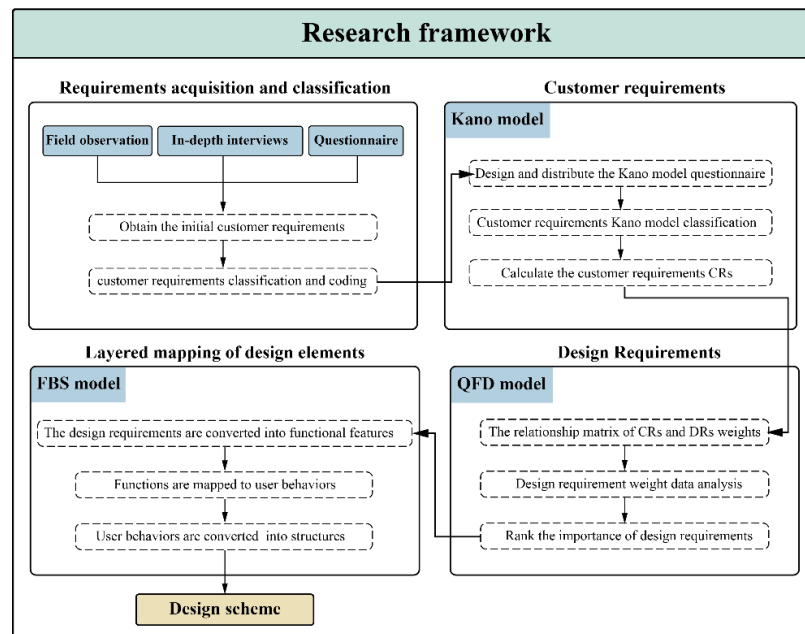


Fig. 1. Research framework

The implementation process began with comprehensive user requirement collection through field observations, in-depth interviews, and structured questionnaires. Subsequently, the Kano model was employed to categorize requirements and calculate the weights of CRs. The QFD methodology then facilitated analytical weighting of design elements to establish development priorities. Following this, the FBS framework enabled systematic translation of QFD-derived DRs into specific structural characteristics through function-behavior-structure mapping. Finally, conceptual development was carried out based on the aforementioned analyses.

Functional Zoning of Kitchen Cabinets

The spatial organization of kitchen cabinets should be designed according to users' operational habits and workflow patterns. Based on standard kitchen workflows, four primary functional zones can be identified: storage, sink, preparation, and cooking. The operational positions of these four zones should be rationally arranged to minimize the number of steps. These zones should be strategically arranged to optimize workflow efficiency by minimizing unnecessary movement (Wu and Wang 2009). The complete kitchen operation sequence comprises six key activities: food storage, washing, meal preparation, cooking, serving, and post-meal cleanup, which correspond to the four functional zones as follows:

- (1) Storage Zone: Includes food storage cabinets and refrigeration, *etc.*
- (2) Sink Zone: Encompasses the cleaning area for food and utensils, including the sink basin, faucet, under-sink cabinet, waste disposal unit, and cleaning supplies storage.
- (3) Meal preparation Zone: Area for food processing activities including cutting, seasoning, dough preparation, and serving (Yang *et al.* 2014).
- (4) Cooking Zone: Contains primary cooking appliances (cooktop, range hood) and secondary cooking areas (for rice cookers, microwave ovens, *etc.*), along with associated utensil storage.

Among these, the sink zone, meal preparation zone, and cooking zone are the key areas for kitchen operations. The rational placement for these three core functional areas should follow the sequential order of sink zone→meal preparation zone→cooking zone, and should also possess continuity.

Analysis of Pain Points in older adults' Kitchen Behavior Patterns

User research based on behavioral observation and in-depth interviews

Observation serves as a fundamental methodology for data acquisition in research. This study employed in-depth observation to investigate the kitchen operation behaviors of older adults. The research aimed to identify the challenges they face in different types of housing, thereby providing insights for the design of age-friendly kitchen cabinets. Given the variability in participants' dining schedules, observational data collection was limited to meal preparation and cooking activities, with post-meal cleanup behaviors excluded from the current phase of investigation.

The purpose of the in-depth interviews was to understand the residential characteristics and cooking habits of older adults to identify their kitchen usage patterns and challenges. The interview content included a survey of participants' basic demographic information, kitchen characteristics, cooking habits, and suggestions on cabinet improvements (Table 1). Complementary field surveys and photography were conducted. The research instruments included telephones, measuring tapes, and standard recording

materials. Participants comprised adults aged 65+ residing in Beijing, representing diverse housing types and family structures, all maintaining good health and self-care capacity.

Table 1. User Research: Observations and Interviews

Research Method	Research Objective	Research Content
Behavioral Observation	To Investigate Cooking Practices	Washing, Preparing, Cooking
In-depth Interviews	Basic Information	Gender, Age, Height, Family Structure, Mobility, Physical Condition
	Kitchen Attributes	Kitchen Area, Cabinet Type, Workflow, Distance to Dining Room
	Cooking Habits	Cooking Frequency, Cooking Practices
	Suggestions on Cabinet Improvements	Pain Points in Using Kitchen Cabinet

The survey included five participants (4 females, 1 male) with an average age of 74.4 years and mean height of 158.8 cm (Table 2). Four participants lived with their children, while one lived independently. Self-reported health assessments revealed that chronic conditions significantly impacted kitchen activities for most participants. The primary physical limitations affecting kitchen work involved restricted mobility in leg and shoulder joints, particularly during bending motions.

The investigation showed different housing characteristics among participants: participants A, B, and C lived in aging residential units exceeding 50 years of age, while participants D and E lived in more recently constructed buildings. The mean kitchen area measured 4.1 m² (Table 3). Workflow efficiency assessments indicated universal participant concern regarding refrigerator placement. Observational data showed that refrigerators were located within the kitchen for Participants C and E, while positioned externally for the remaining three cases. Additionally, the distance between the kitchen and the dining area emerged as another significant consideration for participants.

Table 2. Basic Information of Participants

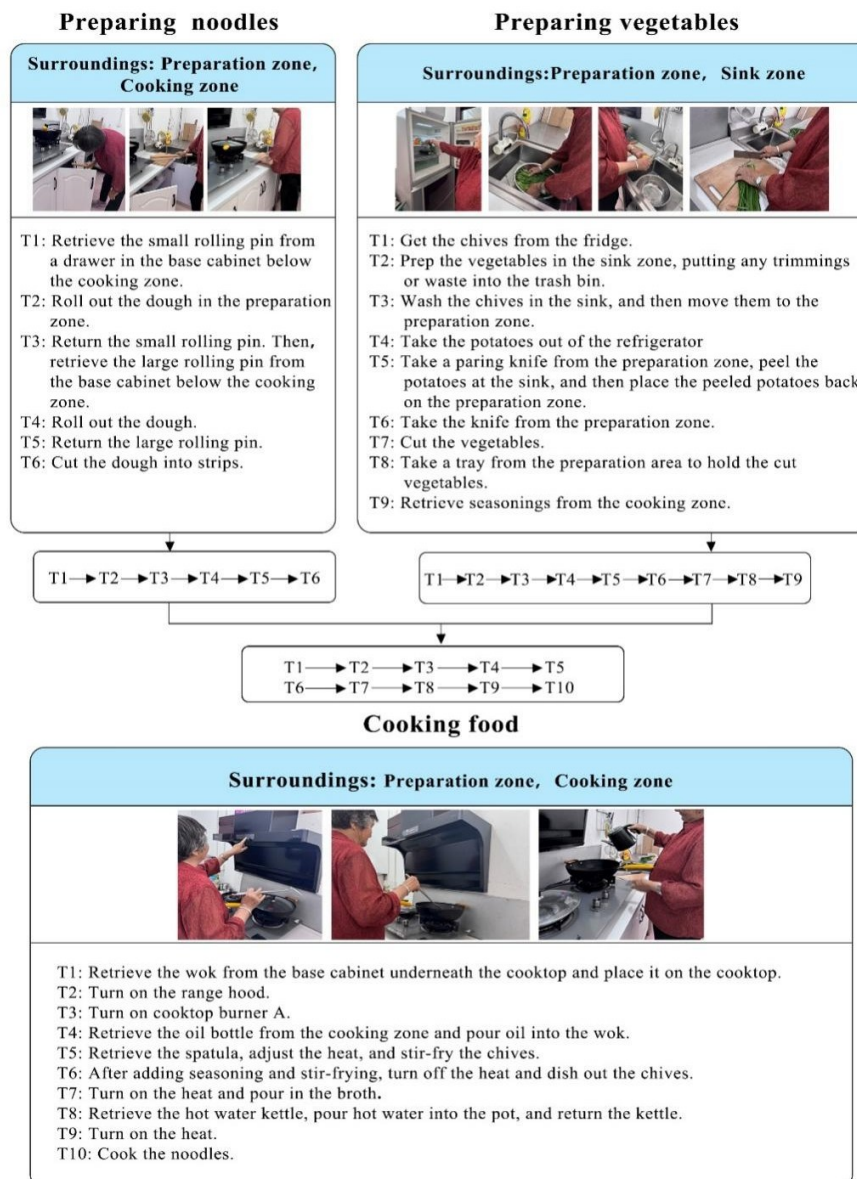
Basic Information	Participant A	Participant B	Participant C	Participant D	Participant E
Family Structure	Three-generation household				Living alone
Gender	Female	Female	Female	Female	Male
Age (years)	67	80	70	75	80
Height (cm)	145	161	160	158	170
Mobility	Independent (Good)	Slow gait (Slow)	Independent (Good)	Slow gait (Slow)	Independent (Good)
Physical Condition	Osteoporosis	Arthritis	Lumbar strain	Cartilage loss	Hearing loss
Does Physical Condition Affect Kitchen Work	No	Yes	Yes	Yes	No
Any accidents in the kitchen	Slipped	None	None	None	None

Table 3. Kitchen Attributes

Residential Attributes	Participant A	Participant B	Participant C	Participant D	Participant E
Kitchen Area (m ²)	3.24	3.66	4.15	3.87	5.6
Cabinet Type	=	=	U	=	U
Workflow Smoothness	Yes	No	Yes	No	Yes
Distance to Dining Area (m)	2.5	3	2.8	3.1	5.2

Observation of participants' kitchen behaviors

The kitchen operational patterns of older adults were systematically documented, with Participants D and E selected as representative cases. Both participants predominantly utilized the standard kitchen work triangle, consisting of the sink zone, preparation zone, and cooking station.

**Fig. 2.** Behavioral observation of Participant D

For Participant D, a detailed task decomposition was conducted (Fig. 2), revealing three distinct operational phases: noodle preparation, vegetable preparation, and ingredient cooking. Participant E demonstrated a more condensed cooking sequence, with meal preparation streamlined into three essential stages: washing, preparing and cooking ingredients (Fig. 3).

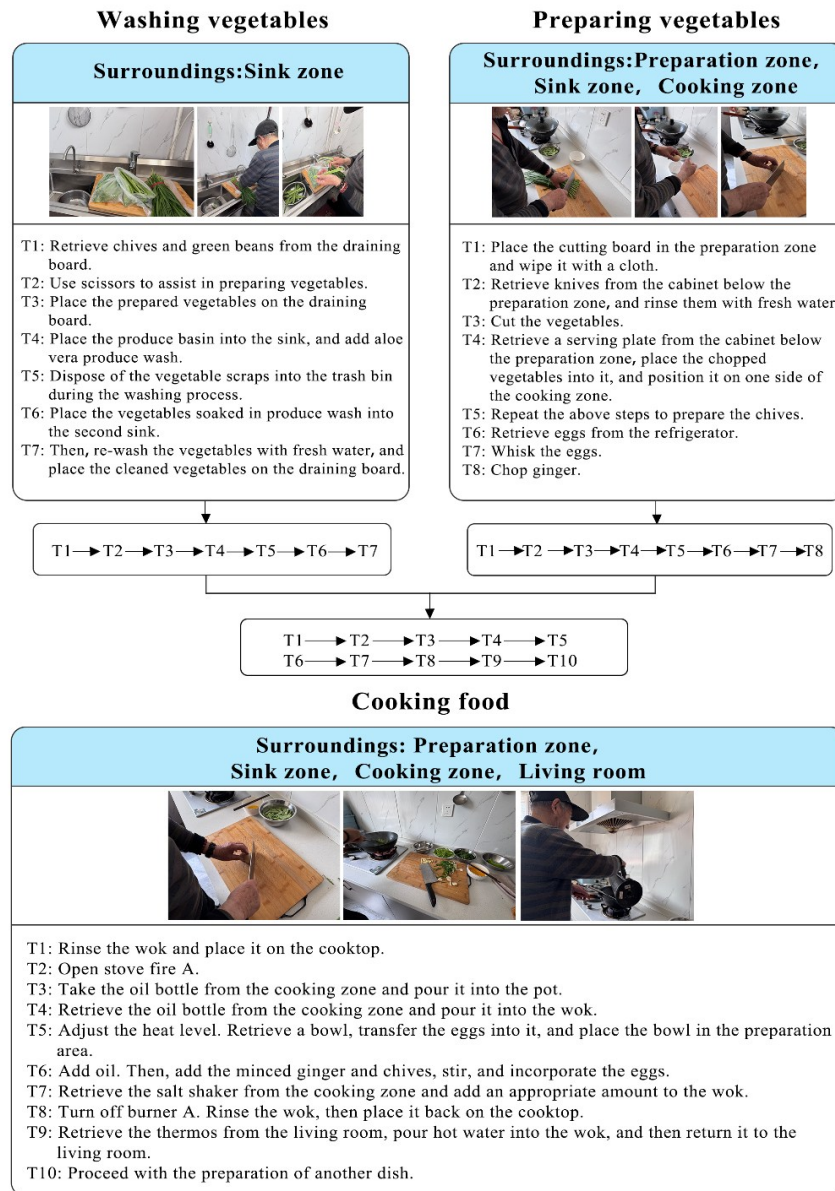


Fig. 3. Behavioral observation of Participant E

Summary of participants' opinions on kitchen cabinet improvement

Key factors influencing older adults' cooking behaviors were systematically identified through an integrated methodology comprising hierarchical task decomposition, detailed action analysis, behavioral observations, and in-depth participant interviews.

(1) Cook-Related Factors: older adults exhibit slower movement patterns, requiring extended transition periods between sequential tasks. Physical constraints, particularly

limited squatting ability, significantly reduce their functional vertical workspace range. Ergonomically unfavorable countertop layouts, such as placing knives or spatulas in distant positions, require strenuous forward-leaning motions for retrieval. Suboptimal cooktop elevation induces prolonged arm elevation during stir-frying, leading to upper limb fatigue and compromised postural stability. During the transportation of kitchenware (bowls, plates, and prepared meals) over distances, older adults face increased risks of losing balance, along with potential breakage of dishes and spillage of food. Age-related cognitive decline may result in food overcooking, burning, or pot evaporation incidents. Additionally, distributing spice containers across multiple drawers beneath the cooking surface often leads to difficulty locating specific seasonings during meal preparation.

(2) Cooking Method-Related Factors: Meal preparation for older adults typically involves extended stewing or simmering durations, resulting in prolonged kitchen occupancy. Additionally, accumulated grease on cooking surfaces and utensils presents significant cleaning challenges.

(3) Kitchen Equipment and Environmental Factors: The spatial relationships between the sink and the preparation zone, cooking zone, and refrigerator significantly impact workflow efficiency. Current kitchen designs present several functional limitations: (i) fixed-flow faucets lack adjustable water direction and flow rate during vegetable washing, (ii) inadequate draining areas hinder proper cookware drying, (iii) excessive kitchenware creates storage constraints, and (iv) improperly positioned trash bins (often too low) lead to surrounding debris accumulation. Additional ergonomic challenges include: (i) excessive distances between cleaning and waste disposal areas creating inefficient movement paths, (ii) elevated cooking zones requiring strenuous arm elevation when adding water to pots (as observed with Participant D), (iii) insufficient or misplaced electrical outlets necessitating external placement of essential appliances (*e.g.*, rice cookers, kettles), and (iv) poorly accessible wall cabinets forcing unsafe retrieval methods (demonstrated by Participant B's need for step stools). Furthermore, disorganized cookware storage systems contribute to operational inefficiencies during food preparation tasks.

Analysis of CRs and DRs for Age-Friendly Kitchen Cabinets

Identification and categorization of customer requirements

Based on behavioral observations and in-depth interviews regarding older adults' use of kitchen cabinets, this study developed a comprehensive survey on age-friendly kitchen cabinet requirements. Initial customer requirements (CRs) were identified through structured interviews with 30 seniors (aged 65 to 80) in Beijing. To ensure the rationality of the questionnaire design, these CRs were screened by professionals specializing in design and aging-related research (Zhou 2017). Through this process, similar or identical needs were eliminated, resulting in a refined set of 20 CR items that constituted the final questionnaire. These needs were subsequently organized into three principal domains through thematic analysis: (i) Cleaning System, (ii) Food Processing System, and (iii) Storage System, comprising 20 sub-items. This requirement set served dual purposes: as the foundation for the Kano model questionnaire and as input parameters for the CRs of the QFD (Table 4).

Table 4. Hierarchy of CRs

Primary Categories	Secondary Items	Code
Cleaning System	Effortless cleaning	A1
	Waste sorting and recycling	A2
	Easy waste storage	A3
	Prevention of sink blockages	A4
	Good ventilation under the sink	A5
	Non-slip flooring	A6
Food Processing System	User-friendly preparation counter	B1
	Large countertop workspace	B2
	Establishment of an auxiliary cooking zone	B3
	Easy access to ingredients	B4
	Automatic reminder function	B5
	Safety alarm function	B6
	Clear view of flame status	B7
	Facilitating emotional communication	B8
Storage System	Easy storage of cookware	C1
	To minimize the need for bending and squatting	C2
	Standing assistance	C3
	Dry and ventilated cabinets	C4
	Food temperature reminders	C5
	Smooth circulation path	C6

Qualitative assessment of requirements using the Kano model evaluation matrix

Following standard Kano model methodology, each customer requirement of older adults was transformed into paired questionnaire items: one positive scenario (need fulfillment) and one negative scenario (need unfulfilled). A total of 104 participants evaluated all 20 item pairs using a standardized five-point satisfaction scale (Satisfied, Basic, Indifferent, Acceptable, Dislike). The responses were then categorized according to Table 5. Through this process, all kitchen system requirements were successfully mapped to Kano categories. The final Kano attribute for each need was assigned based on frequency analysis, by selecting the category (I, A, M, O, or R) with the highest frequency.

Table 5. Kano Attribute Categorization

CRs		Attitude towards the Opposite Questions				
		Satisfied	Basic	Indifferent	Acceptable	Dislike
Attitude toward positive questions	Satisfied	Q	A	A	A	O
	Basic	R	I	I	I	M
	Indifferent	R	I	I	I	M
	Acceptable	R	I	I	I	M
	Dislike	R	R	R	R	Q

Based on the Kano-classified CRs attributes, the CS index was employed to further quantify the influence of different needs on user satisfaction. This approach incorporates both satisfaction and dissatisfaction indices. The Satisfaction Index (S) and the Dissatisfaction Index (D) were calculated as follows (Zhang and Dolah 2024),

$$S_i = (A_i + O_i) / (A_i + O_i + I_i + M_i) \quad (1)$$

$$D_i = (-1) * (M_i + O_i) / (A_i + O_i + I_i + M_i) \quad (2)$$

where A_i , O_i , M_i , and I_i represent the frequencies of the A, O, M, and I categories, respectively, for the i -th customer requirement. Value of S_i or D_i approaching 0 indicates a minimal influence on user satisfaction, whereas absolute value close to 1 signifies greater impact.

Weighting of customer requirements (CRs) for age-friendly kitchen cabinets

To calculate the importance score for each CR, the maximum value between S_i and D_i was taken as the absolute importance score (w_i) for that customer requirement. Subsequently, the relative importance score (W_i) was calculated. The calculation formulas are as follows (Li and Shi 2024):

$$w_i = \text{Max}(S_i, |D_i|) \quad (3)$$

$$W_i = \text{Max}(S_i / \sum_{i=1}^m S_i, |D_i| / \sum_{i=1}^m |D_i|) \quad (4)$$

The results are shown in Table 6. Requirements A2, B2, B5, and C5 were identified as attractive qualities. B8 belongs to the indifferent quality. The remaining fifteen requirements exhibited one-dimensional qualities. Analysis showed that requirements A1, A4, A6, B1, C2, and C3 demonstrated higher S_i . Meanwhile, requirements A3-A6, B1, C1, and C2 showed elevated D_i . For age-friendly kitchen cabinet design, non-fulfillment of these requirements would likely lead to significant user dissatisfaction. Particularly, requirements A4, A6, and C2 emerged as the most critical elements based on user evaluations.

Table 6. Categorization and Weighting of CRs

CRs	Q	A	O	R	I	M	Kano Attribute	S	D	w_i	W_i
A1	2	43	48	0	6	5	O	0.89	0.52	0.89	5.63%
A2	2	39	29	1	28	5	A	0.67	0.34	0.67	4.25%
A3	2	29	52	4	7	10	O	0.83	0.63	0.83	6.09%
A4	2	13	77	1	3	8	O	0.89	0.84	0.89	8.10%
A5	2	20	59	0	9	14	O	0.77	0.72	0.77	6.89%
A6	2	18	74	1	0	9	O	0.91	0.82	0.91	7.91%
B1	1	36	54	0	9	4	O	0.87	0.56	0.87	5.52%
B2	1	43	42	1	16	1	A	0.83	0.42	0.83	5.26%
B3	0	31	38	1	29	5	O	0.67	0.42	0.67	4.23%
B4	1	36	54	0	7	6	O	0.87	0.58	0.87	5.61%
B5	0	47	34	1	22	0	A	0.79	0.33	0.79	4.96%
B6	1	30	52	0	18	3	O	0.80	0.53	0.80	5.14%
B7	0	40	40	0	18	6	O	0.77	0.44	0.77	4.86%
B8	0	33	25	5	39	2	I	0.59	0.27	0.59	3.70%
C1	0	32	51	0	13	8	O	0.80	0.57	0.80	5.46%
C2	1	19	70	0	6	8	O	0.86	0.76	0.86	7.29%
C3	0	39	44	0	19	2	O	0.80	0.44	0.80	5.04%
C4	0	33	48	0	19	4	O	0.78	0.50	0.78	4.92%
C5	0	43	32	0	26	3	A	0.72	0.34	0.72	4.55%
C6	2	38	35	1	27	1	A	0.72	0.36	0.72	4.56%

Investigation of design requirements (DRs) for age-friendly kitchen cabinets

Based on the CRs analyzed through the Kano model, a multidisciplinary expert panel comprising practicing furniture designers, design specialists, academic researchers,

and industry professionals was assembled to establish correlations between user needs and technical design specifications. Through this process, the DRs were systematically classified into three functional subsystems: (i) cleaning, (ii) food processing, and (iii) storage systems. The methodology ultimately produced sixteen validated DRs with associated design parameters, as shown in Table 7.

Table 7. Mapping of DRs

DRs		Design Objective	Code
Primary Category	Secondary Item		
Cleaning Systems	Sink location design	Sink position adjacent to the preparation counter	D1
	Faucet design	Convenient faucet operation	D2
	Draining rack	Extended draining area	D3
	Sink cabinet	Convenient for cleaning and item retrieval	D4
	Trash bin design	Convenient disposal	D5
Food Processing Systems	Preparation counter design	Adaptable for preparing various staple foods	D6
	Rack design	Convenient item retrieval	D7
	Cooktop design	Comfort during cooking activities	D8
	Secondary cooking zone design	Convenient use of kitchen appliances	D9
	Automatic reminder device	Cooking status alerts	D10
Storage Systems	Safety alarm device	Safety alerts for kitchen hazards	D11
	Wall cabinet design	Wall cabinet height suitable for older adults	D12
	Base cabinet design	Base cabinet height suitable for older adults	D13
	Cookware storage design	Storage of cookware in cabinets beneath the cooktop	D14
	Tableware storage design	Storage of tableware adjacent to the food preparation area	D15
	Work triangle planning	Minimization of workflow paths	D16

QFD-based CR-DR Relationship Matrix and Importance Scoring of DRs

To calculate the importance scores of DRs, it is necessary to evaluate the correlation between CRs and DRs. Typically, the degree of association between the two is represented by numerical values or graphical illustrations (Chen *et al.* 2002). In this study, the correlation for each combination was quantitatively scored through expert analysis and group discussions (Table 8). The numerical values represent: 5 points for a strong correlation, 3 points for a moderate correlation, 1 point for a weak correlation, and no correlation is indicated by a blank cell.

The absolute importance score (AI_j) for each DR was derived through computational integration of the relationship matrix values with the relative importance weights (W) of the CRs, as shown in the following equation,

$$AI_j = \left(\sum_{i=1}^m W_i R_{ij} \right) \quad (5)$$

where R_{ij} represents the strength of the relationship between the i -th CR and the j -th DR in

the relationship matrix, $i = 1, 2, 3, \dots, m$, where m represents the number of CRs, and $j = 1, 2, 3, \dots, n$, where n represents the number of DRs.

Table 8. CRs and DRs Correlation Matrix

CRs	DRs															
	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16
A1	5	5	3	3	3											
A2	1			3	5											
A3	1			3	5											1
A4	3			1	1											
A5	1			3	1											
A6	3	3	3			3		1						1	1	3
B1						5	1						1			
B2	1					5		3	1							
B3									5							
B4			3				5					5	5			1
B5								5		5						
B6								5			5					
B7								5								
B8						3		3		3						3
C1							5					5	5	5	5	
C2				3	1		3		1			5	5	3	3	
C3				3		3	3	3					5			
C4												5	5	3	3	1
C5								3								
C6	3			3	3	3	3	3	5					3	3	5
Al _j	1.1 235	0.5 18 8	0.5 74 5	1.2 73 5	1.0 45 5	1.1 75 3	1.1 15 4	1.5 20 4	0.5 65	0.3 59	0.2 57	1.1 64	1.4 71 2	0.8 55 2	0.8 55 2	0.7 42 5
Rank-ing	6	13	11	3	8	4	7	1	12	14	15	5	2	9	9	10

Based on the importance ranking of DRs and integrating findings from the preceding CRs analysis, this study identified the top seven design objectives for elderly-friendly kitchen cabinets. These were, in descending order of importance: (1) Comfort during cooking activities (D8, weight: 1.5204); (2) Base cabinet height suitable for older adults (D13, weight: 1.4712); (3) Convenient for cleaning and item retrieval (D4, weight: 1.2735). (4) Adaptable for preparing various staple foods (D6, weight: 1.1753); (5) Wall cabinet height suitable for older adults (D12, weight: 1.164); (6) Sink position adjacent to the preparation counter (D1, weight: 1.1235); (7) Convenient item retrieval (D7, weight: 1.1154).

Deriving Functional Elements through the FBS Framework

This research integrated the QFD and FBS models by translating the top seven design requirements from the QFD analysis into the core functional inputs for the FBS framework. Driven by the design opportunities uncovered from user behavior observations and in-depth interviews, the “Function-Behavior-Structure” mapping was executed to derive the final product structure, as detailed in Fig. 4.

Fig. 4 shows the mapping process from functional requirements to structural specifications, highlighting the implementation mechanisms of each function (Li *et al.*

2025). For example, function F6 (sink position adjacent to the preparation countertop) is realized through behavior B6 (convenience of water access during meal preparation and cooking), which subsequently maps to structural specification S6 (faucet positioned on the right side of the sink). Furthermore, certain functions may correspond to multiple behavioral requirements. For instance, function F3 (convenient for cleaning and item retrieval) encompasses behaviors B2 (reduction of bending actions), B3 (to accommodate the maximum reach of older users), and B7 (items are stored in the most comfortable storage area for older users). These behavioral requirements are respectively implemented through structural modules S2 (elimination of the lowest level of the base cabinets), S3 (countertop depth accommodating older adults' reach), and S7 (addition of a storage shelf above the work surface).

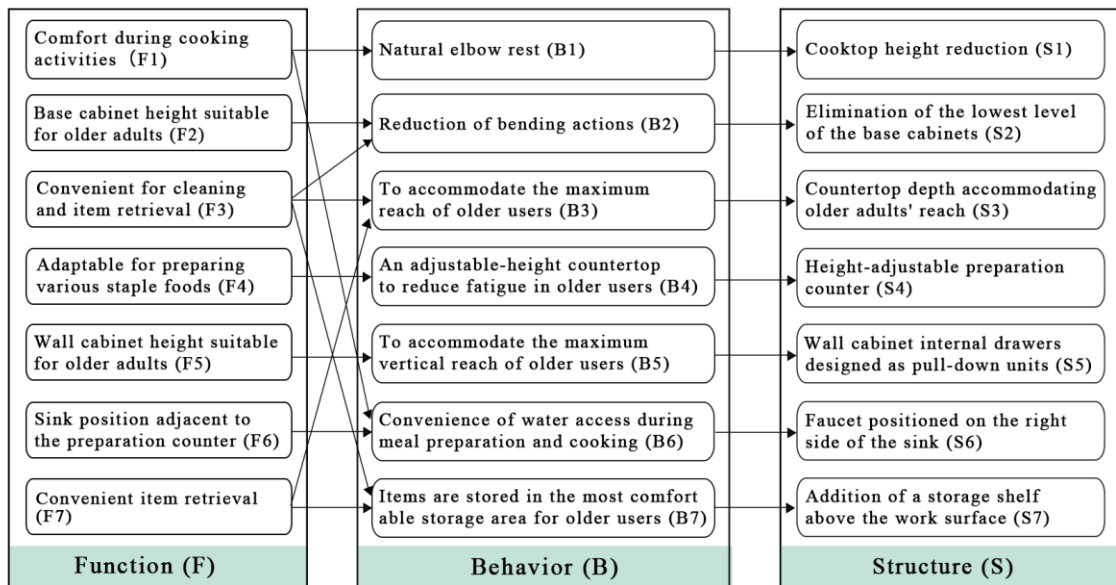


Fig. 4. Function-Behavior-Structural Mapping

The Function-Behavior (F-B) transformation involves converting individual sub-functions into operational behaviors of older adults in the kitchen environment. For example, function F1 (comfort during cooking activities) maps to the need for older adults to reduce arm strain and ensure convenient water access during cooking, resulting in behaviors such as natural elbow rest (B1) and convenient water use during food preparation and cooking (B6). For function F2 (base cabinet height suitable for older adults), the mapping translates to avoiding excessive bending when retrieving items, thus preventing physical discomfort, which leads to the behavior B2 (reduction of bending actions).

The Behavior-Structure (B-S) transformation converts operational behaviors of older adults in kitchen environments into specific cabinet structural designs. For instance, based on the behavioral requirement B3 (to accommodate the maximum reach of older users), the mapping at the structural level involves adjusting countertop depth accommodating older adults' reach (S3). Additionally, based on the behavioral need for convenience of water access during food preparation and cooking (B6), the structural mapping results in positioning the faucet on the right side of the sink (S6) adjacent to the preparation counter, thereby minimizing the movement distance for older adults when accessing water during meal preparation and cooking activities.

RESULTS AND DISCUSSION

Based on the theoretical framework and experimental findings, a conceptual design for age-friendly kitchen cabinets was developed. Following a comprehensive evaluation of user needs, structural feasibility, and cost considerations, the design presented in Fig. 5 was selected as the final solution. Material selection emphasized non-toxic, health-conscious options, with solid wood and moisture-resistant particleboard emerging as optimal choices. Solid wood provides superior environmental sustainability and biocompatibility, whereas moisture-resistant particleboard offers exceptional humidity resistance coupled with cost-effectiveness. For the color design of the cabinets, this study was guided by principles prioritizing comfort and discernment, based on the impact of color on older adults' physiological and psychological states. The specific scheme employed a combination of light beige and beech wood tone, aiming to enhance psychological comfort through its soft and warm tone.

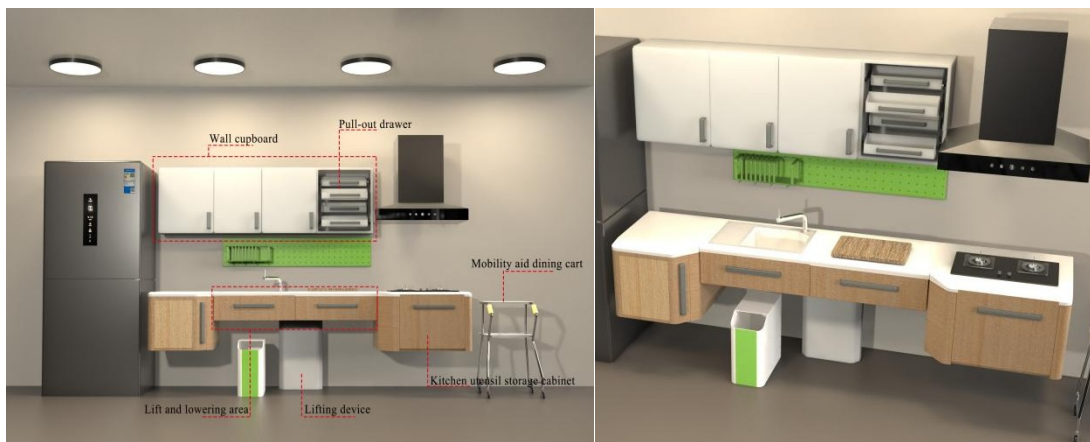


Fig. 5. Conceptual design scheme for age-friendly kitchen cabinets

This study primarily analyzed the functional zoning, ergonomic dimensions, and structural design elements of the product. The optimal arrangement of the three core functional zones follows the sequence: Sink Zone → Preparation Zone → Cooking Zone. The design scheme was planned with reference to this sequence. Within the horizontal work domain, older adults need to move back and forth between these three functional zones. Therefore, adjacent functional zones were ideally positioned such that they can be reached with one large step or two small steps by an elderly user (Fig. 6). To facilitate cleaning and item retrieval, the countertop depth was designed to conform to their reach (S3). Considering that the normal working width for bimanual operation is 1180 mm and the maximum working depth is 500 mm, the following dimensions were determined: the sink zone was designed as 600 mm, the preparation zone as 700 mm, and the cooking zone as 800 mm. The countertop depth for both the sink and preparation areas were set to 500 mm, while countertop depth on the left side of the sink and the cooktop surface was 600 mm (Lei 2001). Additionally, the faucet was positioned on the right side of the sink (S6), immediately adjacent to the preparation zone, to optimize workflow efficiency by reducing hand movement during meal preparation or cooking processes. A wall cabinet depth of 300 mm was adopted to eliminate potential body impact during cabinet door operation, while simultaneously enhancing usability for elderly users in daily item handling operations (Cheng *et al.* 2022).

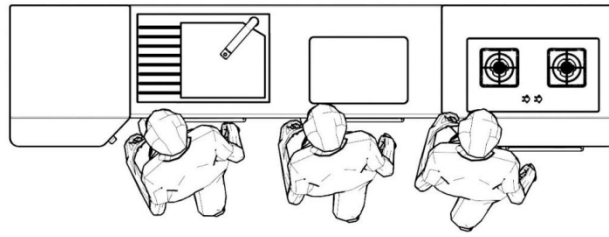


Fig. 6. Operating position of older adults

Within the vertical work domain, consideration must be given to the accessible range for elderly users. As shown in Fig. 7, the green area indicates the optimal working zone for older adults, which spans a vertical range of 400 to 1550 mm from the ground level (Lin 2024). To enhance cooking comfort, the height of the stove was lowered (S1). In response to user expectations for accessibility, the bottom layer of the cabinet was eliminated (S2). Considering the operational convenience for elderly users, the bottom edge of the wall cabinet was positioned at a height of 1400mm above ground level (GB/T 11228-2008 2008, Lin 2024). Based on anthropometric dimensions of the cooking stove and the operational convenience requirements of elderly users, the countertop height of 750 mm was adopted (Li *et al.* 2007). Wall cabinets incorporated a pull-down drawer mechanism (S5), designed to enhance accessibility by bringing elevated storage contents within comfortable reach. Considering the prolonged duration and significant effort elderly users expend on sink-related cleaning tasks, coupled with the need for proper working height during dough preparation, both the preparation and sink zones feature height-adjustable countertops (S4). Figure 8 demonstrates elderly users' usage conditions under two distinct countertop height settings: the left image shows a lowered height configuration suitable for dough preparation and similar operations, while the right image shows the standard height configuration appropriate for routine cutting tasks. To maximize space utilization between the countertop and overhead cabinets, an additional storage shelf (S7) was integrated above the countertop for convenient storage of frequently used utensils.

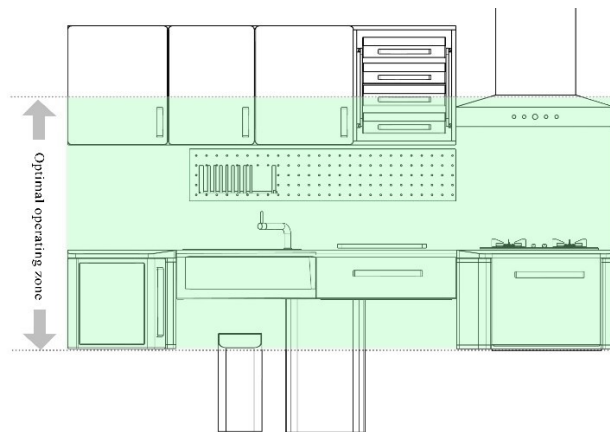


Fig. 7. Optimal operating zone

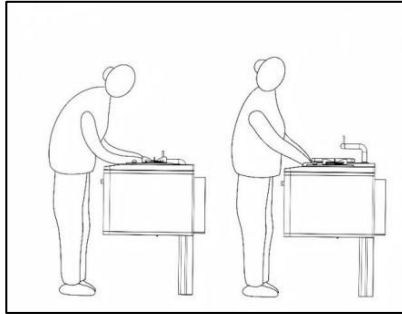


Fig. 8. User postures at different countertop heights

This study established an integrated Kano-QFD-FBS framework to determine DRs for age-friendly kitchen cabinets, from which structural components were derived and conceptual design solutions developed. However, this research had several limitations. Firstly, it lacked comprehensive investigation into special needs groups among older adults, such as those with visual or hearing impairments, which requires further attention in future studies. Secondly, the behavioral observation and in-depth interviews were primarily aimed at identifying pain points in cabinet usage, therefore, the sample size was relatively small. Future research should expand the sample size for in-depth interviews and differentiate the priority weights of needs among distinct elderly populations (*e.g.*, solo-living versus family-supported elderly individuals). Additionally, the specific color design preferences of older adults in kitchen environments require further investigation.

Building upon CRs analysis, this study proposed conceptual design schemes for kitchen cabinets. In further research, it is necessary to employ evaluation tools such as semantic differential methods to systematically assess key indicators of the design schemes, including user satisfaction, usability, and safety. Furthermore, the cost-effectiveness and practical feasibility of the proposed design solutions also require further comprehensive investigation.

CONCLUSIONS

1. This study proposed a method utilizing an integrated Kano-quality function development (QFD)-function behavior structure (FBS) model to investigate the design of age-friendly kitchen cabinets. Initially, 20 customer requirements (CRs) were obtained through behavioral observations, in-depth user interviews, and design surveys. Subsequently, the Kano-QFD model was used to perform qualitative and quantitative analyses to classify the CRs and prioritize the product design requirements (DRs), respectively. Following this, the FBS model was applied to derive the structural elements for age-friendly kitchen cabinets. The resulting design solution provides a comprehensive reference framework for developing age-friendly kitchen systems in China, addressing critical ergonomic and accessibility considerations for older adults.
2. Within the Kano-QFD framework, the CRs were systematically translated into the DRs through the QFD model, with quantitative prioritization of each requirement. Specifically, the design elements with higher DR weights include: (1) comfort during cooking activities, (2) base cabinet height suitable for older adults, (3) convenient for cleaning and item retrieval, (4) adaptable for preparing various staple foods, (5) wall

cabinet height suitable for older adults, (6) sink position adjacent to the preparation counter, and (7) convenient item retrieval. Their respective weight values are 1.5204, 1.4712, 1.2735, 1.1753, 1.164, 1.1235, and 1.1154.

3. Based on systematic analysis, key functional elements for age-friendly kitchen cabinet design were identified and implemented within the FBS model to derive optimal structural configurations. The FBS-based analysis generated seven key structural elements: (1) cooktop height reduction, (2) elimination of the lowest level of the base cabinets, (3) countertop depth accommodating older adults' reach, (4) height-adjustable preparation counter, (5) wall cabinet internal drawers designed as pull-down units, (6) a faucet positioned on the right side of the sink, and (7) addition of a storage shelf above the work surface.
4. This methodology enables systematic integration of elderly users' requirements into the product development process, facilitating optimized design solutions for age-friendly kitchen cabinets, while contributing novel conceptual and methodological advancements to this specialized design domain.

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