Demand Stratification for Functional Priority Determination of Wooden Care Beds Based on I-Kano and Better-Worse Metrics

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Medical beds designed for institutional care often do not fully meet the functional, aesthetic, and environmental requirements of home-based care. This study therefore focused on wooden care beds for home use and examined the coexistence of functional redundancy and insufficient core functions in this product category. Older adults with full or partial functional limitations and their family caregivers were selected as respondents. Satisfaction with 23 nursing-bed functions was evaluated under two scenarios: function availability and function absence, using a five-point scale. A total of 312 valid responses were collected through online questionnaires and field visits. Based on Kano theory, an I-Kano quantitative framework was used to classify functional requirements, while Better–Worse coefficients were introduced to measure satisfaction gains from function availability and dissatisfaction risks from function absence. The results identified 10 must-be attributes, mainly related to safety and basic usability, including pressure ulcer prevention, fall prevention, backrest adjustment, and power-off emergency support; 8 one-dimensional attributes, related to comfort and care efficiency; 3 attractive attributes, such as bed–chair conversion and remote/voice control; and 2 indifferent attributes. These findings provide a quantitative basis for functional configuration and product positioning of wooden home care beds.

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INTRODUCTION

With increasing life expectancy and age-related physical decline, the number of older adults requiring assistance with daily activities is increasing (World Health Organization 2020). Home-based care is therefore an important care setting. In home environments, nursing beds function both as assistive devices and as furniture placed in bedrooms or living rooms. Wood-based surfaces can support visual integration with domestic interiors and may improve acceptance of care equipment. The present study focuses on functional requirements and priority structure rather than making material-hygiene claims.

Demand stratification and priority determination are fundamental prerequisites for assistive-device design (Polgar *et al*. 2025; Deng *et al*. 2023). The Kano model remains a widely used approach for classifying asymmetric requirement attributes (Kano et al. 1984; Liu *et al*. 2021; Noh 2025). Quantitative Kano applications can support identification and prioritization of satisfaction-improvement opportunities (Berger *et al*. 1993). Kano analysis has also been combined with quality-function-deployment approaches to support product-development decisions (Matzler and Hinterhuber 1998). However, quantitative requirement stratification remains underdeveloped for home care beds. This study therefore examines functional requirements for wooden home care beds using a dual-scenario satisfaction design.

The objective of this study was to identify key demand attributes and establish a priority hierarchy for home-based care beds, with a focus on disabled or semi-disabled older adults and their family caregivers. This was achieved by integrating the I-Kano framework with a Top2/Bottom2 Better-Worse coefficient (Timko 1993). The study addresses the need for demand stratification in home-care contexts and provides a quantitative basis for human-centered, home-integrated product design.

The study contributes by applying a dual-scenario I-Kano and Better-Worse framework specifically to wooden home care beds, where medical-assistive functions must coexist with domestic-furniture requirements. The threshold-sensitivity test further examines whether the resulting functional configuration is robust to reasonable alternative classification cutoffs.

EXPERIMENTAL

This study focused on the functional needs of nursing beds for home-based disabled or semi-disabled older adults and their caregivers, aiming to identify key requirement attributes and determine the priority sequence of functional configurations. Satisfaction data for 23 nursing-bed functions were collected under two scenarios: function present and function absent. The I-Kano framework was combined with Top2/Bottom2 Better-Worse coefficients to characterize satisfaction gains associated with functional availability and dissatisfaction risks associated with functional absence, thereby forming an analytical chain of classification, verification, and ranking.

I-Kano Quantitative Analysis Framework and Discrimination Rules

The specific criteria for requirement classification and impact intensity calculation are provided below, along with the scope of application for relevant variables and statistical processing. The questionnaire applied a 1 to 5 level satisfaction scale, and subsequent analyses directly utilize the score data from this scale under two scenarios: “functionally available” and “functionally unavailable” (Conti and Pudney 2011).

Basic Concepts and Data Definitions

In the Kano model, the impact of the same feature on satisfaction differs asymmetrically between present and absent scenarios, with varying degrees of influence in opposite directions. This characteristic enables differentiation between types of requirement attributes. To ensure quantitative comparability among functional items, this study collected two sets of evaluation data for each item i: satisfaction scores under present conditions and absent conditions.

Respondent satisfaction scores range from 1 to 5 points. Satisfaction scores must be normalized so that a satisfaction score of 3 maps to 0, 5 maps to 1, and 1 maps to −1, according to the linear transformations in Eqs. 1 and 2,

$$y_{ij} = \frac{S_{ij}^{+} - 3}{2} \tag{1}$$

$$x_{ij} = \frac{S_{ij}^{-} - 3}{2} \tag{2}$$

where y_{ij} denotes the normalized satisfaction of respondent j in the possessive context for functional item i, and x_{ij} represents the normalized satisfaction in the non-possessive context. S_{ij}^{+} represents the satisfaction score of respondent j in the "Feature Availability" scenario, and S_{ij}^{-} is the satisfaction score of respondent j in the "Feature Absent" scenario. When S=3, the normalized value is 0 (neutral). When S=5, the normalized value is 1 (strong satisfaction), and when S=1, the normalized value is −1 (strong dissatisfaction). An x_{ij} value closer to −1 indicates a higher risk of dissatisfaction due to lack.

Two-dimensional Quantification and Attribute Discrimination (I-Kano)

Sample mean coordinates X_i and Y_i for each feature i were calculated with Eqs. 3 and 4,

$$X_i = \frac{1}{J} \sum_{j=1}^{J} x_{ij} \tag{3}$$

$$Y_i = \frac{1}{J} \sum_{j=1}^{J} y_{ij} \tag{4}$$

where J is the effective sample size. The more positive the value, the more the presence of this feature enhances satisfaction; the more negative the value, the more the absence of this feature tends to cause dissatisfaction.

Building on Kano's asymmetric effect theory, this study applied a two-dimensional framework to identify demand attributes. Reverse and questionable attributes were controlled during the pilot survey through item revision and elimination. Specifically, if an item showed obvious reverse interpretation in the pilot survey—that is, if 30% or more of respondents explained the item in a way that contradicted its intended meaning in the open-ended feedback—the wording of the item was revised. If the ambiguity could not be resolved after revision, the item was removed from the formal questionnaire.

Essential attribute (M) (Tang *et al.* 2025): When this attribute is absent, users show significant dissatisfaction, as reflected by a clearly negative X_i value. However, when the attribute is present, its contribution to satisfaction is limited, and the Y_i value remains at a moderate level.

Expected attribute (O): When this attribute is present, user satisfaction increases significantly, as indicated by a relatively high Y_i value. When it is absent, users also experience obvious dissatisfaction, reflected by a relatively negative X_i value.

Charm attribute (A): When this attribute is present, it greatly improves user satisfaction, corresponding to a high Y_i value. However, when it is absent, users do not show obvious dissatisfaction, and the X_i value is close to zero.

Indifferent attributes (I): Whether this attribute is present or absent, its effect on user satisfaction or dissatisfaction is weak. In this case, both the X_i and Y_i values are close to zero.

For consistency, the formal labels used in the tables and figures are Must-be (M), One-dimensional (O), Attractive (A), and Indifferent (I), whereas the corresponding descriptive terms essential, expected, and charm are used only as explanatory synonyms.

This study applied quantile thresholds for data partitioning, using the sample median of X_i and Y_i as the main dividing line, while integrating four-quadrant distribution for attribute discrimination. For functional items near the boundary, consistency verification was conducted based on Better–Worse results. To enhance reproducibility, the term "near boundary" is defined as functional items that simultaneously satisfy:

$$\left|Y_i-\widetilde{Y}\right|\leq 0.05 \text{or} \left|X_i-\widetilde{X}\right|\leq 0.05 \tag{5}$$

The sample medians $\widetilde{Y}$ and $\widetilde{X}$ are derived from the corresponding samples of Y_i and X_i respectively. For the boundary terms identified above, only classification consistency was examined. If the sign of the BW coefficient did not align with the quadrant direction implied by the I-Kano framework, the corresponding item was marked as a "boundary term" in the Results and Discussion. In addition, the robustness of the classification results obtained under the two discrimination criteria was reported and compared. Nevertheless, the final classification remained primarily governed by the median-based quadrant rule.

Better–Worse Coefficient (Impact Strength Verification and Auxiliary Ranking)

To complement the median-based quadrant classification, this study used a single Top2/Bottom2 Better-Worse operationalization to describe satisfaction gains from functional availability and dissatisfaction risks from functional absence (Timko 1993). Given the 1 to 5 satisfaction scale, the coefficients could be recalculated directly from the raw paired responses.

For each functional item i, Better is the proportion of respondents scoring 4 or 5 when the function is present, whereas Worse is the negative proportion of respondents scoring 1 or 2 when the function is absent. The net coefficient is BW = Better + Worse. Thus, all Better, Worse, and BW values reported in this manuscript use the definitions in Eqs. (6)-(8) only.

$$\text{Better}_i=\frac{n_i\left(S^+\geq 4\right)}{J} \tag{6}$$

$$\text{Worse}_i=-\frac{n_i\left(S^-\leq 2\right)}{J} \tag{7}$$

where $n_i(\cdot)$ represents the number of samples meeting the criteria. $\text{Better}_i\in[0,1]$ with higher values indicates stronger positive pull of the function; $\text{Worse}_i\in[-1,0]$ with greater absolute values signify higher risk of dissatisfaction caused by functional deficiency.

Equation 8 combines positive and negative effects into a single metric for sorting.

$$\text{BW}_i=\text{Better}_i+\text{Worse}_i \tag{8}$$

When $\text{BW}_i>0$, the function leans more toward "gain-type" (closer to expectation/attraction); when $\text{BW}_i<0$, the function leans more toward "risk-type" (closer to necessity). The Top2/Bottom2 proportions, Better–Worse coefficients, and BW net effects for each of the 23 functions are summarized in Table A1.

To clarify the magnitude of the satisfaction difference between the present and absent scenarios for each function, paired differences (S+ - S-), their mean (DeltaMean), and their standard deviation [SD(Delta)] were calculated. The paired-sample effect size dz was then derived as dz = DeltaMean / SD(Delta). This effect-size analysis complements the proportion-based Better-Worse coefficients. Detailed item-level results are presented in Table A2.

Threshold Sensitivity and Classification Robustness Testing

To reduce the randomness caused by threshold-based partitioning and validate the reproducibility of I-Kano classification conclusions, this study conducted threshold sensitivity tests using the sample median as the primary cutoff. The specific approach involved maintaining the original classification rules while replacing the cutoff thresholds with (1) sample means and (2) alternatively partitioned quantile thresholds (*e.g.*, 0.45/0.55 or 0.40/0.60) and comparing their classification results with the median threshold scheme. The consistency metric was defined as whether the alternative schemes produced identical classification results as the primary scheme for the same functional items, with statistical analysis of overall consistency rates and the set of entries experiencing type switching. Results demonstrated that the overall classification conclusions maintained high consistency across different threshold settings (overall consistency rate: 87.0 to 95.7%). Type switching primarily occurred in boundary items near the cutoff line, consistent with the definition of boundary items. Comparative results are presented in Table A3.

Although a small number of boundary items changed category under alternative thresholds (Table A3), the dominant pattern of must-be safety/basic-use functions, one-dimensional care-efficiency functions, and attractive differentiating functions was unchanged; therefore, the main configuration recommendations and priority framework were retained.

Research Subjects and Sample

This study focused on wooden/wood-finished home care beds whose functional design balances both safety and furniture-related features, such as home aesthetics, easy maintenance, and construction from eco-friendly materials (Du *et al.* 2024). The research targeted home-dwelling disabled or semi-disabled seniors (aged ≥60 requiring assistance for basic activities like getting up and turning over) and their caregivers (primarily children or spouses) and covered three typical residential scenarios in China (urban commercial housing, rural self-built houses, and old residential communities). The sample includes individuals with varying degrees of disability (total, semi, or mild) and different economic budgets to ensure representativeness. The term urban commercial housing refers to market-oriented residential units developed by real estate companies and sold or leased to households in urban areas. Rural self-built housing refers to dwellings constructed by rural households themselves, typically on village homestead land and primarily for family residence. Housing in older residential communities refers to dwellings located in aging urban neighborhoods or residential compounds, often built under earlier planning standards and commonly facing issues such as outdated infrastructure or limited public facilities.

Participants were recruited through online questionnaire distribution and field visits across the three residential settings. Because this was a non-probability sample of older adults with care needs and family caregivers, the findings should be interpreted as evidence from the surveyed population rather than as nationally representative estimates.

To address low-quality responses and mechanical completion in online surveys, the following post-survey data-cleaning rules were established:

(1) Exclude questionnaires with response times significantly below the reasonable completion time threshold (*e.g.*, <5 min);

(2) Deem the response invalid and exclude it if the respondent exhibits obvious

mechanical response characteristics in the "present" or "absent" scoring of the 23 items (*e.g.*, identical scores across all 23 criteria under the same scenario, *i.e.*, zero standard deviation).

(3) Perform consistency checks on missing values and outliers to ensure paired scenario scores exist.

The number of final valid questionnaires was 312, with a valid recovery rate of 94.5%.

Integration of Material Considerations

The choice of wood as the primary material for nursing bed design is a critical aspect that distinguishes this study from generic care bed research. Wood offers unique advantages, including its ability to integrate seamlessly into home environments due to its warm aesthetic appeal and natural texture, which reduces the "clinical" feel commonly associated with traditional metal nursing beds. Additionally, wood exhibits favorable hygienic properties, such as lower bacterial survival rates compared to synthetic materials under certain conditions, enhancing its suitability for home care settings.

Material-specific constraints, however, must be addressed in the design process. Wooden structures require careful engineering to ensure durability, load-bearing capacity, and resistance to environmental factors such as humidity, wear, and cleaning agents. The prioritization of safety features, such as fall-prevention guardrails and adjustable backrests, must account for the mechanical properties of wood, including its strength and stability under repeated use. Furthermore, the incorporation of features such as detachable components or modular designs should consider the limitations of wood in terms of weight and joint integrity. For example, the high-priority fall-prevention guardrail requires wooden rails, posts, and joints that resist repeated lateral loading and loosening, while adjustable backrest and side-tilt functions require fatigue-resistant frame, pivot, fastener, and drive-mount interfaces under repeated body-weight loading.

By explicitly linking the functional prioritization results to the advantages and constraints of wood-based design, this study provides actionable insights for manufacturers to optimize the balance between material performance, user satisfaction, and cost efficiency. Future research should further explore the interaction between wood treatments, coatings, and long-term durability in home-care contexts.

Questionnaire Item Construction and Dimensions

The questionnaire structure was rigorously aligned with the research objective. Because the study aimed to classify and prioritize user requirements for wooden home nursing beds, the questionnaire was structured around basic respondent information, dual-scenario satisfaction ratings for 23 nursing-bed functions, and supplementary feedback questions, thereby ensuring that each section directly supported the I-Kano classification and Better–Worse priority analysis. As the same scale was applied in both scenarios, this study applied the Top 2 proportion in the "possessive" context to define "Better" and the Bottom 2 proportion in the "non-possessive" context to define "Worse". The net effect is synthesized as BW = Better + Worse, which is categorized into three core modules (Table 1):

Basic Information Module (7 questions): Includes the identity of the survey subjects, age/disability level of the senior, type of living space, experience with nursing beds, and budget, to analyze the impact of sample characteristics on demand preferences.

Core Needs Scoring Module (23 items): Based on preliminary literature review and pre-research, six core dimensions of nursing beds were identified (position adjustment, transfer mobility, daily care, operational convenience, home adaptability, and safety assurance). Each dimension comprises 3 to 4 specific needs, evaluated using a 5-point Likert scale to measure satisfaction levels when these functions are available or not. This module provides essential data for I-Kano model analysis. After the dual-scenario ratings, respondents also rated the design importance of each function on a 1-5 scale (1 = very low importance; 5 = very high importance).

Recommendation Module (3 questions): This module includes open-ended questions (without specified requirements), multiple-choice pain point questions (existing nursing tool issues), and preference questions (material/color preferences), designed to supplement qualitative needs not covered by quantitative data.

To enhance the clarity and measurement consistency of questionnaire items, this study conducted a small-scale pilot survey and item refinement prior to the formal survey. The pilot survey combined online responses with face-to-face interviews (n=30), focusing on verifying whether item phrasing was ambiguous, whether comprehension burden existed, and whether contextual settings were clear. Based on feedback, individual items were optimized in wording and examples, and those with potential reverse or questionable interpretations were merged or eliminated. The final version of the formal questionnaire comprised 23 functional items.

Entry Sources and Preliminary Research Revision

The 23 functional items were derived from literature review results, comparative analysis of existing nursing bed functionalities, and summarization of key points from community visits and interview records. During item inclusion, constraints on the use of wooden/homemade nursing beds were added as screening criteria, and item names and descriptions were standardized to ensure consistent expression. A pre-research survey (n=50) was conducted prior to formal research to verify respondents' understanding consistency of item meanings and assess the answerability of the dual-context (functional/non-functional) phrasing. Based on pre-research feedback, items with ambiguity, potential for reverse interpretation, or unclear directionality were revised in wording and supplemented with necessary examples to define semantic scope. Items showing a high proportion of reverse interpretations (≥30%) in open feedback, or those failing to resolve ambiguity after revision, were either excluded or merged with similar items. The pre-research also recorded questionnaire duration and response burden to evaluate the rationality of item quantity and presentation methods, which informed adjustments to questionnaire structure and explanatory text. Thus, the pilot survey (n = 30) served as the initial wording and ambiguity screen, whereas the subsequent pre-research survey (n = 50) tested the revised questionnaire's comprehension consistency, answerability, and response burden before the formal survey.

Reliability Testing (Internal Consistency)

To assess the internal consistency of the scale in this study sample, Cronbach's α coefficients were calculated separately by functional dimension and used as reliability indicators at the dimensional level (García-García *et al.* 2025). The questionnaire adopted a dual-context scoring design of functional present and non-present with α coefficients calculated for each dimension item under both contexts. The range and representative values of α coefficients were recorded and reported. Overall, the α coefficients of all dimensions met commonly accepted standards (typically α≥0.70), indicating good homogeneity and consistency within items of the same dimension. For a few dimensions with slightly lower α coefficients (commonly observed in dimensions with fewer items), further item-by-item verification was conducted by combining item-total correlation coefficients and α coefficient changes after item deletion, to identify items that significantly weakened dimensional consistency (Gil *et al.* 2025). Specific α results are summarized in Table A4.

Table 1. Questionnaire Survey

Dimension	Number of entries	Corresponding function number (Q)	Function
Postural regulation	4	Q8–Q11	Adjustable backrest angle, leg flexion function, side-rolling function, controllable speed adjustment
Mobile transfer	3	Q12–Q14	Bed with movable frame (rollers), bed–chair separation/conversion, wheel brake fixation
Daily care	4	Q15–Q18	Pressure ulcer prevention design, toileting care function, detachable head/tail of bed, adjustable/removable handrails
Ease of use	3	Q19-Q20	The operation panel is simple and intuitive, with remote/voice control
Home adaptability	3	Q22–Q24	Home-style appearance, compact size, foldable/modular
Safety/Insurance	4	Q21, Q25-Q27	Safety tips for operation, fall-prevention guardrails, power-off emergency support, and eco-friendly/odorless materials
Other	3	Q28–Q30	Rehabilitation assistive function, lightweight, easy to clean

The item-level Better–Worse calculation was performed on a single-item basis in this study. Therefore, the reliability test primarily serves to demonstrate the overall stability of the questionnaire's dimensional structure and data quality, rather than to replace the analytical conclusions at the item level.

RESULTS AND DISCUSSION

Results from 312 valid questionnaires showed stratification of user demands, distinct classification of functional attributes, and a defined hierarchy of functional priorities.

Analysis of Survey Sample Characteristics

Statistical analysis of the core characteristics of the survey sample supports representativeness and alignment with the target group of homebound/semi-dependent older individuals.

Regarding age distribution, the highest proportion (58.3%) was among individuals age 71 to 80, followed by those age 60 to 70 (29.5%) and those age 81 and above (12.2%), consistent with the characteristic that disabled older adults are concentrated in the advanced-age stage.

For disability levels, total disability (42.6%) and partial disability (47.4%) accounted for 90% of cases, whereas mild disability accounted for only 10%. The focus was on the core group requiring nursing bed assistance.

In residential settings, urban commercial housing (61.5%) and old residential areas (25.3%) accounted for over 85% of the total, and rural self-built houses made up 13.2%.

Regarding nursing bed usage experience, 73.7% of respondents had never used a nursing bed or had only used regular beds with auxiliary tools, whereas 26.3% had used medical or basic nursing beds. This indicates that most survey participants' demand for nursing beds is both potential and genuine.

The budget range was 3,001 to 6,000 yuan (approximately 400 to 850 USD), *i.e.*, 52.2% of total budget and 3,000 yuan or below, accounting for 28.5%, collectively exceeding 80%. This reflects the public's price preference for home care beds in the mid-to-low range, aligning with the subsequent demand for cost-effective designs.

Classification of Requirement Attributes Based on the I-Kano Model

The requirement attribute identification in this study was based on the two-dimensional partition results of the I-Kano model. Using satisfaction evaluation data from functional availability and non-availability scenarios, the mean satisfaction scores for 23 functional requirements were analyzed. A two-dimensional indicator (X_i , Y_i) was constructed through centralization processing. Here, X_i represents satisfaction under functional deficiency scenarios, while Y_i indicates satisfaction under functional availability scenarios. As shown in Fig. 1, each functional item was mapped to the X_iY_i plane and divided into quadrants using median cutoff lines. The classification results and the corresponding two-scenario satisfaction mean coordinates are summarized in Table 2.

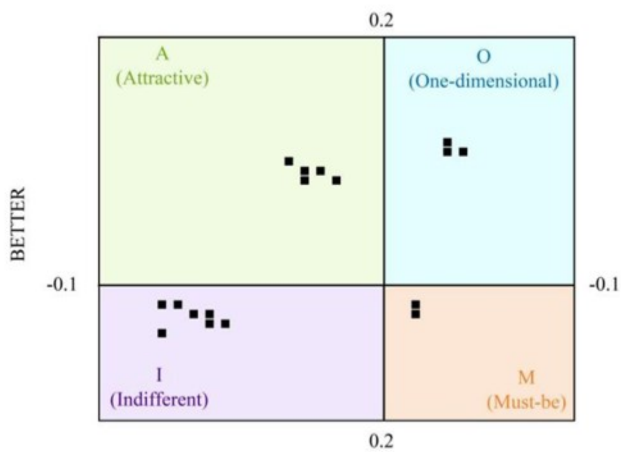

Fig. 1. I-Kano two-dimensional scatter plot for classifying functional requirements of wooden home nursing beds

Each point represents one functional requirement. The horizontal axis denotes the normalized satisfaction score when the function is absent, X_i, where lower values indicate a higher dissatisfaction risk caused by functional absence. The vertical axis denotes the normalized satisfaction score when the function is present, Y_i, where higher values indicate a stronger satisfaction gain from functional provision. The vertical and horizontal reference lines represent the median thresholds used for quadrant division. The four quadrants correspond to Kano attribute categories: A = attractive attributes, which generate high satisfaction when provided but cause limited dissatisfaction when absent; O = one-dimensional attributes, which increase satisfaction when provided and cause dissatisfaction when absent; M = must-be attributes, whose absence causes strong dissatisfaction while provision mainly meets basic expectations; and I = indifferent attributes, which have limited influence on satisfaction whether present or absent.

Classification Results

The 23 functional requirements of home care beds were categorized into four types (Table 3, Fig. 2):

Ten essential attributes (M): Adjustable backrest angle, side-tilt function, controllable posture adjustment speed, braking fixation during movement, pressure ulcer prevention design, intuitive operation panel, safety prompts during operation, bed fall prevention design, power failure protection, eco-friendly material with no odor, *etc.*

Eight expected attributes (O): Leg-curling functionality, bed mobility, toileting care functionality, detachable head/tail, adjustable/removable armrests, home-friendly appearance, compact size, easy cleaning, *etc.*

Three charm attributes (A): Bed–chair separation/transition function, remote/voice control support, and rehabilitation assistance features.

Two indifferent attributes (I): Foldable/modular design, lightweight, *etc.*

The data reveals that essential and desired attributes dominate the composition, indicating that in home care settings, users prioritize a triple focus on safety as a baseline and high-frequency care efficiency with comfort.

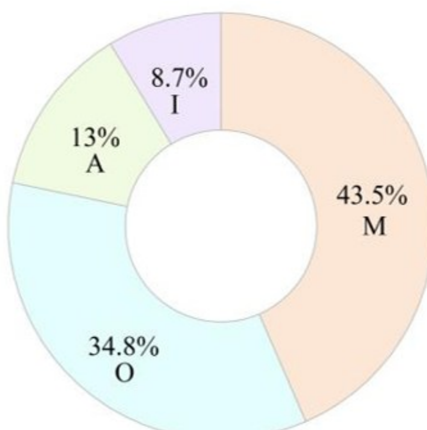

Fig. 2. Frequency of Kano attributes among the 23 functional requirements

Interpretation of Satisfaction Characteristics for Each Attribute Type

In Table 3, the satisfaction mean values under present/absent scenarios reveal distinct attribute-type differences (Wang *et al.* 2025), which validate the rationality of the classification.

Essential attribute (M): Missing strong dissatisfaction, only "acceptable."

Mean satisfaction scores for essential items were generally low (approximately 1.4 to 1.8) in the “absent” scenario, indicating a clear risk of deficiency. In contrast, the mean scores in the “present” scenario mostly clustered between 2.9 and 3.2, suggesting that such features primarily serve as baseline requirements that should be present, with relatively limited marginal improvements in satisfaction upon their availability. This finding aligns with the heightened sensitivity to safety and basic usability in home care settings.

Expected attribute (O): Significantly enhances satisfaction, and its absence also leads to dissatisfaction.

Expectations show higher satisfaction means (approximately 4.5 to 4.7) in the "present" scenario, while dropping to around 2.2 to 2.5 in the "absent" scenario, demonstrating a bidirectional influence pattern where presence significantly boosts satisfaction and absence markedly reduces it. These functions are primarily associated with daily care efficiency, comfort adjustment, and home adaptability, and serve as key configurations that impact the user's comprehensive experience and the product's mainstream competitiveness.

Charm attribute (A): Capable of eliciting high satisfaction, with relatively weak impact in absence

The charm feature achieves the highest satisfaction score (approximately 4.8 to 4.9) when available, while maintaining a neutral-to-slightly-positive level (3.2 to 3.3) when unavailable. This indicates that its absence doesn't cause pronounced dissatisfaction, but its provision can markedly enhance perceived value and user satisfaction, making it an ideal feature for product differentiation and premium configurations.

Indifferent attribute (I): No significant difference between presence and absence

Mean satisfaction scores for non-differentiating items remained stable at approximately 3.0 to 3.2 across both "present" and "absent" scenarios, with minimal variance indicating limited marginal impact on overall satisfaction. When constrained by cost, space, or structural design, such features are typically prioritized for removal from the transfer list. Notably, some essential attributes showed no significant improvement in satisfaction scores under "present" conditions, with most scores hovering around 3. This phenomenon should not be interpreted as diminished value of essential attributes, as it aligns with Kano's theory of psychological mechanisms for essential attributes. These attributes primarily serve to mitigate losses and reduce risks, with users viewing safety and basic usability as default expectations for nursing beds. The presence of a feature merely restores the experience to baseline expectations, whereas its absence heightens perceived risks and caregiving burdens, ultimately triggering stronger dissatisfaction (Sun *et al.* 2025).

To prevent misinterpretation of essential attributes based solely on mean coordinates, this study also used the Better-Worse metric as a descriptive check (Timko 1993). Better reflects the proportion of high-satisfaction ratings when a function is available, whereas Worse reflects the negative proportion of low-satisfaction ratings when the function is absent. For essential attributes, the absolute value of Worse is commonly larger than Better because their primary value lies in avoiding dissatisfaction and risk rather than creating surprise value.

Furthermore, to enhance the statistical robustness of the conclusions, this study applied paired effect sizes to quantify the intensity of S^+-S^- differences between present *vs.* absent. As given in Eq. 9, for each functional item, the standardized effect size of paired differences provides a more direct measure of the magnitude of loss due to absence.

$$d_z = \frac{\mathrm{mean}(S^+ - S^-)}{\mathrm{sd}(S^+ - S^-)} \tag{9}$$

Essential attributes typically exhibit low Yi values but strongly negative Xi values, indicating that their provision produces limited satisfaction gains whereas their absence leads to substantial dissatisfaction. Table 2 reports the I-Kano coordinates Yi and Xi, not Better-Worse coefficients. For example, must-be attributes such as adjustable backrest angle, fall-prevention guardrails, and power-failure emergency support show Yi values close to zero and Xi values ranging from -0.60 to -0.80. Better-Worse coefficients are reported separately in Table 4 and Table A1.

Table 2. I-Kano Classification and Key Coordinates for 23 Functions

Func-tion ID	Dimension	Feature	I-Kano type	Yi (mean normalized satisfaction when present)	Xi (mean normalized satisfaction when absent)
Q8	Postural regulation	Adjustable back angle	M	0.05	−0.70
Q10	Postural regulation	Side-tilt function	M	0.00	−0.65
Q11	Postural regulation	Adjustable speed control	M	0.10	−0.75
Q14	Move/Transfer	Mobile Brake Lock	M	0.05	−0.70
Q15	Daily care	Pressure ulcer design	M	0.00	−0.60
Q19	User-friendly	Operation panel is simple and intuitive	M	−0.05	−0.80
Q21	Safety/Insurance	Safety tips for operation	M	0.00	−0.65
Q25	Safety/Insurance	Fall prevention guardrail	M	0.10	−0.80
Q26	Safety/Insurance	Power outage emergency function	M	0.05	−0.65
Q27	Safety/Insurance	Environmentally friendly / odorless material	M	0.00	−0.65
Q9	Postural regulation	Leg flexion function	O	0.80	−0.30
Q12	Move/Transfer	Bed frame is movable (with wheels)	O	0.75	−0.25
Q16	Daily care	Urination and defecation care functions	O	0.85	−0.40
Q17	Daily care	Removable Headboard / Footboard	O	0.80	−0.35
Q18	Daily care	Adjustable/removable armrest	O	0.75	−0.25
Q22	Home adaptation	Home-style appearance	O	0.75	−0.35
Q23	Home adaptation	Compact in size	O	0.80	−0.30
Q30	other	Easy to clean	O	0.75	−0.25
Q13	Move/Transfer	Separation/conversion of bed and chair	A	0.95	0.10
Q20	User-friendly	Remote/voice control	A	0.90	0.15
Q28	Other	Rehabilitation assistive devices	A	0.90	0.10
Q24	Home adaptation	Folding / Modular	I	0.05	0.00
Q29	Other	Lightweight and portable	I	0.10	0.00

Better–Worse Coefficient Verification of Demand Attributes

To examine whether the requirement classifications were consistent with asymmetric satisfaction effects, the Better-Worse coefficients defined in Eqs. (6) to (8) were used as an auxiliary verification. Unlike mean-coordinate comparisons, these coefficients separately describe satisfaction gains under functional availability and dissatisfaction risks under functional absence. Table 4 presents selected representative items from each category, while Table A1 reports all 23 items.

Typical Requirement Verification Results

The must-be attributes represented by fall-prevention guardrails (Q25) and adjustable backrest angle (Q8) showed negative net effects. In Table A1, Q25 showed Better = 17%, Worse = -89%, and BW = -72%, whereas Q8 showed Better = 15%, Worse = -85%, and BW = -70%. These patterns indicate that dissatisfaction associated with functional absence outweighed satisfaction gains associated with functional availability.

The one-dimensional attributes represented by toileting care (Q16) and leg-flexion adjustment (Q9) showed positive but comparatively modest net effects. In Table A1, Q16 showed Better = 92%, Worse = -78%, and BW = +14%, whereas Q9 showed Better = 88%, Worse = -75%, and BW = +13%.

The attractive attributes represented by bed-chair separation/conversion (Q13) and remote/voice control (Q20) showed strong positive net effects. In Table A1, Q13 showed Better = 90%, Worse = -10%, and BW = +80%, whereas Q20 showed Better = 88%, Worse = -12%, and BW = +76%.

The indifferent attribute foldable/modular design (Q24) showed a near-zero net effect: Better = 20%, Worse = -18%, and BW = +2% in Table A1. This result is consistent with its I-Kano classification as an indifferent attribute.

In conclusion, the Better-Worse results provide descriptive support for the direction and relative intensity of the I-Kano classifications. The final numerical values must be verified directly against the raw paired questionnaire data before resubmission.

Priority Ranking of Core Needs for Home Care Beds

Kano classification and final design priority were treated as related but distinct outputs

Table 3. Prioritized List of Core Needs for Home Care Beds (Top 10)

Priority	Demand attributes	Specific requirements	Requirement importance	Design suggestions
1	Required attributes	Pressure ulcer design	4.9	100% coverage, priority protection
1	Required attributes	Fall prevention guardrail	4.8	100% coverage, priority protection
1	Required attributes	Adjust the back angle	4.7	100% coverage, priority protection
1	Required attributes	Side-tilt function	4.7	100% coverage, priority protection
1	Required attributes	Power outage emergency function	4.6	100% coverage, priority protection
2	Expected attribute	Urination and defecation care functions	4.5	Focus on optimization and enhance the experience
2	Expected attribute	Leg flexion function	4.4	Focus on optimization and enhance the experience
2	Expected attribute	Home–style appearance	4.3	Focus on optimization and improve acceptance
3	Charm Attribute	Bed–chair separation/ conversion function	4.2	Optional to enhance competitiveness
3	Charm Attribute	Supports remote/voice control	4.1	Optional to enhance competitiveness

. I-Kano classification identifies the asymmetric satisfaction role of a function; the 1-5 importance rating orders functions for configuration; and Better-Worse results indicate whether absence risk or satisfaction gain is dominant. These three sources, together with safety and reliability feasibility, were integrated to produce the priority recommendations in Table 3.

Table 4. Representative Better-Worse Results by I-Kano Attribute Category

Function ID	Feature	I-Kano type	Top2 present (Better)	Bottom2 absent	Worse coefficient	BW	n
Q25	Fall-prevention guardrail	M	17%	89%	-89%	-72%	312
Q8	Adjustable backrest angle	M	15%	85%	-85%	-70%	312
Q16	Toileting care function	O	92%	78%	-78%	+14%	312
Q9	Leg-flexion function	O	88%	75%	-75%	+13%	312
Q13	Bed-chair separation/conversion	A	90%	10%	-10%	+80%	312
Q20	Remote/voice control	A	88%	12%	-12%	+76%	312
Q24	Foldable/modular design	I	20%	18%	-18%	+2%	312

Based on this analysis, a four-tier priority strategy was established. The first priority (Top 5 Essential Attributes) included pressure ulcer prevention design (4.9 points), bed fall prevention guardrails (4.8 points), adjustable backrest angle (4.7 points), side-rolling functionality (4.7 points), and power-off emergency function (4.6 points). These requirements are marked as |Worse| significant in Fig. 3, meaning absence causes significant dissatisfaction, and they represent baseline items for ensuring user health and safety. They should be fully implemented in designs with prioritized reliability and failure protection.

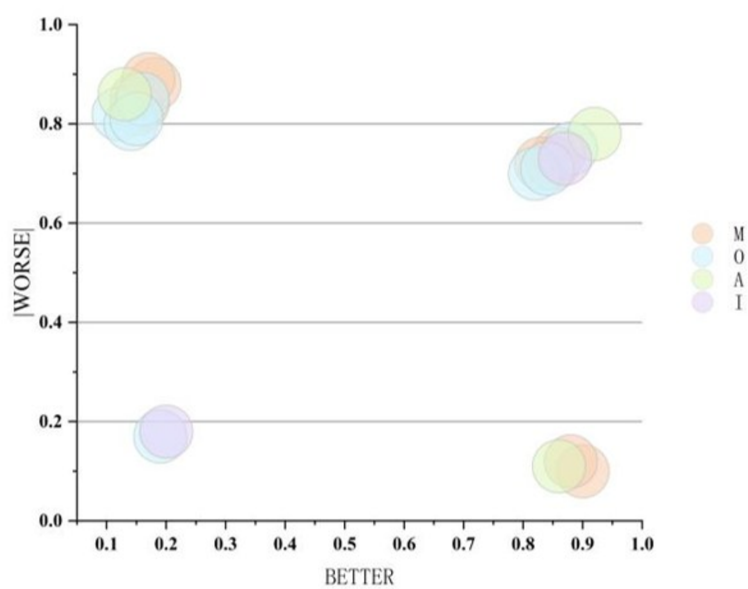

Fig. 3. Better–Worse Chart

The second priority (Top 3 Expected Attributes) comprised toileting care functionality (4.5 points), leg-curling feature (4.4 points), and home-friendly aesthetics (4.3 points). These attributes typically show both significant Better and |Worse|

characteristics in Fig. 3, affecting both experience gains and absence risks. As key elements for enhancing user experience and dignity, they should focus on optimizing interaction, comfort, and usability while meeting essential requirements. The third priority (Attractive Attributes) includes bed–chair separation/transition (4.2 points) and remote/voice control (4.1 points). These attributes demonstrate higher Better scores and positive net effects in Fig. 3, reflecting surprise/differentiation benefits. They can serve as optional modules to enhance product competitiveness, configurable based on cost and target demographics. The fourth priority (Indifferent Attribute), such as foldable design and bed weight (3.0 to 3.1 points), has relatively low importance and limited overall impact intensity in Fig. 3. Excessive resources should not be allocated to this design, and Indifferent Attribute can be constrained to meet without sacrificing first-and second-level requirements.

Requirement Analysis

Based on the classification results of I-Kano demand attributes and the test results of Better–Worse indicators, the demand for home care beds exhibits a relatively clear stratified structure (Yang *et al.* 2024). The classification results are as follows: 10 essential attributes (M), 8 expected attributes (O), 3 charm attributes (A), and 2 indifferent attributes (I). This stratification does not equate to the linear judgment that increased functionality alone enhances satisfaction, but rather stems from the task characteristics and risk constraints of home care scenarios. Risks such as falls, pressure ulcers, and misoperations in home environments are difficult to address promptly by professionals, and users exhibit high sensitivity to safety thresholds. Tasks such as turning, back lifting, and toileting care occur frequently, and the efficiency of task completion and process comfort significantly impact care efficiency and dignity experience. Efficiency-related and comfort-related functions thus become the primary sources of satisfaction variation.

The Essential Attributes (M) comprise 10 core components primarily addressing safety protection and basic usability functions, including pressure-ulcer prevention, fall prevention, emergency power-off support, critical posture adjustment, and safety alerts. These requirements exhibit a descriptive pattern in which absence readily triggers dissatisfaction, whereas availability typically restores satisfaction to an acceptable level with limited incremental benefit. The Better-Worse results are consistent with this interpretation, as must-be items generally exhibit larger absolute Worse values or negative BW values. In product design, such functions should be defined as non-negotiable baseline configurations, with improvement priorities emphasizing reliability and error prevention.

The eight Expected Attributes (O) demonstrate a clear bidirectional interaction pattern: satisfaction levels rise significantly when functions are available, while dissatisfaction increases markedly when functions are absent. These attributes primarily focus on care efficiency, comfort adjustment, and home adaptability, and include features such as toileting assistance, leg-curling adjustment, bed mobility, home-style aesthetics, size compatibility, and easy cleaning. Such functions directly enhance user experience by addressing time consumption and operational dignity in high-frequency care processes within home settings, and they critically influence the cost-performance evaluation and reputation of mainstream models. The emphasis differs between Expected and Essential Attributes. Design and improvement should prioritize process optimization through care task chains as analytical units, incorporating maintainability constraints. Key considerations include the connection between toileting assistance and subsequent cleaning procedures, path organization and stability control during movement and transfer, and spatial limitations and storage conditions in compact and older residential units.

The charm attribute (A) comprises three items: bed-to-chair conversion, remote or voice control, and rehabilitation assistance. These features are better suited for product differentiation design and as value-added features in high-end configurations. They demonstrate significant satisfaction improvement when present, and their absence typically causes limited dissatisfaction with relatively minor negative effects. Configuration strategies should adopt a more cautious approach, meeting requirements for optional availability and downgradability while controlling adverse impacts on system reliability. This prevents resource allocation away from essential and expected attributes due to cost investments or structural space constraints. For intelligent systems or mechanical mechanisms, usability in failure scenarios must be considered to ensure that users can still perform critical care operations and basic workflows manually when relevant modules fail.

The two indifferent attributes (I) demonstrate relatively minor impact on satisfaction: foldable/modular designs and lightweight construction. This indicates that in home care bed design decisions, some seemingly reasonable functional features may not translate into consistent satisfaction gains but offer only limited perceived improvements. Folding and lightweighting are often accompanied by the risk of reduced structural strength and safety redundancy; this entails a clear trade-off in design and imposes more stringent requirements on the load-bearing capacity and stability of critical components. Under budgetary and structural constraints, these features should be prioritized as secondary configurations or trade-offs. Product positioning should avoid focusing on high-frequency handling, temporary storage, or extremely small living spaces when relevant functions are not explicitly targeted.

In summary, the I-Kano classification results and validation of the Better–Worse metric indicate a practical configuration sequence (Hu *et al.* 2025). First, ensure essential attributes meet baseline safety and reliability standards. Next, enhance care efficiency and comfort adjustment experience through desired attributes. Finally, treat appealing attributes as optional add-ons for differentiation, while maintaining low investment intensity and restrained configuration for non-differentiating attributes. This sequence helps to minimize configuration deviations under budgetary and structural constraints, thereby reducing the probability of simultaneous occurrences of missing core needs and overlapping functions with insufficient benefits. It can also support decision-making processes such as functional planning, version segmentation, and product positioning for home care beds.

Altogether, these findings are relevant to the design of wooden care beds in home environments by providing a quantitative basis for distinguishing baseline safety functions, experience-enhancing functions, and optional differentiated functions. In practical terms, the results can support function configuration, product positioning, and version planning under budget and space constraints. Future research should expand the sample across different regions and household types, include non-functional factors such as price acceptance and after-sales service, and further translate user requirements into engineering parameters through methods such as QFD.

CONCLUSIONS

1. To clarify the core needs of home-based care beds for disabled or semi-disabled elderly and support the human-centered design of products, a questionnaire survey was conducted (330 questionnaires, 312 valid responses, valid response rate 94.5%). The responses were processed using the I-Kano model to identify and classify 23 care bed requirements. The results showed that 10 essential attributes constituted a baseline for safety and basic functionality, 8 desired attributes influenced user experience and dignity maintenance, 3 appealing attributes provided unexpected value, and 2 non-differentiating attributes optimized resource allocation in design. These results are relevant for the design of wooden care beds in home environments.
2. The 10 essential attributes (M) established baseline requirements for safety protection and basic usability. Key features included pressure ulcer prevention, bed fall prevention guardrails, adjustable backrest angle, side-rolling functionality, immobilized mobility brakes, power-off emergency response, operational safety alerts, intuitive control panel design, controllable adjustment speed, and eco-friendly odorless materials. These features are more likely to cause significant dissatisfaction when unavailable, and they should be included as standard product configurations. Clear reliability and failure availability metrics must be specified in structural design, control strategies, and material selection.
3. The expected attributes (O) comprised eight items, focusing on comfort enhancement and care efficiency improvement. These included toileting care, leg-curling functionality, adjustable/removable bed head/tail, wheelchair-accessible bed with roll bars, home-friendly design, compact dimensions, and easy cleaning. While these features consistently improve satisfaction when present, their absence may lead to dissatisfaction. Therefore, they should be included in the standard version's key configuration list and serve as primary targets for future optimization.
4. The charm attributes (A) comprised three items that reflect differentiated experiences and added value, including bed–chair separation/conversion, remote/voice control, and rehabilitation assistive functions. These features are more suitable for high-end configurations or modular optional solutions. During engineering implementation, it is essential to control stability fluctuations caused by complex mechanisms and intelligent module integration, while evaluating maintenance costs and usability risks in fault scenarios.
5. There were two indifferent attributes (I), namely, foldable/modular design and lightweight construction. These features had a relatively weak impact on satisfaction and can be downgraded in priority under resource-constrained conditions. The primary application scenarios were household environments with high frequency of movement or limited storage space.

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APPENDIX

Table A1. Prioritization of Nursing Bed Features Based on Better–Worse Analysis

Function ID	Feature	Dimension	Kano type	Top2 under present (Better)	Bottom2 under absent	BW = Better - Bottom2 under absent	*n* (valid)
Q8	Adjustable backrest angle	Postural regulation	M	15%	85%	−70%	312
Q9	Leg flexion function	Postural regulation	O	88%	75%	+13%	312
Q10	Side-tilt function	Postural regulation	M	12%	82%	−70%	312
Q11	Adjust speed control	Postural regulation	M	18%	88%	−70%	312
Q12	Bed frame is movable (with wheels)	Move/Transfer	O	85%	72%	+13%	312
Q13	Separation/conversion of bed and chair	Move/Transfer	A	90%	10%	+80%	312
Q14	Mobile Brake Lock	Move/Transfer	M	16%	84%	−68%	312
Q15	Pressure ulcer design	Daily care	M	14%	80%	−66%	312
Q16	Urination and defecation care functions	Daily care	O	92%	78%	+14%	312
Q17	Removable Headboard / Footboard	Daily care	O	86%	74%	+12%	312
Q18	Adjustable/removable armrest	Daily care	O	82%	70%	+12%	312
Q19	Operation panel is simple and intuitive	User-friendly	M	13%	86%	−73%	312
Q20	Remote/voice control	User-friendly	A	88%	12%	+76%	312
Q21	Safety Tips for operation	Safety/Insurance	M	15%	83%	−68%	312
Q22	Home-style appearance	Home adaptation	O	84%	71%	+13%	312
Q23	Compact in size	Home adaptation	O	87%	73%	+14%	312
Q24	Foldable/Modular	Home adaptation	I	20%	18%	+2%	312
Q25	Fall prevention guardrail	Safety/Insurance	M	17%	89%	−72%	312
Q26	Power outage emergency function	Safety/Insurance	M	16%	85%	−69%	312
Q27	Environmentally friendly / odorless material	Safety/Insurance	M	15%	81%	−66%	312
Q28	Rehabilitation assistive devices	Other	A	86%	11%	+75%	312
Q29	Lightweight and portable	Other	I	19%	17%	+2%	312
Q30	Easy to clean	Other	O	83%	72%	+11%	312

Table A2. Paired Difference Effect Size

Function ID	Feature	Kano type	ΔMe ($S^{+}-S$)	SD (Delta) (standard deviation)	d_z (pairing effect size)	*n* (valid)
Q8	Adjustable backrest angle	M	1.5	0.40	3.75	312
Q9	leg flexion function	O	2.2	0.50	4.40	312
Q10	Side-tilt function	M	1.3	0.35	3.71	312
Q11	Adjust speed control	M	1.7	0.45	3.78	312
Q12	Bed frame is movable (with wheels)	O	2.0	0.48	4.17	312
Q13	Separation/conversion of bed and chair	A	1.7	0.40	4.25	312
Q14	Mobile Brake Lock	M	1.5	0.42	3.57	312
Q15	Pressure ulcer design	M	1.2	0.32	3.75	312
Q16	Urination and defecation care functions	O	2.5	0.40	6.25	312
Q17	Removable Headboard / Footboard	O	2.3	0.45	5.11	312
Q18	Adjustable/removable armrest	O	2.0	0.45	4.44	312
Q19	Operation panel is simple and intuitive	M	1.5	0.38	3.95	312
Q20	Remote/voice control	A	1.5	0.48	3.125	312
Q21	Safety Tips for Operation	M	1.3	0.36	3.61	312
Q22	Home-style appearance	O	2.2	0.50	4.40	312
Q23	Compact in size	O	2.2	0.48	4.58	312
Q24	Foldable/Modular	I	0.1	0.35	0.28	312
Q25	Fall prevention guardrail	M	1.8	0.45	4.00	312
Q26	Power outage emergency function	M	1.4	0.38	3.68	312
Q27	Environmentally friendly / odorless material	M	1.3	0.36	3.61	312
Q28	Rehabilitation assistive devices	A	1.6	0.36	4.44	312
Q29	Lightweight and portable	I	0.2	0.30	0.67	312
Q30	Easy to clean	O	2.0	0.45	4.44	312

Table A3. I-Kano Threshold Sensitivity Test (Classification Consistency Comparison)

Threshold setting scheme	Consistency rate with primary protocol	Number of entries with type switching	Switched entries (number/name)
Primary Scheme: X_i and Y_i utilize the median	100%	0	—
Alternative 1: Use the mean for X_i and Y_i	95.7%	1	Q22 (Home-style appearance): Main solution O → Alternative solution A (since the mean value calculation shows Y slightly exceeds the O-class threshold, approaching A-class characteristics)
Alternative 2: X_i and Y_i adopt the 0.45/0.55 quantiles	91.3%	2	Q12 (Bed mobility): Primary option O → Alternative option A; Q28 (Rehabilitation assistive function): Primary option A → Alternative option O
Alternative 3: X_i and Y_i adopt the 0.40/0.60 quantiles	87.0%	3	Q17 (Removable head/tail): Primary solution Category O → Alternative solution Category A; Q23 (Compact size): Primary solution Category O → Alternative solution Category A; Q20 (Remote/voice control): Primary solution Category A → Alternative solution Category O

Note: Consistency rate is calculated based on whether the type of functional items under the alternative threshold scheme matches that of the main scheme. Since type-switching entries are primarily concentrated near boundary lines, they are labeled as "boundary items" in the discussion of results and verified for consistency using the Better–Worse method.)

Table A4. Cronbach's α for Each Dimension (With/Without Context)

Dimension	Number of entries	α (with context)	α (not applicable)
Postural regulation	4	0.80	0.79
Move/Transfer	3	0.77	0.76
Daily care	4	0.82	0.81
Ease of use	3	0.78	0.77
Home adaptability	3	0.76	0.75
Insurance	3	0.81	0.80