

Research on the Design of Growable Solid Wood Children's Beds

Jinjing Wang, Qianwei Liang, Xinyu Ma, Yihan Wei, and Yushu Chen *

To meet children's needs for beds at different stages of growth, a product design model integrating the KANO Model, the Hierarchical Analysis Method, and Axiomatic Design (KANO-AHP-AD) was adopted to conduct a design study on the growability of solid wood children's beds. In accordance with the KANO model, the demands for children's beds coming from questionnaires among families with children were classified and sorted, and the demand indicators were then summarized. Secondly, AHP was introduced to establish a multilevel hierarchical model, construct a judgment matrix of design elements, and calculate the weights of these elements to improve the accuracy of users' demand weights. Then, AD was used to complete the mapping of the demand domain, function domain, and design domain of children's beds and to judge their reasonableness through the matrix. Such a design allows users to evaluate and verify the rationality of the program. Through modular design techniques, the growability requirements were fulfilled. A low number of product modules were freely combined to form product types with multiple functions to meet customers' needs for personalization and functional diversification. The work has value for the design of growable children's beds, thus contributing to sustainable development and environmental protection causes.

DOI: 10.15376/biores.19.4.8257-8272

Keywords: Children's beds; KANO; AHP; AD; Growability; Modular design

Contact information: College of Furnishings and Industrial Design, Nanjing Forestry University, Nanjing, Jiangsu Province, China 210037; *Corresponding author: cys@njfu.edu.cn.

INTRODUCTION

According to the National Bureau of Statistics data for 2023, China's high-quality consumer demand continues to grow, especially in the furniture market. High-end consumers of children's furniture have increasing requirements for functionality, safety, and sustainability. China's young generation of parents have changed their views on parenting, paying more attention to the impact of the home environment on children's growth and choosing home furnishings that match children's physiological and psychological characteristics. As a result, the children's furniture industry has fertile ground for growth. China's children's furniture industry has experienced a budding stage from 1997 to 2002, an explosive growth stage from 2003 to 2012, and has entered a steady growth stage since 2013. From 2013 to 2021, the children's furniture market size increased from 52.9 billion yuan to 100 billion yuan (Fig. 1), with a compound annual growth rate of 8.3%. (In the relevant trend discussion of this study, in view of the fact that the major public health emergency of the COVID-19 pandemic worldwide in 2020 has caused unprecedented impacts and disruptions on the economy, society, and other aspects, making the data of this year extremely special, this study does not include the data of 2020 in the

analysis category.) According to relevant research organizations, China's children's furniture market size may reach 182.5 billion yuan in 2024. Despite the rapid development, most products on the market still exist as scaled-down versions of adult furniture, ignoring children's special physiological and psychological needs such as safety, fun, and growability (Xu and Xu 2023). Therefore, design for growth provides an under-explored research space as one of the solutions.

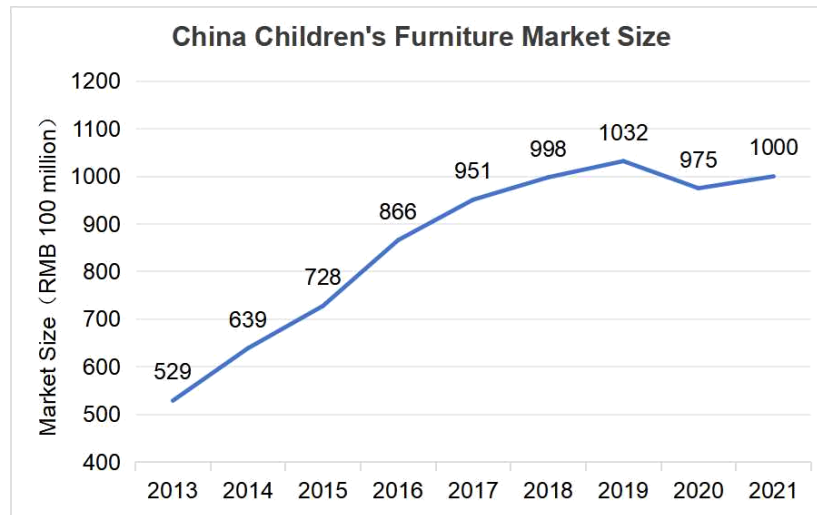


Fig. 1. China children's furniture market size line chart

Western countries have conducted more in-depth theoretical research and accumulated rich practical experience in the design of children's furniture for growth. Research shows that since the 1950s, Western countries have emphasized child-centered design (Phuah *et al.* 2022), focusing on multifunctionality and environmental friendliness in practice. For example, Finnish designer Bilka Stenlus and Danish furniture brand FLEXA focus on safety and comfort while meeting the needs of different growth stages through modular design. As the children's furniture industry develops, the research perspective has expanded from basic physical functions to psychological research. Studies have found that different design elements affect preschoolers' perceptions, such as warm colors on desks and chairs, cool colors on bookshelves, and the use of patterns, natural forms, and materials. These results help designers choose elements for furniture used by preschoolers (Tamthintha *et al.* 2018).

In China, some progress has been made in the safety of children's furniture and modular design, but systematic research on growable children's furniture is scarce. Initial research on growth furniture aimed to make functions flexible to meet children's needs by changing the height or combining accessories (Kang 2004). Existing literature mainly focuses on functionality and safety, with insufficient exploration of children's growth needs and interdisciplinary design methodology (Zhang and Xu 2023). Growability design is beginning to be applied but lacks depth in research and development of individual product categories. This study aims to explore new modes of children's furniture design, especially innovative designs in terms of growability and sustainability, through comprehensive interdisciplinary theories and methods, providing scientific and systematic theoretical support and practical guidance for children's furniture design.

EXPERIMENTAL

KANO Model (KANO)

The KANO model (Kano *et al.* 1984) is a qualitative analysis tool to categorize and prioritize user needs. It clarifies the association between products/services and consumer satisfaction by analyzing user need categories, locates user needs and product/service attributes, and provides decision analysis support for designers (Violante and Vezzetti 2017). It identifies, categorizes, summarizes, and clarifies demand attributes and indicators for beds of children and parents. The user demand data mainly come from questionnaires conducted among families with children.

Analytical Hierarchical Process Method (AHP)

The AHP (Saaty 1977) improves the accuracy of user requirements weighting, thereby promoting rational division of target guidelines and sub-criteria levels (Wang and Zhai 2020). It is an analytical method linking quantitative and qualitative judgments used for scientific and rational decision-making in fields involving hierarchical analysis.

Axiomatic Design (AD)

The AD method proposed by Nam P. Suh forms the basis for engineering design studies. In AD, the user, function, and design domains can be expressed by a judgment matrix (Cai *et al.* 2010). The independence principle is used to confirm design parameter solutions. AD maps these domains to clarify parameters. User feedback is collected to help designers understand satisfaction and extend the brand life cycle while meeting children's growth needs.

KANO-AHP-AD Integrated Application

KANO can reflect the user demand and attribute division, while AHP can calculate the weight of the design elements, effectively solving the problem of comprehensive ranking of the demand indicators of KANO (Wang and Fan 2024).

AD can be used to carry out a “Z” mapping of the functional domains and design domains of the design of solid wood children's beds (Cheng *et al.* 2016), to comprehensively analyze the user demand and product characteristics of the solid wood children's beds. AD can map the functional domains and design domains of solid wood children's bed design in a “Z” shape, to comprehensively analyze the user needs and product characteristics of solid wood children's bed.

The user domains (CAs) of the product are converted to the corresponding function domains (FRs), and then the function domains (FRs) are converted to the corresponding design domains (DPs), to clarify the design parameters of the solid wood children's bed. The design process integrating the KANO-AHP-AD theoretical model can convert users' subjective needs into design elements, and reasonably integrate qualitative and quantitative analysis into the design thinking process from multiple perspectives, such as system and hierarchy, so that the decision-making program can be more reasonable and scientific to meet users' needs (Fig. 2).

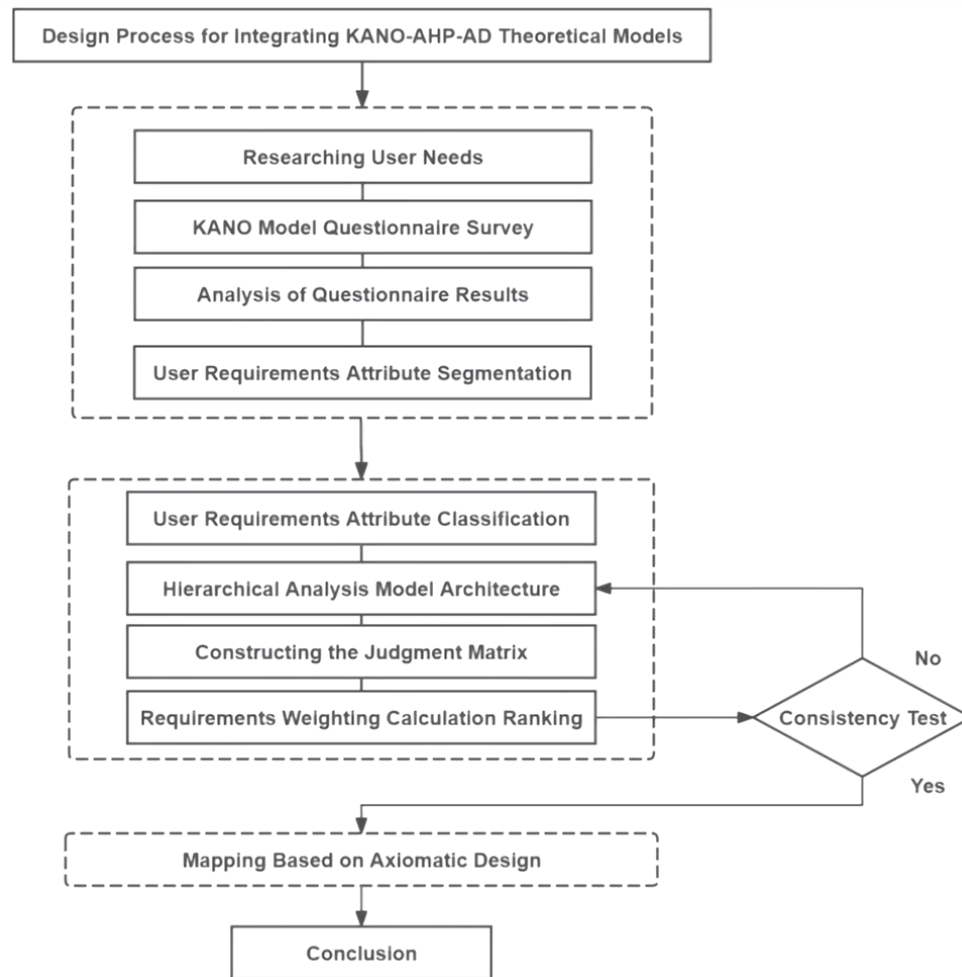


Fig. 2. The framework for integrating KANO-AHP-AD

CONSUMER PREFERENCE ANALYSIS

User Orientation

In psychology, 3 years old is the dividing line for preschool children (Deng *et al.* 2000). Before the age of 3, young children need adult assistance for activities. After the age of 3, children experience significant psychological and physiological changes, becoming energetic and able to participate independently under adult guidance, showing strong curiosity and a desire to learn. Children's growth is dynamic. Growable solid wood children's beds target users aged 3 to 14, able to engage in independent activities. These beds meet children's needs for safety, space, decoration, and functionality throughout their growth.

Data Analysis

Due to preschool children's inability to accurately express product needs, and the strong influence of parents as buyers, the target users of this research were parents and children aged 10 to 14. Through user interviews and other initial user research analyses, user needs were initially identified, 16 demand attributes were divided, and the demand options in the questionnaire research were summarized, based on which the KANO

questionnaire was distributed. According to the resultant values of each quality in each demand, the data results were obtained by applying the method of maximum value categorization to further categorize that demand.

In the KANO model (Ren *et al.* 2024), based on the analysis and research of user needs from questionnaires, user satisfaction is categorized into five categories, which are basic quality (M), performance quality (O), excitement quality (A), neutral quality (I) and reverse quality (R). According to the research data as well as the formula, the Better-Worse coefficient of each function of the growable children's bed was calculated, and a total of 12 design elements of basic quality (M), performance quality (O), and excitement quality (A) were finally filtered out. These elements are plotted in Table 1 to analyze the impact of each design element on user satisfaction (Fig. 3).

Table 1. Summary of Analysis Results of KANO Model

Number	Demand Attributes	A	O	M	I	R	Classification	Better Coefficient	Worse Coefficient
1	Rational Structure	9	18	26	12	0	M	41.54%	-67.69%
2	Anti-bump Corners	11	17	18	19	0	M	43.08%	-53.85%
3	Safe Spacing Dimensions	10	13	25	17	0	M	35.38%	-58.46%
4	Safe Height of Guardrail	5	24	28	8	0	M	44.62%	-80.00%
5	Comfort	25	15	8	17	0	O	61.54%	-35.38%
6	Simple Shape	26	11	9	19	0	O	56.92%	-30.77%
7	Soft Color	19	19	7	20	0	O	58.46%	-40.00%
8	Adjustable Height	27	13	3	22	0	O	61.54%	-24.62%
9	Storage Function	30	11	6	18	0	O	63.08%	-26.15%
10	Changeable Shape	23	13	21	7	1	A	55.38%	-52.31%
11	Multi-purpose	18	20	17	10	0	A	58.46%	-56.92%
12	Fun	18	19	19	9	0	A	56.92%	-58.46%

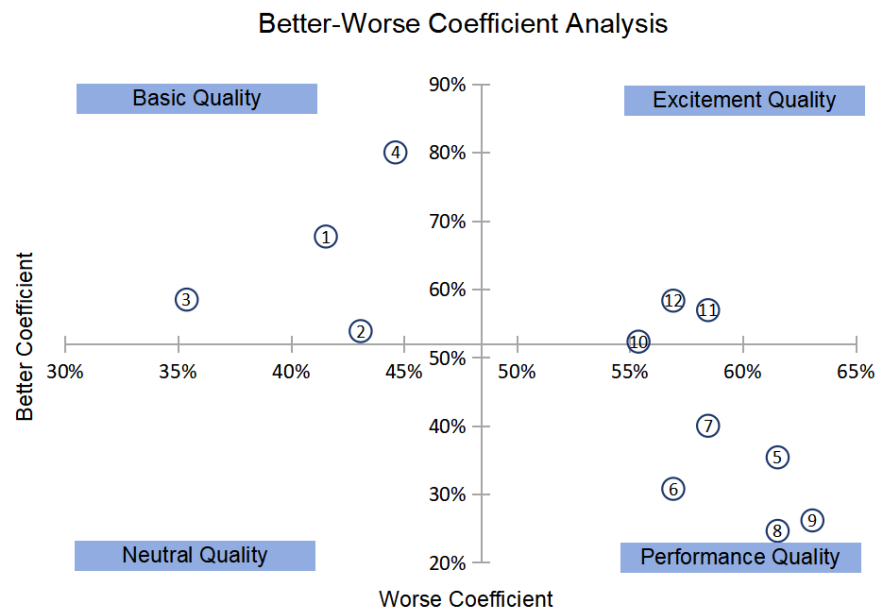


Fig. 3. Scatterplot of user satisfaction quadrant

Summary

Based on data and quadrant diagrams, the following conclusions were drawn:

1. Basic quality requirements include reasonable structure, corners protected against bumping, and safe spacing size. These were the needs of users that had to be met by children's beds. If these needs were not met, user satisfaction dropped significantly. However, even if these needs were optimized, user satisfaction did not increase significantly. Therefore, the design of children's beds had to ensure that these basic needs were met but did not need to over-optimize them.

2. Excitement quality requirements include changeable shape, multi-purpose, and fun. These were the desired needs that users wanted to see in children's bed design. The more these needs appeared in the design, the higher the user satisfaction. If they were not met, user satisfaction decreased. Therefore, when designing children's beds, these desired needs had to be met as much as possible to increase user satisfaction.

3. Performance quality requirements include comfort, simple shape, soft color, adjustable height, and storage function. These were the "charm" needs that could greatly enhance user satisfaction. If these needs were not met, user satisfaction did not decrease, but if they could be met, they significantly increased user satisfaction. These needs were unexpected additional attributes for users and had to be prioritized when designing and developing children's beds to greatly increase user satisfaction and enhance the attractiveness of the product to users, thus improving market competitiveness.

This categorization method helped to clarify the priority of different needs in the design process, which helped allocate design resources more effectively and develop products that better met users' expectations (Zhao *et al.* 2022). Through satisfying users' needs, the design of beds not only improved user satisfaction but also enhanced the market competitiveness of the product and extended the product life cycle.

HIERARCHICAL ANALYSIS OF CHILDREN'S BED DESIGN ELEMENTS

Establish A Multi-Level Hierarchical Structural Model

The core needs of users were identified through a KANO process, and these needs were prioritized using the AHP method (Zhong *et al.* 2023). Combining these two methods not only identified the needs but also quantified their impact on user satisfaction, providing more accurate decision support for the design. Based on the analysis of the attributes of requirements for growable children's beds using KANO, the three most important requirements were identified. A hierarchical model was constructed through KANO-AHP (Neira-Rodado *et al.* 2020), consisting of a target layer, criterion layer, and sub-criterion layer, as follows:

1. *Goal layer*: The target layer element of this study was the optimal design solution for growable children's bed.

2. *Guideline layer*: Through the research of children and parents about the growable children's bed, the three elements of safety demand, practicality demand, and modularity demand were set as the criterion layer.

3. *Sub-criteria layer*: For the safety demand, 4 elements were proposed: stable structure, anti-corner bumping, safety gap size, and safety height of guardrail; for the practicality demand, 4 elements were proposed: comfort, simple shape, soft color and

storage function; for the modularity demand, 4 elements were proposed: adjustable height, changeable shape, multi-purpose, and fun.

Constructing Judgment Matrix and Determining Weights

To calculate the importance weights of the elements at each level, the questionnaire adopted the 1 to 9 scale method. Experts in the field of furniture design (5 furniture designers) were invited to score (Tables 2, 3, 4, and 5). The scores were derived using a two-by-two comparison (Eq. 1), followed by the construction of the target judgment matrix and the calculation of the weight values, as follows,

$$M = (M_{ij}) \quad n \times n = \begin{bmatrix} M_{11} & M_{12} & \cdots & M_{1n} \\ M_{21} & M_{22} & \cdots & M_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ M_{n1} & M_{n2} & \cdots & M_{nm} \end{bmatrix} \quad (1)$$

where $M_i, M_j (i, j = 1, 2, \dots, n)$ represent the elements and M_{ij} represents the relative importance value of M_i over M_j and vice versa $1/M_{ij}$.

Table 2. Optimal Scheme Judgment Matrix and Weight

Z	Security Requirements (M_1)	Utility Requirements (M_2)	Modularity Requirement (M_3)	Weight (w)
Security Requirements (M_1)	1	2	4	0.5714
Utility Requirements (M_2)	1/2	1	2	0.2857
Modularity Requirement (M_3)	1/4	1/2	1	0.1429

Table 3. Security Requirement Judgment Matrix and Weight

Z	Structural Stability (M_{11})	Anti-corner Bumping (M_{12})	Safe Gap Size (M_{13})	Safety Height of Guardrail (M_{14})	Weight (w)
Structural Stability (M_{11})	1	5	3	1/2	0.3309
Anti-corner Bumping (M_{12})	1/5	1	1/4	1/5	0.0635
Safe Gap Size (M_{13})	1/3	4	1	1/2	0.1871
Safety Height of Guardrail (M_{14})	2	5	2	1	0.4185

Table 4. Practical Demand Judgment Matrix and Weight

Z	Comfort (M_{21})	Simple Styling (M_{22})	Soft Color (M_{23})	Storage (M_{24})	Weight (w)
Comfort (M_{21})	1	4	5	3	0.5322
Simple Styling (M_{22})	1/4	1	2	1/3	0.1278
Soft color (M_{23})	1/5	1/2	1	1/3	0.0833
Storage (M_{24})	1/3	3	3	1	0.2567

Table 5. Modular Demand Judgment Matrix and Weight

Z	Height Adjustable (M_{31})	Changeable Shape (M_{32})	Multi-Purpose (M_{33})	Fun (M_{34})	Weight (w)
Height Adjustable (M_{31})	1	5	2	3	0.4695
Changeable shape (M_{32})	1/5	1	1/4	1/3	0.0730
Multi-purpose (M_{33})	1/2	4	1	1/2	0.2119
Fun (M_{34})	1/3	3	2	1	0.2456

Consistency Test

Equation 2 is a consistency test for the above results,

$$R = \frac{C_I}{R_I} \quad (2)$$

where R is the consistency ratio, C_I is the judgment matrix consistency index, and R_I is the average random consistency index. Before consistency verification, firstly, the maximum characteristic root λ_{max} (Eqs. 3 and 4) needed to be calculated, and if $R < 0.1$, the consistency test was passed. According to the formula, it was determined that R equaled 0.079, 0.056, and 0.076, respectively, meeting the consistency test requirement:

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^n \frac{(CW)_i}{w_i} \quad (3)$$

$$C_I = \frac{\lambda_{max} - n}{n - 1} \quad (4)$$

The weights of the elements of the sub-criteria layer were ranked to provide a scientific and reasonable data reference for the design program of solid wood children's beds, and the calculated target weights were ranked (Table 6).

Table 6. Weight Ranking of Elements in Sub-Criteria Layer

Ranking	Sub-criteria Layer	Combined Weights
2	Structural Stability (M_{11})	0.1891
8	Anti-corner Bumping (M_{12})	0.0363
4	Safe Gap Size (M_{13})	0.1069
1	Safety Height of Guardrail (M_{14})	0.2391
3	Comfort (M_{21})	0.1521
7	Simple Styling (M_{22})	0.0365
11	Soft color (M_{23})	0.0238
5	Storage (M_{24})	0.0733
6	Height Adjustable (M_{31})	0.0671
12	Changeable Shape (M_{32})	0.0104
10	Multi-purpose (M_{33})	0.0303
9	Fun (M_{34})	0.0351

Summary

The design elements of the solid wood children's bed were analyzed by AHP, and the weights and priorities of the elements were obtained as follows:

Safe height of guardrail > Structural stability > Comfort > Safe clearance size > Storage function > Height adjustable > Simple modeling > Edge anti-bumping > Interestingness > Multi-purpose > Soft color > Changeable modeling.

When designing a children's bed, it was important to first ensure that the highest priority design elements were met (Tan *et al.* 2023), such as guardrail safety height and structural solidity, which were directly related to the basic safety and functionality of the product. Subsequently, features, such as providing comfort and safe clearance dimensions, could be considered to enhance overall user satisfaction. Finally, sub-priority elements, such as storage functions, adjustable height, and simple styling, could be added, which were not essential but could increase the added value and competitiveness of the product. Design elements for supplementary consideration, such as fun, soft colors, changeable shapes, and multi-purpose, use could be optimized based on meeting the above needs to further enhance the market attractiveness of the product.

AD-based Parameter Mapping for the Design of Children's Beds

The AD mapped the functional domain and design domain of the solid wood children's bed design in a "Z" shape, and in the solid wood children's bed design, AD could better match the user needs with the R&D and provided the corresponding design parameters for the solid wood children's bed design. Based on the important user requirement items derived from AHP, user requirements were converted into functional requirements by combining AD (Tables 7 and 8).

Table 7. User Requirements and Functional Requirements Mapping

User Requirements (CA _s)	Functional Requirements (FR _s)
Safe height of guardrail (CA ₁)	Ensure that children do not fall (FR ₁)
Structural stability (CA ₂)	Sleep without rocking (FR ₂)
Comfort (CA ₃)	Use of comfortable materials (FR ₃)
Safety clearance dimensions (CA ₄)	Keep limbs out of the way (FR ₄)
Storage function (CA ₅)	Convenience and storage space (FR ₅)
Height adjustable (CA ₆)	Meeting the changing needs (FR ₆)
Simple styling (CA ₇)	Optimize product shape (FR ₇)
Anti-crash corners (CA ₈)	Soft materials and no sharp edges (FR ₈)

Table 8. Mapping of Functional Requirements and Design Parameters

Functional Requirements (FR _s)	Design Parameters (DP _s)
Ensure that children do not fall (FR ₁)	Guardrail height ≥ 30 mm (DP ₁)
Sleep without rocking (FR ₂)	Stabilized support for bed legs and reasonable connection between modules (DP ₂)
Use of comfortable materials (FR ₃)	Selection of environmentally friendly materials, such as wood and fabric (DP ₃)
Keep limbs out of the way (FR ₄)	hole and gap size < 6 mm or ≥ 12 mm (DP ₄)
Convenience and storage space (FR ₅)	Reasonable use of structure for storage (DP ₅)
Meeting the changing needs (FR ₆)	Different heights for different age groups (DP ₆)
Optimize product shape (FR ₇)	Model-following function (DP ₇)
Soft materials and no sharp edges (FR ₈)	Inverted radius of accessible part ≥ 10 mm or inverted arc length ≥ 15 mm (DP ₈)

According to AD, the functional requirements FR_s in the functional domain of solid wood children's beds were mapped to the design parameters DP_s in the design domain, and the relationship between them was as follows,

$$\{FR_s\} = X \{DP_s\} \quad (5)$$

where X is the design matrix, FR_s and DP_s represent sets of functional requirements and design parameters respectively. $\{FR_s\} = \{FR_1, FR_2, FR_3 \dots FR_m\}$; $\{DP_s\} = \{DP_1, DP_2, DP_3 \dots DP_n\}$, were substituted into Eq. 6 to obtain the functional requirements of the set and the design of the set of parameters as follows:

$$\begin{bmatrix} FR_1 \\ FR_2 \\ \vdots \\ FR_n \end{bmatrix} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & x_{ij} & \vdots \\ x_{n1} & x_{n2} & \dots & x_{nn} \end{bmatrix} \times \begin{bmatrix} DP_1 \\ DP_2 \\ \vdots \\ DP_n \end{bmatrix} \quad (6)$$

where x_{ij} is the degree of correlation between the elements, the parameters were brought into Eq. 6 to calculate the matrix X as follows:

$$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \\ FR_4 \\ FR_5 \\ FR_6 \\ FR_7 \\ FR_8 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \\ DP_4 \\ DP_5 \\ DP_6 \\ DP_7 \\ DP_8 \end{bmatrix} \quad (7)$$

From the type of design matrix, it could be observed that matrix X was a diagonal matrix, indicating a decoupled design that satisfied the axiom of independence. The design parameters were thus reasonable and provided a basis for the design scheme.

Results and Discussion

According to the index weight ranking of each alternative, the design of the children's bed was summarized with the top ranking solution elements as the main guide and in strict compliance with national standards. Through combining the comprehensive application of AD theory and AHP method, the designed solid wood children's bed had multifunctionality and comfort while meeting the basic safety requirements, which were specifically reflected in the following aspects:

1. *Safety and solidity.* The height of the guardrail and the design of the bed legs needed to ensure necessary safety and solidity; the guardrail height was ≥ 30 mm to prevent falls from the bed. The hole spacing and gap were strictly controlled to be < 6 mm or ≥ 12 mm to avoid children's limbs getting stuck, ensuring safety. The accessible parts had an inverted radius of ≥ 10 mm or an inverted arc length of ≥ 15 mm to prevent harm from sharp edges and corners. The bed legs covered an area of ≥ 150 cm² and utilized thickened metal and embedded parts for stable connection, ensuring bed stability.

2. *Environmentally friendly material selection.* Environmentally friendly materials were selected, including an all solid wood bed body, skin-friendly fabrics, and environmentally friendly, low-odor water-based paints to minimize harmful substances impacting children's health, reflecting environmental protection in design.

3. *Functional diversity.* The bed was designed with various modules to adjust heights as needed and included storage functions in the modules to enhance bed flexibility with children's growth.

4. *Aesthetics and practicality.* The product featured simple design and rounded corners to enhance aesthetics while improving durability and comfort.

SOLID WOOD CHILDREN'S BED DESIGN PRACTICE

Design Strategy

In the previous study, this project identified and analyzed the key elements of children's bed design through AHP and AD (Tang *et al.* 2023). These elements included guardrail safety height, structural solidity, comfort, and safety clearance dimensions, all of which significantly influenced the safety, functionality, and user satisfaction of children's beds (Tian *et al.* 2023).

In designing for growability, the original shape and size of the product are typically altered through combinations of morphology and structure, such as flipping, folding, telescoping, rotating, stacking, moving, disassembling, and adjusting height. These transformations enhance the product's functionality, ensuring that it meets children's evolving needs as they grow. Additionally, it addresses children's psychological needs for novelty and adaptability. Modular design is one effective approach to achieving product disassembly, allowing for the use of standardized components and interfaces. This enables children to freely assemble and customize products according to their individual preferences, fostering creativity and enhancing their manual dexterity. Through implementing these principles into the design of growable solid wood children's beds, this project aims to develop a design program that effectively meets the diverse needs of users.

Design Program

This product design was primarily divided into three modules: the bed module, heightening module, and guardrail module (Fig. 3). The assembly of each module utilized a mortise and tenon structure for stability, while metal connectors were employed for disassembly, ensuring a secure connection. The overall design was characterized by its simplicity, with rounded and soft corners aimed at preventing accidents from children playing and bumping into the bed. The guardrail was made from removable and washable soft cloth and sponge-wrapped multi-layer board, providing comfort and safety.

Furthermore, the design accommodated changes in children's height during growth by allowing the split combination of different modules to meet the varying needs of different age stages. The product's dimensions featured a single bed size of 1200 × 2000 mm², with adjustable heights under the bed at 0, 150, and 1200 mm.



Fig. 4. Floor bed pattern proofing drawing

At 0 mm height under the bed (Fig 4). The floor bed module catered specifically to preschool children aged 3 to 6 years. Positioned close to the ground with a frame height of less than 100 mm, it provided a sense of security for young children learning to independently get in and out of bed, fostering their exploration and freedom in the children's room space.

At 1200 mm height under the bed (Fig. 5). The half-height bed module met the energetic needs of school-age children. It featured a raised bookshelf module that effectively utilized under-bed storage space, along with adjustable guardrails at heights of 38 cm and 50 cm to prevent falls. The integrated bookshelf structure stabilized the bed while displaying picture books, and the half-enclosed space under the bed served as a secure enclosure or secret space, expanding the room's functional areas.



Fig. 5. Half-height bed pattern proofing drawing

At 150 mm height under the bed (Fig. 6). The design incorporated standard legs tailored to the ergonomic dimensions of adolescent children. The bed legs were diagonally octagonal in design for increased torsion resistance by 50%, accommodating the dynamic forces of children bouncing on the bed. The detached raised bookcase module could also function as a standalone bedside bookcase, fulfilling multi-purpose use requirements.



Fig. 6. Standard bed mode proofing chart

Evaluation of Solid Wood Children's Bed Design Program

To further verify the practicality of the product, 10 groups of children and parents were recruited to experience the product in real children's room scenarios. Their perceived effectiveness, comfort, and satisfaction were quantified and analyzed through user experience evaluations and scoring. The Likert five-point scale method was employed, where 5 points indicated "Very satisfied," 4 points indicated "Satisfied," 3 points indicated "Neutral," 2 points indicated "Dissatisfied," and 1 point indicated "Very dissatisfied." After tallying the survey data, the average satisfaction score was calculated to be 3.84, indicating a high level of satisfaction. The product solutions met all the design-oriented requirements (Fig. 7), aligning with the study's conclusions.

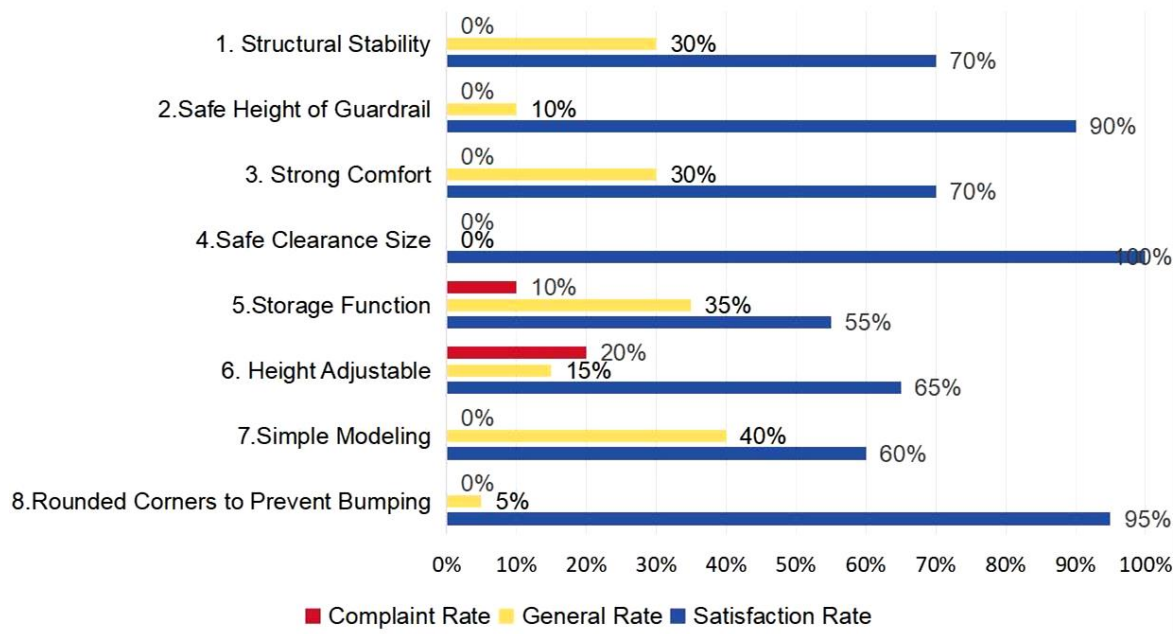


Fig. 7. Satisfaction with design elements

CONCLUSIONS

1. Application of integrated design process: This study employed an integrated design process, combining KANO, AHP, and AD methods to thoroughly analyze the safety requirements, practical needs, and modularity requirements of solid wood children's beds. Through identifying 12 key influencing factors, a comprehensive user-design evaluation system was established, effectively enhancing the scientific rigor and accuracy of design decisions.
2. Advantages of modular design: Modular design achieved product scalability. With a small number of modules, it created diverse product types, meeting users' individualized and diverse needs. It also extended product lifespan, reduced resource waste, and lowered family economic burden. Moreover, this design approach was significant. It enabled children to modify furniture configuration, promoting their cognitive development and manual dexterity. In terms of future trends, as consumer demand for personalized products grows, modular design will hold a more important position in children's furniture and become a key market factor.

3. Market and environmental benefits: This study supported furniture companies to understand user needs. It helped them develop modular children's beds for kids' growth, extending the brand's life cycle. Modular design reduced one-time use of children's furniture, promoting environmental protection and sustainable development. From the market view, as environmental awareness rises, consumers prefer eco-friendly products. Modular children's beds fit this trend and have broad prospects. For example, eco-conscious parents prioritize modular beds for their practicality and scalability and environmental friendliness. In the long run, modular design will be the mainstream in the children's furniture market and drive the industry to develop more environmentally friendly and sustainable.

ACKNOWLEDGMENTS

The authors are grateful for the support of the National Key R&D Program of China (2017YFD0601104), sponsored by Qing Lan Project (Jiangsu Teacher Letter [2022] No. 51).

REFERENCES CITED

- Cai, C. L., Xiao, R. B., and Yang, P. (2010). "The method for analysing and disposing of functional interaction in axiomatic design," *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science* 224(2), 401-409. DOI: 10.1243/09544062JMES1683
- Cheng, X. F., Yang, Y. F., and Xu, X. H. (2016). "An evaluation method of product platform adaptability based on information axiom," *Mechanical Design and Research* 32(1), 68-71+79. DOI: 10.13952/j.cnki.jofmdr.2016.0017
- Deng, C. P., Sang, B., and Miao, X. C. (2000). "Several basic issues in the study of the development of 'theory of mind' in early childhood," *Psychological Science* 04(004), 399-403+508-509. DOI: 10.16719/j.cnki.1671-6981.
- Kano, N., Seraku, N., Takahashi, F., and Tsuji, S. (1984). "Attractive quality and must-be quality," *Journal of the Japanese Society for Quality Control* 41, 39-48. DOI: 10.20684/quality.14.2-147.
- Li, Z. Q., Hu, S. Y., Wang, J. H., Yu, H. L., Fu, X. H., Yang, J. H., Li, L. M., Li, S., and Zhu, W. K. (2024). "Functional requirements and design strategy of E-sports chair based on the KANO model," *BioResources* 19(3), 4679-4697. DOI: 10.15376/biores.19.3.4679-4697
- Neira-Rodado, D., Ortíz-Barrios, M., De la Hoz-Escorcía, S., Paggetti, C., Noffrini, L., and Fratea, N. (2020). "Smart product design process through the implementation of a fuzzy Kano-AHP-DEMATEL-QFD approach," *Applied Sciences* 10(5), article 1792. DOI: 10.3390/app10051792
- Phuah, Z. Y., Ng, P. K., Lim, B. K., Nathan, R. J., Ng, Y. J., and Yeow, J. A. (2022). "The conceptualisation of inventive and repurposable children's furniture," *Forests* 13(12), article 2053. DOI: 10.3390/f13122053

- Ren, Y. J., Chen, R. Q., and Wei, Z. Y. (2024). "A study on product design of stress relieving toys for adolescents based on AHP-TOPSIS model," *Packaging Engineering* 45(8), 178-188. DOI: 10.19554/j.cnki.1001-3563.2024.08.020
- Saaty, T. L. (1977). "A scaling method for priorities in hierarchical structures," *Journal of Mathematical Psychology*, 15(3), 234-281. DOI: org/10.1016/0022-2496(77)90033-5.
- Tamthintha, P., Palaprom, K., and Nawattanaprasert, K. (2018). "A study on perceptions of preschool children's furniture design: Pictorial stimuli experiment," in *MATEC Web of Conferences* 204, article 01003. DOI: 10.1051/mateconf/201820401003
- Tan, Y. J., Yang, X. Y., Zhang, J. J., and Zhang, Z. F. (2023). "Research on children's bedroom furniture design based on AHP-TOPSIS method," *Forest Industry* 60(04), 69-74. DOI: 10.19531/j.issn1001-5299.202304012
- Tang, R. M., Li, J. J., Luo, Q., Lin, D. D., and Peng, X. B. (2023). "Design practice of pediatric dental consultation chair based on KANO-AHP-AD theoretical model," *Packaging Engineering* 44(22), 169-180. DOI: 10.19554/j.cnki.1001-3563.2023.22.019
- Tian, X. R., Xie, Y. F., and Zhao, X. (2023). "Research on intelligent furniture product based on user needs," *Furniture and Interiors* 30(11), 15-21. DOI: 10.16771/j.cn43-1247/ts.2023.11.004
- Violante, M. G., and Vezzetti, E. (2017). "Kano qualitative vs quantitative approaches: An assessment framework for products attributes analysis," *Computers in Industry* 86, 15-25. DOI: 10.1016/j.compind.2016.12.007
- Wang, M. X., and Zhai, H. L. (2020). "Evaluation method and application of rehabilitation training product design for autistic children based on AHP and TOPSIS method," *Journal of Graphics* 41(3), 453-460. DOI: 10.11996/JG.j.2095-302X.2020030453
- Wang, S., and Fan, M. (2024). "Research on the design of ageing-friendly shoe-changing seats based on Kano-AHP-QFD," *Packaging Engineering* 45(10), 42-51. DOI: 10.19554/j.cnki.1001-3563.2024.10.005
- Wu, Z. Z., Zhao, J. X., and Sun, P. J. (2023). "Research on office furniture design based on Kano/AHP/QFD," *Forest Industry* 60(11), 52-57. DOI: 10.19531/j.issn1001-5299.202311008
- Xu, Q. L., Jiao, R. J., Yang, X., Helander, M. G., Khalid, H. M., and Anders, O. (2007). "Customer requirement analysis based on an analytical Kano model," in *2007 IEEE International Conference on Industrial Engineering and Engineering Management*, Singapore, pp. 1287-1291.
- Xu, R., and Xu, B. M. (2023). "Visualization and analysis of domestic children's furniture research posture based on Citespace," *Furniture* 44(5), 20-24. DOI: 10.16610/j.cnki.jiaju.2023.05.004
- Zhang, X. Y., and Xu, W. (2023). "Emotional design of children's furniture based on AHP," *Forest Industry* 60(6), 70-75. DOI: 10.19531/j.issn1001-5299.202306012
- Zhao, X., Wei, F., and Mu, Y. (2022). "A user demand-driven approach to furniture product design," *Journal of Forest Engineering* 7(04), 194-200. DOI: 10.13360/j.issn.2096-1359.202110038

Zhong, G. M., Zhang, Y. H., Fu, X. Y., Xing, H. L., Liu, J. P., and Li, Y. B. (2023). “A study on the design of growable children’s sitting furniture based on KANO-AHP,” *Packaging Engineering* 44(14), 118-126. DOI: 10.19554/j.cnki.1001-3563.2023.14.012

Article submitted: June 30, 2024; Peer review completed: August 1, 2024; Revised version received and accepted: August 6, 2024; Published: September 12, 2024.
DOI: 10.15376/biores.19.4.8257-8272