Wooden Infant Bed Design under the Background of Two-child Policy

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To cope with low fertility rate and an aging population, China introduced and implemented a two-child policy to make an overall population adjustment. Because of this, there are now problems, such as the uncoordinated sleep space for the two children, competition between older children, insufficient care for older children, and additional family affairs. In view of this, this study focused on the two-child family and parents as the main users of wooden infant beds. The method of constructing I-Kano model was used to determine the needs of users and their importance. Based on the QFD theory, the user needs and engineering measures were analyzed and explored. Based on the TRIZ theory, the analysis of engineering conflict resolution was performed. Based on the results, the wooden infant bed design strategy was developed for the background of two-child policy. The purpose of this work is to meet the parenting needs of two-child families in various periods with the developed design strategy, avoid the parenting problems of two-child families, improve the parenting quality of two-child families, adjust the sleeping space of two-child families, and fill the vacancy in the design theory of wooden baby beds for two-child families.

DOI: 10.15376/biores.19.3.6076-6094

Keywords: Two-child family; Wooden Infant bed; I-Kano model; QFD theory; TRIZ theory

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INTRODUCTION

In order to cope with the low fertility rate and aging population, China officially launched the "universal two-child" policy on January 1, 2016 to make a population adjustment (Chen *et al.* 2019; Wu *et al.* 2019; Yang *et al.* 2022). Under the condition of continuously complete policy support and related supporting facilities, the number of second-child families is also increasing, and more parenting families are changing from the original only-child family structure to the family structure of multiple children (Xu *et al.* 2019; Meng and Lyu 2022). Due to the change of the structure of the parenting family, there are some new problems to be solved among family members (Hong and Liu 2021). There are problems, such as how to deal with the relationship between eldest children, second children, and the parents, and how to adjust the sleep space of the second child. However, at present, the design research of infant beds mainly focuses on the research of a single infant bed, and there are few design studies specifically for families with two children. In addition, the furniture research of second-child families mainly focuses on the home research of children, and less involving the furniture design of the infant stage of second-child families (Li *et al.* 2014; Salvador 2015; Liu *et al.* 2018). There is a vacancy in the design of infant beds in two-child families.

Compared to other materials, solid wood is advantageous as the primary material for infant beds in two-child families. It offers numerous benefits such as environmental friendliness and overall health. Meanwhile, solid wood provides excellent support and ensures a restful sleep for infants and young children. Moreover, high-quality wooden beds exhibit exceptional durability, allowing them to be used for an extended period of time (Gu and Zhang 2022). Additionally, solid wood possesses a natural aesthetic appeal that complements various decoration styles. Furthermore, its stable structure minimizes security risks effectively. From a production standpoint, solid wood materials facilitate a relatively simple manufacturing process while enabling the creation of diverse products. Consequently, solid wood is highly suitable for crafting infant beds in two-child families.

From the perspective of furniture design, the design of the product is divided into internal factors and external factors. Firstly, based on the method of I-Kano model analysis, the eldest child, second-child, and parents in the second-child family are centered, their core needs are analyzed, and the external factors of wooden infant bed design in the second-child family are determined (Lee *et al.* 2022). Then, according to QFD theory (Quality Function Deployment, QFD), external factors are transformed into internal factors of product design, and the contradictory relationship between engineering measures, the importance of engineering measures, and engineering measures are determined (Cristiano *et al.* 2001; Herzwurm *et al.* 2003; Kim *et al.* 2008; He *et al.* 2017). TRIZ theory (theory of inventive problem solving, TRIZ) was used to analyze and solve the contradiction engineering measures, and finally form a design strategy.

The purpose of this work is to meet the parenting needs of two-child families in various periods with design strategy, avoid the parenting problems of two-child families as much as possible, improve the parenting quality of two-child families, adjust the sleeping space of two-child families, and fill the vacancy in the design theory of wooden baby beds for two-child families.

I-KANO MODEL ANALYSIS DETERMINES USER CORE REQUIREMENTS

Based on user interviews, the living conditions and needs of the second-child parenting families were determined. A total of 10 representative families with two children were selected for interviews. From the respondents' family situations and events, the living conditions of second-child families, as well as the use and needs of cribs, were learned. Then, the I-Kano questionnaire was distributed, and the I-Kano model was used to analyze the attributes and importance of various user needs.

Requirements Collection and Summary

First, the needs of wooden infant bed users were summarized. The demand for wooden baby beds in second-child families is divided into two levels, namely, the first level demand and the second level demand. Among them, the first-level demand is the demand for five aspects of the second-child family wooden infant bed design, including growth demand, security demand, humanized demand, intelligent demand, and emotional demand. Secondary requirements are detailed requirements for various aspects, as shown in Table 1.

Table 1. Summary of User Requirements

First Level Demand	Second Level Demand
Security Requirements	Prevent knock touch
	Prevent mosquitoes
	Prevent baby movement
Growth Needs	Suitable for different stages of infants and young children
	Extend the service cycle
Humanized Demand	Adjust the sleep space for the two children
	It is convenient to change diapers
	It covers a small area
	Easy to splice with large bed
	Reasonable storage
	It is convenient for parents to observe and care for their children in the large bed
	Removable
Intelligent Demand	Night lighting
	Bedwetting monitoring
	Real time monitoring
	Temperature heating
	Temperature detection
	Intelligent coax sleep
Emotional Needs	Fun appearance
	Entertainment function

Demand Questionnaire Survey

Due to the limited number of interviewed users, surveys need to be conducted on a larger scale with the I-Kano model questionnaire and determine the core needs.

According to the requirements of the Kano model questionnaire survey, two positive and negative questions are set for each demand, and the needs of users are studied (Xu *et al.* 2007; He *et al.* 2017; Koomsap *et al.* 2023). The questionnaire is then sent by the Internet. After excluding the invalid questionnaires, 173 valid questionnaires were collected.

Core Requirements Screening

According to the I-Kano model calculation, the user demand data was summarized, and the user demand analysis table (Table 2) from the I-Kano model was obtained.

Because this user demand is not obtained with traditional brainstorming and other methods, but based on user interviews, the requirements for participating in the I-Kano model research are all proposed and needed by real users. That is to say, all of the above needs are not differentiated in the traditional sense but divide the investigated needs into core needs and non-core needs. In the I-Kano model user requirements analysis table, $\overline{X}_i$ the value with $\overline{Y}_i$ all the values are positive, indicating that there is no requirement for reverse attributes and problem attributes in the survey. To screen out the core requirements of wooden infant beds, the importance index (R_i) and the satisfaction index (α_i) were introduced. The importance index (R_i) indicates the importance of the requirement. The satisfaction index (α_i) represents the relative level of satisfaction or dissatisfaction of the user after the requirement is met. One selects the importance index R_0 = 0.850, which is used as the critical value. User needs are divided into core needs and non-core needs, select α_L = 0.785 as the critical value below the satisfaction index. Also, the researcher selects α_H = 0.873 as the critical value above the satisfaction index.

Table 2. User Requirements Analysis Table of the I-Kano Model

Sort	Requirement	$\overline{X}_i$	$\overline{Y}_i$	R_i	α_i	P_i
1	Adjust the sleep space for the two children	0.639	0.652	0.913	0.775	0.648
2	It is convenient to change diapers	0.572	0.675	0.885	0.703	0.647
3	It covers a small area	0.730	0.581	0.933	0.898	0.628
4	Suitable for different stages of infants and young children	0.582	0.645	0.869	0.735	0.627
5	Entertainment function	0.642	0.620	0.892	0.803	0.626
6	Fun appearance	0.575	0.633	0.855	0.738	0.617
7	Extend the service cycle	0.598	0.624	0.865	0.764	0.617
8	Prevent knock touch	0.608	0.618	0.868	0.777	0.616
9	Easy to splice with large bed	0.676	0.585	0.894	0.857	0.613
10	Intelligent coax sleep	0.639	0.597	0.874	0.819	0.609
11	It is convenient for parents to observe and care for their children in the large bed	0.617	0.598	0.859	0.801	0.604
12	Reasonable storage	0.621	0.591	0.858	0.810	0.600
13	Bedwetting monitoring	0.578	0.605	0.837	0.762	0.598
14	Real time monitoring	0.582	0.598	0.835	0.772	0.594
15	Removable	0.591	0.594	0.838	0.783	0.593
16	Night lighting	0.624	0.578	0.851	0.824	0.592
17	Temperature heating	0.597	0.588	0.838	0.793	0.591
18	To prevent mosquitoes	0.617	0.579	0.846	0.817	0.591
19	Prevent baby movement	0.582	0.591	0.830	0.778	0.589
20	Temperature detection	0.600	0.577	0.832	0.805	0.583

Eventually, adjustments are made so that the two children's sleep space, convenient diaper changing, suitable for different stages, interesting appearance, extended service cycle, and collision are the essential attributes in the core requirements; entertainment function, easy to splice with large bed, intelligent sleep, convenient for parents to observe and take care of children in the big bed, and reasonable storage were determined as the expected attribute requirements in the core requirements; it covers a small area was identified as the charm attribute in the core requirements; other requirements were identified as non-core requirements.

Although the attributes of user needs have been determined, the importance of demand cannot be determined solely by the division of demand attributes, and the importance of demand is the result of the joint action of many aspects. Therefore, the user demand priority index (p_i) is introduced (Jie *et al.* 2009). Priority index (p_i) is used to represent the comprehensive value of each user demand in meeting customer expectations, and as a basis for prioritizing which user needs are met. Based on the comprehensive analysis of the importance index and satisfaction index, the value of each user demand priority index is obtained, and the importance of demand is ranked according to its value from large to small. The specific ranking is shown in Table 2 and p_i is calculated as below (Jie *et al.* 2009):

$$p_i = \frac{2\sqrt{2}}{3}\left(1-\frac{\alpha_i}{\pi}\right)R_i \qquad (1)$$

QFD THEORETICAL ANALYSIS DETERMINES THE ENGINEERING MEASURES

Using the quality house analysis method in QFD theory, the needs of users are transformed into the corresponding engineering measures, according to the importance of each engineering measures, to determine the core engineering measures. Then, the contradictory relationship between the engineering measures is analyzed, and the mutual hindering engineering measures are determined.

Determine the Demand Importance

According to the above analysis, the importance of the user's core needs is obtained. However, the importance range of the I-Kano model is ($0 \leq p_i \leq 1.333$).

Table 3. Importance of Quality House User Requirements

User Demand	P_i	K_i
Adjust the sleep space for the two children	0.648	5.000
It is convenient to change diapers	0.647	4.992
It covers a small area	0.628	4.846
Suitable for different stages of infants and young children	0.627	4.838
Entertainment function	0.626	4.830
Fun appearance	0.617	4.761
Extend the service cycle	0.617	4.761
Prevent knock touch	0.616	4.753
Easy to splice with large bed	0.613	4.730
Intelligent coax sleep	0.609	4.699
It is convenient for parents to observe and care for their children in the large bed	0.604	4.660
Reasonable storage	0.6	4.630

In this study, the maximum user demand of I-Kano model is 0.648. This does not match the value range of user demand importance ($0 \leq k_i \leq 5$) in the House of Quality. Therefore, the adjustment coefficient I = 7.716 is introduced.

$$K_i = I \times P_i \qquad (2)$$

The priority index in the I-Kano model is connected with the importance of user demand in the quality house, and the final results are shown in the importance of user demand in the quality house in Table 3.

Determination of Engineering Measures

Based on the analysis of the core needs of the users, the engineering measures to meet the corresponding needs were determined, as shown in Table 4.

In terms of safety requirements, preventing infant and child bumps has been identified as a core requirement. The bump mainly occurs in the prominent corner position, so the two engineering measures are put forward. An increase of the chamfer radius of the corner and fence and other frames can be implemented to increase the contact area and reduce the damage to infants and children. Additionally, a cushion is padded at the position of the corners to soften it. Based on these measures, one can avoid incidents in two-child families in the process of child care accidental injury.

In terms of growth needs, different periods suitable for infants and young children and extended use periods were identified as core needs. As the child grows up, the size of the original crib cannot meet the needs of the child's sleep space, and its size needs to be expanded to have more space. When the needs and state of the children are different, the wooden baby bed needs to carry out the corresponding changes. When the child grows up and sleeps separately from his parents, the traditional crib loses its use and is no longer needed, and the use cycle is over. This causes a certain amount of waste. It can continue to be used by second-child families by making it have other furniture functions to meet the needs of extending its use cycle. Alternatively, it can be given or sold to another family that needs it. With these measures, the crib can be adapted to the various parenting situations of two growing children and can be used as the children grow up.

In terms of humanized needs, adjusting the sleep space of two children, convenient diaper change, covering a small area, convenient splicing with the big bed, reasonable storage, and convenient for parents to observe and take care of children in the big bed were identified as the core needs. In terms of regulating the sleeping space for two children, it is crucial to provide appropriate and adequate sleeping arrangements. When designing wooden infant beds for families with two children, more emphasis should be placed on adjusting the sleeping space compared to those designed for single-child families. Firstly, it is essential to meet the varying sleeping space requirements of two children at different stages of growth simultaneously. For instance, an infant as a second child would require a smaller sleeping area, while an older child would need a bed size similar to that of an adult. This example represents only one possible combination in families with two children; therefore, this study will further analyze various potential combinations that may arise during the parenting process in such families. Additionally, optimizing limited bedroom space utilization and facilitating seamless transitions between different combinations are also important considerations. The traditional wooden infant bed height is too low, and parents need to bend down as much as possible to change their children's diapers, which is prone to cause waist and back pain. A care desk needs to be set up to address this pain point. Another problem is that the operation space of the traditional wooden baby bed is too small, parents in the diaper change action are often blocked by the fence, and the temporary storage of new diapers, new bedding, and other items also lack suitable storage space. It covers a small area, mainly considering the limited space of the parents' bedroom, and an excessively large baby bed is difficult to place in the parents' bedroom space or would seriously hinder the daily life actions. For this reason, a smaller baby bed size and more compact function module are used to reduce the footprint. In terms of convenience and large bed splicing needs, measures that can adjust the height of wooden infant beds are needed to adapt to the height of large beds in different families. In terms of storage requirements, in order to store children's toys, diapers and other daily items, larger storage space and reasonable storage methods are needed to make the storage area more reasonable. For the measure of making it convenient for parents to observe and take care of their children when resting in the big bed, it is mainly to deal with the situation of child care when parents sleep at night. At this time, if the wooden baby bed is fenced, it will bring inconvenience to parents to observe and care for the children. Therefore, to reduce the sight blocking in the crib, removable barrier measures become an important measure to meet this need. Based on these measures, the common problems in the parenting process and the unique problems, such as two children competing for sleeping space in two-child parenting families have been solved.

Table 4. Engineering Measures to Meet the Requirements

First Level Demand	Second Level Demand	Engineering Measures
Security Requirements	Prevent knock touch	Reasonable chamfer radius; Soft pad covering
Growth Needs	Suitable for different stages of infants and young children	Change the length as the child grows up; Change patterns according to demand
	Extend the service cycle	With other furniture functions
Humanized Demand	Adjust the sleep space for the two children	Sleep space is reasonable
	It is convenient to change diapers	Set up the care table; Reasonable operation space
	It covers a small area	The space volume is appropriate; The function module is compact
	Easy to splice with large bed	The bed surface height is adjustable
	Reasonable storage	The storage space is reasonable; The storage method is reasonable
	It is convenient for parents to observe and care for their children in the large bed	Reduce the sight blocking in the crib; The guardrail is removable
Intelligent Demand	Intelligent coax sleep	Shake function module; Music playing module
Emotional Needs	Fun appearance	Color design, modeling design, cartoon elements
	Entertainment function	Music playing module; Toy entertainment

In terms of intelligence, intelligent sleep coaxing has been identified as a core need of second-child parenting families. According to the study, for the other conditions of parenting families, the way to sleep is mainly the use of sound to induce sleep and shaking to encourage sleep. For these two methods, two engineering measures of the shaking sleep coax module and the music playback module are used to meet the needs of intelligent sleep coax (Möller *et al.* 2019).

In terms of emotional needs, fun appearance and entertainment are identified as core needs. Interesting appearance demand needs to pay attention to the design of color, modeling, and the use of cartoon elements. The entertainment aspect can be satisfied *via* music entertainment and upper hanging toys. These measures can be used to meet the emotional needs of parents and children in parenting families.

Build the Relationship Matrix between Requirements and Engineering Measures

After communication with relevant experts in the industry, the close relationship between the user's core needs and engineering measures is analyzed, and the relationship matrix between user needs and engineering measures is summarized and drawn. The closeness of user requirements and engineering measures (r_{ij}) adopts the scoring method of 0, 1, 3, and 5 points:

0- There is no correlation between user needs and engineering measures;

1- There is a weak relationship between user demand and engineering measures;

3- There is a close relationship between user demand and engineering measures;

5- There is a very close relationship between user needs and engineering measures.

The corresponding score is represented by the specific symbol when the matrix is plotted to facilitate the observed analysis of the matrix: △ represents 1, ○ represents 3; ◉ represents 5, blank represents 0.

The relationship matrix analysis between specific user needs and engineering measures is reflected in the data of the room part of the wooden infant bed quality house under the background of the two-child policy in Fig. 7.

Determine the Importance of Engineering Measures

The relationship matrix between user requirements and engineering measures is analyzed by calculating the importance of engineering measures (h_j). The importance of engineering measures is determined by the value of engineering measures (hj). The larger the value, the more important the engineering measure. (Lyu *et al.* 2022).

$$h_j = \sum_{i=1}^{m} r_{ij} k_i$$

According to the formula, the importance of each engineering measure is obtained, which is summarized and sorted according to the importance of engineering measure from the largest to the smallest, and the summary table of the importance of engineering measure is made in Table 5. In addition, the average of the importance of engineering measures is 54.203, and the average of 1.25 times is 67.254. Generally, engineering measures whose importance is higher than the average of 1.25 times of all engineering measures are taken as the control focus. Therefore, the guardrail can be removed, the shape can be changed according to the demand, the sleep space is reasonable, the height of the bed surface can be adjusted, the length changes with the growth of children, and the space volume is appropriately determined as the key engineering measures.

Table 5. Summary of the Importance of Engineering Measures

Order Number	Engineering Measures	Importance Degree
1	The guardrail is removable	104.868
2	Change patterns according to demand	96.914
3	Sleep space is reasonable	91.628
4	The bed surface height is adjustable	86.419
5	Change the length as the child grows up	82.286
6	The space volume is appropriate	72.341
7	Reasonable operation space	53.757
8	The storage method is reasonable	52.664
9	With other furniture functions	48.311
10	Music playing module	47.645
11	Toy entertainment	43.271
12	Cartoon elements	43.133
13	The function module is compact	43.112
14	Set up the care table	39.474
15	Color design	38.295
16	Modeling design	38.295
17	Reasonable chamfer radius	37.958
18	Soft pad covering	37.958
19	Reduce the sight blocking in the crib	28.300
20	The storage space is reasonable	28.142
21	Shake function module	23.495

Construct the Engineering Measures Correlation Matrix

There may be some interactions between the engineering measures. Some interactions will have positive effects on other engineering measures, namely, a positive correlation, with the "+" symbol in this study, and some will have a negative effect, namely, a negative correlation, with the "-" symbol in this study. If the correlation between each of the two engineering measures is not strong, it is left blank. After the analysis of the interaction between various engineering measures, the correlation matrix of engineering measures is finally summarized and formed. See Table 7 for the roof part of the wooden infant bed quality under the background of the two-child policy.

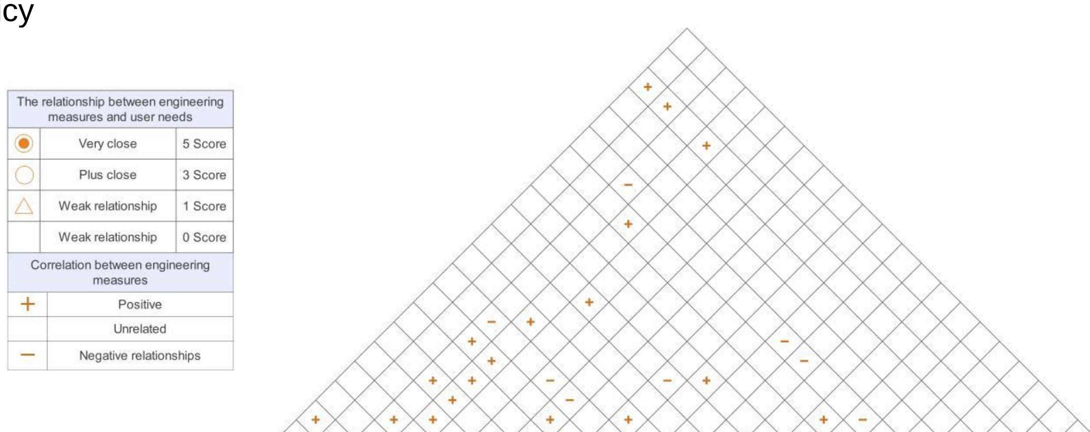
With the analysis of the correlation of engineering measures, it is found that the engineering measures that offset and hinder each other are divided into two aspects. They are space problems and shaking to sleep. The negative related engineering measures are summarized in Table 6.

Based on the above analysis, it is found that the shaking module is mainly used to meet the needs of intelligent sleep, and the music playback function module is also closely related to the needs of intelligent sleep, and music sleep can also meet the needs of intelligent sleep. Shake the functional module is the least important in the analysis of the importance of the engineering measures. In addition, the shaking module conflicts with a number of engineering measures, deciding that the design of the wooden baby bed in the second child family is to abandon the shaking function module, and the music playback module replaces it to meet the demand of intelligent sleep.

Table 6. Negative-related Engineering Measures Table

Order Number	Contradiction Measure A	Contradiction Measure B
1	The space volume is appropriate	Change the length as the child grows up
2	The space volume is appropriate	Sleep space is reasonable
3	The space volume is appropriate	Set up the care table
4	The space volume is appropriate	The storage space is reasonable
5	Shake function module	Change the length as the child grows up
6	Shake function module	The bed surface height is adjustable
7	Shake function module	The storage space is reasonable
8	Shake function module	The guardrail is removable

Table 7. Wooden Baby Bed Quality House under the Background of the Two-Child Policy



User demand \ Engineering measures	Importance of user needs K_i	Reasonable chamfer radius	Soft pad covering	Change the length as the child grows up	Change patterns according to demand	With other furniture functions	Sleep space is reasonable	Set up the care table	Reasonable operation space	Space volume is appropriate	The function module is compact	The bed surface height is adjustable	The storage space is reasonable	The storage method is reasonable	Reduce the sight blocking in the crib	The guardrail is removable	Shake function module	Music playing module	Color design	Modeling design	Cartoon elements	Toy entertainment
Prevent knock touch	4.753	◉	◉	△	△		○		○													
Suitable for different stages of infants and young children	4.838			◉	◉	○	○	○		○		○				○					△	△
Extend the service cycle	4.761			◉	◉	◉						○				○						
Adjust the sleep space for the two children	5.000			○	○	△	◉			○		○			△	○						
It is convenient to change diapers	4.992				○	△		◉	◉		△	△	△	○								
It covers a small area	4.846			○			○		○	◉	◉			○								
Easy to splice with large bed	4.730				○							◉				◉						
Reasonable storage	4.630						△			○	○		◉	◉								
It is convenient for parents to observe and care for their children in the large bed	4.660						○					○			◉	◉						
Intelligent coax sleep	4.699																◉	◉				
Fun appearance	4.761	○	○																◉	◉	◉	○
Entertainment function	4.830																	◉	○	○	○	◉
Importance of the engineering measures h_j	/	37.958	37.958	82.286	96.914	48.311	43.61	54.798	54.713	38.12	43.112	86.419	28.142	52.664	28.300	104.868	23.495	47.645	38.295	38.295	43.133	43.271

Finally, in the wooden infant bed design research under the background of the two-child policy, the space volume is appropriate. Engineering measures, such as children's growth and change of length, reasonable sleep space, setting and care platform, and reasonable storage space, are determined to have a negative correlation.

Quality House Drawing

Based on the analysis of the interrelationship between user needs and the importance of engineering measures and engineering measures, the above studies completed the construction of the wooden infant bed quality house under the background of the two-child policy.

TRIZ THEORY ANALYSIS TO SOLVE THE CONTRADICTION OF ENGINEERING MEASURES

The component analysis method of TRIZ theory is used to analyze the system of the wooden infant bed and the super system of the environment. It is also used to analyze the contradictory engineering measures of mutual obstruction. The 40 invention principles and 4 separation principles in TRIZ theory were used to solve the contradictory problems (Rong *et al.* 2024).

Problem Description

The main design contradiction of the wooden infant bed focuses on the use of the space. On the one hand, the need to let the wooden baby bed change with the growth of children, and reasonable arrangement of the two children's sleep space, have storage ability and set up the care table, all need a larger size wooden baby bed. But on the other hand, due to the limited parents' bedroom space, the bed cannot take up larger space, so a relatively small space is needed. The core of the ideal solution to the problem is that the two children can sleep comfortably in their parents' bedroom, and at the same time, the placement of the wooden baby bed will not hinder the life of the bedroom, and other needs of users can also be met.

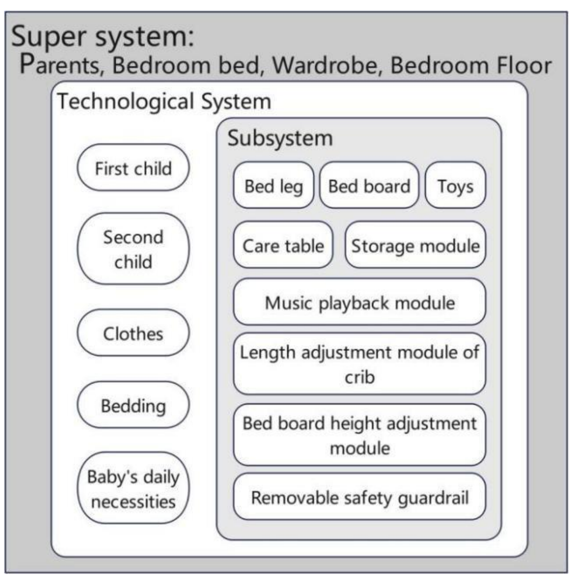


Fig. 1. Collection diagram of the system components

Problem Analysis

The bedroom space where the wooden baby bed is located is an integrated system for the family to rest. And the analysis can not only stay in the product itself, but also needs to include the super system of its environment for analysis. In the analysis of the wooden infant bed system, the components included in the system are determined by drawing the set diagram of the system components in Fig. 2. Based on the investigation of the top 471 sales of related products on Taobao shopping site, there is no baby bed designed for two-child families. Because there is no similar product on the market for reference, the current component analysis is a possibility analysis, that is, the theoretical functions of each component and the interaction between components.

Figure 2 shows the system function model diagram, the interrelationships between the components are fully analyzed, and prominent problems in the system are revealed.

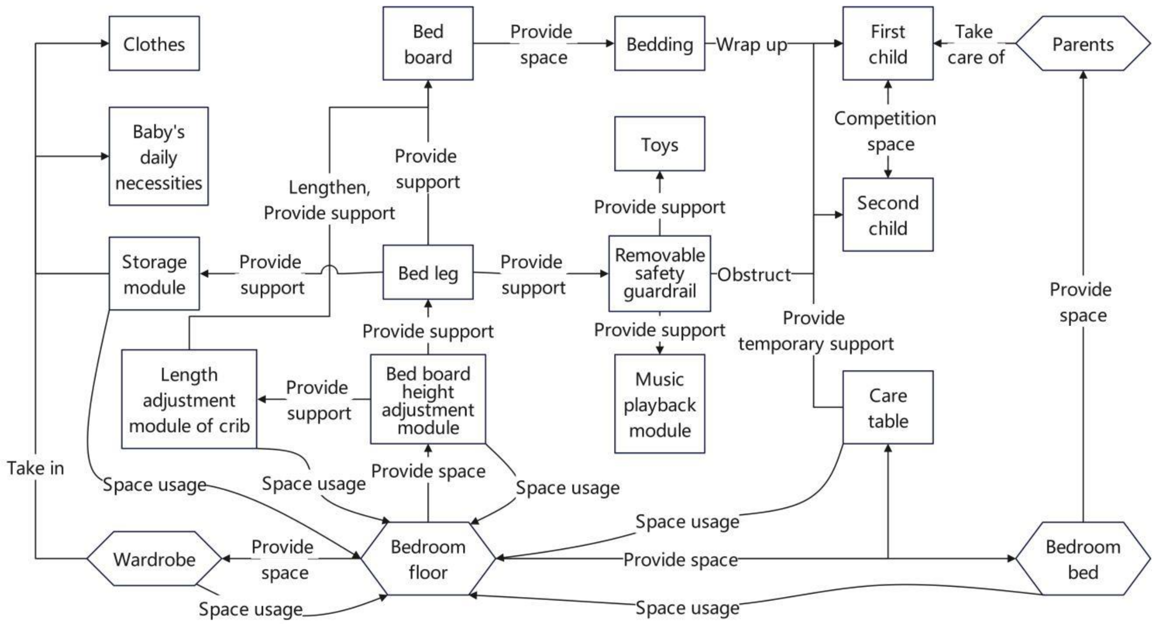


Fig. 2. A system functional model diagram

Problem Solving

Conflicting judgment

The requirement that the length of the wooden infant bed changes as the child grows and the requirement of the proper size of the wooden infant bed are considered to have opposite effects. That is, as the child grows up, the wooden baby bed needs to be longer, and the area of the wooden baby bed will increase. Because under the contradiction, the height of the wooden baby bed has little impact on the problem. This contradiction can be translated into a contradiction between the length of the stationary object and the area of the stationary object. This constitutes a technical contradiction.

Reasonable sleep space and proper space volume are considered to constitute a group of contradictions. In order to adjust the different stages of sleep, this requires as much space as possible. However, in the actual family environment, the parents' bedroom space size is limited, and the volume of the wooden infant bed should not be too large. On the one hand, the wooden infant bed sleep space should be as large as possible, on the other hand, it should not be too large, this constitutes a group of physical contradictions.

The requirements of setting the care table and the requirements of appropriate space volume are considered to constitute a set of contradictions. The height of the traditional crib is too short, so parents need to bend over when changing diapers for the baby, which leads to back pain. The care table can help solve this problem. However, setting the care table will increase the volume of the wooden baby bed, the bedroom space is limited, and the wooden baby bed needs to occupy the space as small as possible. On the one hand, it is required to provide more space for the storage of the care table, and on the other hand, it requires that the volume of the space should not be too large, which constitutes a group of physical contradictions.

The requirements for reasonable storage space and the requirements for proper volume are considered to constitute a set of contradictions. On the one hand, the two children have more items to be stored, and the wooden baby bed needs to occupy more space; on the other hand, the wooden baby bed needs to have the appropriate space volume. This constitutes a set of physical contradictions.

Table 8. The Contradictory Judgment Table

Order Number	Contradiction of Engineering Measures	Contradictory Parameters	Contradiction Type
1	Change the length as the child grows up	Length of the still object (expected improvement)	Technical contradiction Physical contradiction
	The space volume is appropriate	Area of a stationary object (to avoid deterioration)	
2	Sleep space is reasonable	The volume of a stationary object	Physical contradiction
	The space volume is appropriate	The volume of a stationary object	
3	Set up the care table	The volume of a stationary object	Physical contradiction
	The space volume is appropriate	The volume of a stationary object	
4	The storage space is reasonable	The volume of a stationary object	Physical contradiction
	The Space volume is appropriate	The volume of a stationary object	

Resolution of technical contradictions

According to the analysis in the contradictory judgment table of Table 8, the improvement parameter is the length of the static object, and the deterioration parameter is the area of the static object. With the analysis of the technical contradiction matrix, the final two schemes were selected. One is to use the seventh TRIZ invention principle, that is, the nested method to embed the length adjustment module of the wooden baby bed into the wooden baby bed, the other is to use the 17th TRIZ invention principle, that is, the spatial dimension change principle of the wooden baby bed in the layered length direction. The two-monomer wooden infant beds are stitched together in the length direction to achieve the goal of changing the length. Based on the other contradictory solving requirements below, the scheme of 17 spatial dimensions change principle is finally selected. At the same time, the method of time separation in physical contradiction is adopted, and the contradiction separation is conducted according to the specific needs of bedroom space use in different periods. Each child can use only a single wooden infant bed as a baby, providing more room for action at a time when the baby needs the care from their parents. When the child grows up, the child does not need so much care, and wooden the parents need less space to take care of the child. At this time, the space volume of the wooden infant bed can be appropriately expanded, and the two wooden infant beds are stitched together to meet the needs of changing the length as the child grows up.

Resolution of physical contradictions

In the contradiction between reasonable sleep space and proper space volume, the method of temporal separation and spatial separation is adopted to solve the contradiction. In the component analysis stage, it is found that there is a contradiction of competition space between the eldest children and the second children, and the contradiction is separated with spatial separation. According to the user interviews and expert consultation, it was found that a single child could sleep in a big bed without discomfort. That is to say, when the older child has a certain ability to take care of themselves, they can sleep in the big bed with their parents, which provides the possibility for spatial separation.

There are many different periods in the parenting process of second-child families. The contradiction solutions of different parenting situations (Table 9) classify them in detail and solve them by means of time separation.

The process of children growing can be divided into many stages (Horvath 2003; Parent *et al.* 2016). To facilitate the classification research, family-raised children are divided into three categories, according to their physical and psychological growth: A, B, and C. Class A refers to children who do not have self-care ability or poor self-care ability. This category is similar to the infant stage. Category B refers to children who have certain self-care ability but need to be accompanied by parents to sleep. This category is similar to children in early childhood. Class C mainly refers to children with good self-care ability and who have started to sleep independently. This category is divided according to the specific physiological and psychological development of infants and the subjective identification of parents, and age is not used as the absolute division basis. Based on the classification, the parenting situation of families with two children in this period can be divided into 8 situations in Table 9.

Situations ① and ③ are families that have raised the eldest child and plan to raise a second child. At this time, only the eldest child sleeps with their parents, and the second child has not been born. Situations ⑥ and ⑦ are where the eldest children sleep alone away from their parents, and the second child still sleeps with their parents. In the situation analysis, the situations ⑦ and ③ can be approximate as a situation analysis, and the situations ⑥ and ① can be approximate as a situation analysis. Situation ⑧ explains that two children sleep alone away from their parents, which was not in the study. Situation ② is where both children are not able to take care of themselves. Situation ④ is that the eldest child has the ability to take care of themselves, but the second child does not have self-care ability. Situation ⑤ means that both children have a certain self-care ability.

In the contradiction resolution of setting care platform and proper volume, the principle of separation of whole and part is adopted. The care table is mainly divided into two parts: stand and mesa. Based on the results, it is found that in the process of changing diapers for children, only the top of the care table directly holds infants and toddlers. That is to say, the tabletop is the main component. Then, the components, such as the fence of the wooden baby bed, can be used as the function of the bracket part, so as to realize the overall function of the care table. In this way, the contradiction between the care table and the space volume is solved.

Table 9. Contradictory Solutions for Different Parenting Situations

Order Number	The First Child	The Second Child	Problem Solution
①	A	/	Individual cribs are available for elder children
②	A	A	Two cribs for two children
③	B	/	The two cribs can be stitched together and the middle barrier removed
④	B	A	The older child sleeps in the big bed with his parents, and the second child uses a separate crib
⑤	B	B	The two cribs and the big bed are stitched together to form a larger bed
⑥	C	A	Same ①
⑦	C	B	Same ③
⑧	C	C	As furniture for other functions

In the setting of the appropriate contradiction between storage space and volume, the way of spatial dimension change for the spatial separation principle and technical contradiction is adopted. First of all, it is found that there are two components that can provide storage function, one is the storage module of the wooden baby bed, and the other is the storage module of the wardrobe. In view of this, the not commonly used clothes are stored by the wardrobe, so as to reduce the space pressure of the wooden baby bed storage module, only need to store some often used daily necessities. The idea of spatial dimension change is adopted in the space layout, and the wooden infant bed is layered by the bed board in the height direction, and the upper part is used for the sleep, and bottom part is for infants and children for storage.

RESULTS AND DISCUSSION

The design research of the wooden infant bed was divided into two parts: internal factors and external factors. In terms of external factors, questionnaire survey and user interview can clarify the living conditions of users and explore the parenting needs of users. Quantitative requirements with the I-Kano model are as follows. In terms of internal factors, the methods of QFD theory and TRIZ theory are analyzed, the core engineering measures for demand realization are defined, the contradiction of engineering measures is solved, and reasonable design strategies are formulated, to achieve the unity of external factors and internal factors. Finally, the wooden infant bed design research is practical, appropriate design strategies are formulated, and a complete and feasible design research system is formed.

In terms of the wooden infant bed design strategy of the second-child families, the modular strategy is adopted to carry out the product design (Ye *et al.* 2021; Mu'az and Zulkifli 2022; Wang 2022; Zhao and Xu 2023; Xiong *et al.* 2021). The modules mainly include bed body, bed surface height adjustment module, safety removable guardrail, guardrail bracket, music playback module, toy entertainment module and decoration module, and other parts. Based on the collocation of different functional module components, measures are taken to meet the variable parenting needs of two-child families in different periods. Among them, the bed plate and the bed leg are the whole main body of the baby bed, and the other functional components are connected with the main body with the interface according to the needs of real life. With the splicing of the two wooden infant beds, the length of the wooden infant bed is increased. The wooden infant bed of a two-child family relies on the flexible combination of modular components to achieve the purpose of changing the shape and having other furniture functions according to needs, so as to meet the needs of extending the product life cycle and suitable for different stages of infants and young children. The wooden infant bed for two-child families relies on the bed height adjustment module and safety detachable guardrail to make it easy to achieve splicing with the large bed and convenient for parents to care for the infant in bed. The wooden infant bed of the two-child family relies on the splicing and matching of the wooden infant bed and the large bed to adjust the sleeping space of the two-child family. It is hoped that this study on the design of the wooden infant bed in the second-child family can provide help to solve the problems in the parenting process of the second-child family, and indirectly play some positive role in the demographic adjustment.

Solid wood is used as the main material of each module of the wooden baby bed with its advantages of easy processing, good stability, safe, and being non-toxic. Since the design of wooden infant beds for two-child families takes into account the use of infants, it is necessary to pay attention to the safety of materials. It is recommended to use unpainted solid wood material as the main material of infant bed. This can minimize the damage of chemicals in the paint to infants and young children. On the other hand, special attention can be given to the treatment of burrs in the process of material processing to prevent pricking children.

However, this study is mainly to study the problems and difficulties that need to be solved at the present stage of two-child families, and there is not much involved in the intelligence of infant beds. The main reasons are the following points. First of all, although there are many intelligent baby bed products in the market, and there are many corresponding studies in the international scope (Liu *et al.* 2018; Huang and Hao. 2020). However, due to their relatively high price, ordinary Chinese parenting families have little contact with them, which makes it difficult to be widely used by ordinary parenting families. Secondly, it is found that the functions of intelligent cribs can rarely enter the core needs of infant bed users at this stage. The popularity of smart baby beds still needs a long way to go. Intelligent crib represents a higher quality of parenting life, and is also an important direction of the development of smart home. Its popularity still needs more in-depth research and practice by relevant personnel (Han 2008; Han and Lim 2010).

CONCLUSIONS

To cope with the parenting issues of raising two children and meet the parenting needs of two children, an analytical method based on the combination of I-Kano model, QFD theory, and TRIZ theory was used to explore the wooden infant bed design. The main conclusions are drawn as follows:

1. The core requirements of users are determined by the analysis of I-Kano model. Adjusting the sleeping space of two children, convenient diaper change, suitable for different stages of infants and young children, interesting appearance, extending the use cycle, and anti-bumping are the essential attributes of the core needs. Entertainment function, convenient splicing with the big bed, intelligent coaxing to sleep, convenient for parents to observe and take care of their children in the big

bed, and reasonable storage are identified as the expected attribute needs of the core needs. Covering a small area is identified as the core demand of charm attribute demand. Other requirements are identified as non-core requirements.

2. The key engineering measures are determined by QFD theory analysis, and the engineering measures with negative correlation are determined. The guardrail is removable, the shape can be changed according to the demand, the sleeping space is reasonable, the bed surface height is adjustable, the length can be changed with the growth of the child, and the space volume is appropriate are identified as the key engineering measures. Engineering measures that change the length with the growth of the child, reasonable sleeping space, set up the care table, and reasonable storage space were all identified as having a negative correlation with the appropriate engineering measures of space volume.
3. The contradictions between engineering measures were solved with TRIZ theory analysis. A modularization strategy was adopted to carry on the design of two-child family wooden infant bed. Based on the principle of time separation, the collocation of different functional modules was developed to meet the changing needs of two-child families in different periods. With the principle of spatial dimension change and the separation principle of whole and part, the contradiction of wooden infant bed space volume is solved.

ACKNOWLEDGMENTS

The authors are grateful for the financial support of the Jiangsu Provincial Social Science Foundation [21GLD016], the International Cooperation Joint Laboratory for Production, Education, Research and Application of Ecological Health Care on Home Furnishing.

REFERENCES CITED

Chen, R., Xu, P., Song, P., Wang, M., and He, J. (2019). "China has faster pace than Japan in population aging in next 25 years," *Bioscience Trends* 13(4), 287-291. DOI: 10.5582/bst.2019.01213

Cristiano, J. J., Liker, J. K., and White, C. C. (2001). "Key factors in the successful application of quality function deployment (QFD)," *IEEE Transactions on Engineering Management* 48(1), 81-95. DOI: 10.1109/17.913168

Gu, Y. T., and Zhang, J. L. (2022). "Fatigue performance of natural and synthetic rattan strips subjected to cyclic tensile loading," *Forests* 13, 76-79. DOI: 10.3390/f13010076

Han, D. M., and Lim, J. H. (2010). "Design and implementation of smart home energy management systems based on zigbee," *IEEE Transactions on Consumer Electronics* 56(3), 1417-1425. DOI: 10.1109/TCE.2010.5606278

Han, J. Y. (2008). "A study on the direction of smart furniture by changes in ubiquitous technology-based residential environment," *The Journal of the Korean Society of Furniture* 19(4), 283-293.

He, L., Song, W., Wu, Z., Xu, Z., Zheng, M., and Ming, X. (2017). "Quantification and integration of an improved Kano model into QFD based on multi-population adaptive genetic algorithm," *Computers and Industrial Engineering* 114, 183-194. DOI: 10.1016/j.cie.2017.10.009

Herzwurm, G., Schockert, S., and Pietsch, W. (2003). "QFD for customer-focused requirements engineering," in: *Proceedings. 11th IEEE International Requirements Engineering Conference*, Monterey, CA, USA, pp. 330-338.

Hong, X., and Liu, Q. (2021). "Parenting stress, social support and parenting self-efficacy in Chinese families: Does the number of children matter?," *Early Child Development and Care* 191(14), 2269-2280. DOI: 10.1080/03004430.2019.1702036

Horvath, D. L. (2003). *Parenting Over Time: A Developmental Perspective*, Temple University, Philadelphia, PA, USA.

Huang, Q., and Hao, K. (2020, March). "The development of artificial intelligence (AI) algorithms to avoid potential baby sleep hazards in smart buildings," in*: Construction Research Congres*s, American Society of Civil Engineers, Reston, VA, USA, pp. 278-287. DOI: 10.1061/9780784482865.030

Jie, L., Peng, Z., and Xia, H. (2009). "Research on I-Kano model of improving decision making for customer satisfaction," *Statistics and Decision* (20), 152-153. DOI: 10.13546/j.cnki.tjyjc.2009.20.043

Kim, K. J., and Kim, D. H. (2008). "Research issues in robust QFD," *Industrial Engineering and Management Systems* 7(2), 93-100.

Koomsap, P., Dharmerathne, B. R. Y., and Hussadintorn Na Ayutthaya, D. (2023). "Examination of common mistakes for successful leveraging the Kano model and proposal for enhancement," *Journal of Engineering Design* 34(8), 591-615. DOI: 10.1080/09544828.2023.2245533

Lee, S., Park, S., and Kwak, M. (2022). "Revealing the dual importance and Kano type of attributes through customer review analytics," *Advanced Engineering Informatics* 51, article ID 101533. DOI: 10.1016/j.aei.2022.101533

Li, G., Zhong, L. J., and Zhang, R. (2014). "Design and development of portable folding baby bed," *Applied Mechanics and Materials* 443, 65-68. DOI: 10.4028/www.scientific.net/AMM.443.65

Liu, Y., Zheng, D., Lin, T., Liu, X., Wang, D., and Hopfgartner, F. (2018). "Smart Crib Control System Based on Sentiment Analysis," in: *2018 IEEE 16th Intl. Conf. on Dependable, Autonomic and Secure Computing, 16th Intl. Conf. on Pervasive Intelligence and Computing, 4th Intl Conf on Big Data Intelligence and Computing and Cyber Science and Technology Congress* (DASC/PiCom/DataCom/CyberSciTech), Athens, Greece, pp. 222-229. DOI: 10.1109/DASC/PiCom/DataCom/CyberSciTec.2018.00047

Lyu, J., Chen, R., Yang, L., Wang, J., and Chen, M. (2022). "Applying a hybrid Kano/quality function deployment integration approach to wood desk designs for open-plan offices," *Forests* 13(11), article 1825. DOI:10.3390/f13111825

Meng, T., and Lyu, S. (2022). "The impact of the selective two-child policy on residents' fertility intentions in China," *Applied Economics Letters* 29(16), 1455-1459. DOI: 10.1080/13504851.2021.1937492

Möller, E. L., de Vente, W., and Rodenburg, R. (2019). "Infant crying and the calming response: Parental *versus* mechanical soothing using swaddling, sound, and movement," *PLoS One* 14(4), article ID e0214548. DOI: 10.1371/journal.pone.0214548

Mu'az, A., and Zulkifli, R. (2022). "Modular furniture for compact living through sustainable development goals (SDG)," *Environment-Behaviour Proceedings Journal* 7(SI7), 255-257. DOI: 10.21834/ebpj.v7iSI9.3953

Parent, J., McKee, L. G., N Rough, J., and Forehand, R. (2016). "The association of parent mindfulness with parenting and youth psychopathology across three developmental stages," *Journal of Abnormal Child Psychology* 44, 191-202. DOI: 10.1007/s10802-015-9978-x

Rong, H., Liu, W., Li, J., and Zhou, Z. (2024). "Product innovation design process combined Kano and TRIZ with AD: Case study," *Plos one* 19(3), e0296980. DOI: 10.1371/journal.pone.0296980

Salvador, C. (2015). "Contributions of ergonomics to an affective sustainability in children's furniture," *Procedia Manufacturing* 3, 6483-6489. DOI: 10.1016/j.promfg.2015.07.931

Wang, S. (2022). "Application of product life cycle management method in furniture modular design," *Mathematical Problems in Engineering* 2022, article ID 7192152. DOI: 10.1155/2022/7192152

Wu, Y., Song, Y., and Yu, T. (2019). "Spatial differences in China's population aging and influencing factors: The perspectives of spatial dependence and spatial heterogeneity," *Sustainability* 11(21), article 5959. DOI: 10.3390/su11215959

Xiong, X., Lu, G., and Lu, D. (2021). "Research on children's customized furniture design based on group technology," *Applied Sciences* 11(23), 11371. DOI: 10.3390/app112311371

Xu, L., Yang, F., Sun, J., Nicholas, S., and Wang, J. (2019). "Evaluating family planning organizations under China's two-child policy in Shandong province," *International Journal of Environmental Research and Public Health* 16(12), article 2121. DOI: 10.3390/ijerph16122121

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. DOI: 10.1109/IEEM.2007.4419400

Yang, S., Jiang, Q., and Sánchez-Barricarte, J. J. (2022). "China's fertility change: An analysis with multiple measures," *Population Health Metrics* 20(1), 1-14. DOI: 10.1186/s12963-022-00290-7

Ye, J., Li, W., and Yang, C. (2021). "Research on modular design of children's furniture based on scene theory," in: *Human-Computer Interaction. Design and User Experience Case Studies, HCI 2021* Lecture Notes in Computer Science, Vol, 12764, Springer, Cham, Switzerland, pp. 153-172. DOI: 10.1007/978-3-030-78468-3_11

Zhao, Y., and Xu, Y. (2023). "Evaluation model for modular children's wooden storage cabinet design," *BioResources* 18(4), 7818-7838. DOI: 10.15376/biores.18.4.7818-7838

Article submitted: April 9, 2024; Peer review completed: June 8, 2024; Revised version received and accepted: July 1, 2024; Published: July 17, 2024.
DOI: 10.15376/biores.19.3.6076-6094