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Research article

Design of breastfeeding chairs for maternity rooms based on Kano-AHP-QFD: User requirement-driven design approach

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A R T I C L E I N F O

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A B S T R A C T

In maternity rooms, breastfeeding chairs are crucial pieces of equipment that greatly influence the breastfeeding experience. However, an abundance of data indicates that there are still issues with breastfeeding chairs, including inadequate support for breastfeeding, poor body type adaptability, and failure to adequately analyse the requirements of mothers and baby users. This study used an innovative research approach to breastfeeding chair design from the standpoint of user requirements to improve breastfeeding willingness and user experience. We propose a user requirement assessment design approach that integrates the Kano model, analytic hierarchy process (AHP), and quality function development (QFD) based on the requirements of mother and baby groups. This approach was intended to build a user experience evaluation model for mother- and baby-friendly products. Following this approach to breastfeeding chair design, a fuzzy comprehensive evaluation (FCE) was used to assess the chair. Compared to the original breastfeeding chairs, the designs of breastfeeding chairs that met important requirements for mothers and infants, such as safety, hygiene, and breastfeeding support, resulted in an approximately 23 % increase in user satisfaction. This effectively improved the user experience of both mothers and infants. This approach is centred on the basic requirements of mothers and babies. It evaluates the essential requirements that impact the breastfeeding experiences of mothers and babies and provides multifaceted data regarding the attributes of the different requirements of mothers and babies. This results in theoretical research references for ensuing user-driven design products that cater to the requirements of mothers and their infants and play a pivotal role in formulating design guidelines for mother- and baby-friendly products.

1. Introduction

World Breastfeeding Week is observed from the first of August to the seventh, with a range of events centred around certain themes by the United Nations International Children's Emergency Fund (UNICEF) since 1992 [1]. Meanwhile, the UNICEF-sponsored Breastfeeding Friendly Communities Initiative (BFCI) encourages the development of mother-child-friendly, supportive community settings to facilitate breastfeeding and foster a welcoming nursing environment in various locations [2]. Therefore, it is imperative to guarantee that mothers and infants, as distinct user groups, have access to welcoming nursing spaces and suitable breastfeeding

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experiences. This encourages breastfeeding and the variety, customisation, and high standards of public service facilities for mothers and babies.

Until the mid-20th century, the requirements of breastfeeding mothers and babies were not specifically considered in chair design, and most families simply used ordinary chairs for breastfeeding. However, as the mid-to late-20th century progressed, designers began to develop chairs specifically designed for breastfeeding to ease the discomfort and pain experienced by mothers and babies caused by improper posture. Jones' research, for example, improved the ergonomics of breastfeeding chairs to ensure proper breastfeeding posture and, through testing prototypes, demonstrated that the new design effectively supported mothers in maintaining better posture, reduced discomfort, and facilitated breastfeeding more efficiently than ordinary chairs [3]. Since the early 21st century, the design of breastfeeding chairs has evolved further and has begun to fully consider the risks associated with improper design. A study by Gumasing et al. revealed that mothers using currently designed breastfeeding chairs (single-piece plastic chairs and sofas) are at risk of musculoskeletal disorders due to poor posture during breastfeeding. Using Corlett's Body Part Discomfort Questionnaire, mothers felt significant pain in several areas, including the head, neck, upper back, lower back, and hips, while using these chairs. The team applied ergonomic principles to design a breastfeeding chair that conformed to the body dimensions of the target user. This significantly improved the comfort and safety of mothers during breastfeeding, demonstrating the importance of design improvements in improving the functionality of breastfeeding chairs [4].

Despite significant advances in breastfeeding chair design, research continues to expose its shortcomings in terms of practicality. Haight and Ortiz conducted a statistical analysis of 100 airports in the United States and observed that only 8 % of the airports surveyed provided the minimum requirements for breastfeeding rooms. The study showed that although many airports claim to support breastfeeding, they provide facilities that do not meet the basic requirements of breastfeeding mothers, overlooking mothers who need specific amenities such as power and storage space to support the use of breast pumps [5]. In another study, a survey of 100 mothers conducted by Prima et al. revealed significant deficiencies in the design and comfort of the long couch-type breastfeeding chairs currently in use. The shortcomings include inadequate protection of the mother's privacy and insufficient consideration of supporting proper breastfeeding positions [6]. The existing problems with breastfeeding chairs are shown in Fig. 1.

As shown in Fig. 1, the specific advantages and disadvantages of each of the three types of breastfeeding chairs are as follows.

1) The first type of breastfeeding chair considers the support structure during breastfeeding but lacks space for essentials and charging facilities, resulting in the need for mothers to move around frequently.
2) The second type of breastfeeding chair is better designed for storage and charging ports; however, improper breastfeeding chair ergonomics lead to physical fatigue and pain from prolonged breastfeeding, and sharp cabinet corners are a safety risk.
3) The third type of breastfeeding chair offers soft materials and privacy; however, the size of the chair may not be friendly to mothers of different sizes, and the fabric material and seat seams can lead to problems with cleaning and hygiene.

In addition, the exploration of the above issues should go beyond functional considerations and expand to broader dimensions to comprehensively analyse the multiple factors that affect the mother-and-baby user experience. This involves the necessity of an in-depth analysis of user satisfaction and the requirement of comprehensively exploring elements such as user pain points, psychological requirements, and usage habits in the breastfeeding experience [7]. Therefore, there is an urgent need to develop innovative theoretical frameworks and research methodologies for the in-depth exploration and design optimisation of maternal and infant requirements to significantly enhance the user experience and willingness of maternal and infant users to breastfeed in real-life environments.

1.1. Mother- and baby-friendly environments and breastfeeding chairs

An example of a nursing aid device is a breastfeeding chair designed considering the requirements of mothers and their infants. The

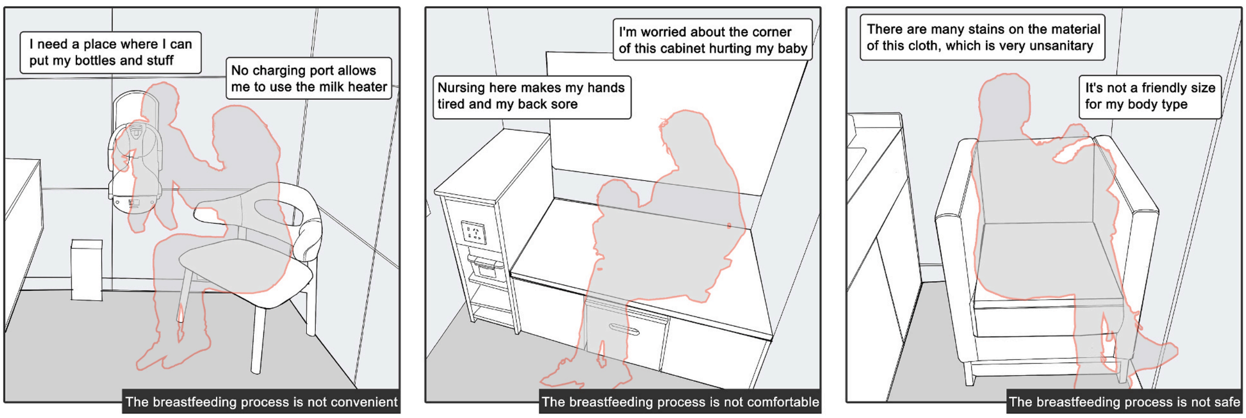

Fig. 1. Existing problems with breastfeeding chairs.

Wisdom Research Consulting report "2024–2030 China Maternal and Infant Industry Market Panoramic Survey and Investment Potential Research Report" projects that the market size of China's maternal and infant products and services will reach 265.63 billion yuan and 205.27 billion yuan, respectively, in 2022. This represents a substantial market size, and the industry is still in its rapid maturity stage [8]. In the future, increasing the added value of products and services for mothers and babies will be crucial to the industry as women's focus on child-rearing will grow. Consequently, to improve the competitiveness of products, mother and baby product design must move from satisfying the use function of the past to improving the mother and baby experience, thereby increasing user satisfaction and offering mother- and baby-friendly products and services [9].

Mother- and baby-friendly surroundings are those that consider the requirements of both mother and child and foster a warm, supportive atmosphere. According to previous studies, mothers' feelings of trust, empathy, and spatial belonging are strengthened when they have a positive experience using mother and baby facilities [10]. Scholars have conducted analyses and studies on mother- and baby-friendly designs pertaining to breastfeeding chairs in maternity rooms. In a study on the breastfeeding process and posture, Sutapa et al. examined mothers' breastfeeding posture and embraced an ergonomic design to enhance user comfort and stability during use [11], whereas Santiana et al. optimised the size of the breastfeeding chair through ergonomics in response to mothers' weariness and soreness during breastfeeding [12]. Ivana and Filip created the Heer Bench as part of a study on the privacy requirements of breastfeeding mothers and infants. This device offers a semi-independent wrapping space that satisfies the privacy requirements of breastfeeding mothers and infants [13].

The requirements and product functions of mothers and infants have not been thoroughly studied or analysed. As custodians of customary breastfeeding practices, mothers encounter major obstacles and challenges during breastfeeding. It is essential to fulfil user requirements related to the feeding behaviours of mothers and infants as well as product design requirements. Therefore, designers of breastfeeding chairs must consider the distinct viewpoints and emotions that mothers have toward public spaces.

1.2. User requirements and design methods

In the field of product design, the user-requirement-driven design methodology is considered one of the core theories driving innovation research, which mainly includes the Kano model, the analysis hierarchy process, quality-function development, and kansei engineering [14]. To better understand the pain points and psychological requirements of breastfeeding for mothers and infants and to truly improve the satisfaction of the breastfeeding experience for mothers and infants from the perspective of products or functions, it is necessary to design from the perspective of the requirements of mothers and infants [15]. Chapman and Kuhnly conducted focus groups with users as part of a mother-infant requirements study and described the requirements for mother-infant interactions based on transcript screening [16]. Bai and Wunderlich identified four essential conditions for breastfeeding facilitation using a questionnaire survey [17]. These include rest time, work environment, technical support, and workplace policies. The above studies explored the characteristics and criteria of the requirements of mothers and infants; however, there is a research gap in the analysis of the correlation between different requirements and the satisfaction of mothers and infants. This makes it difficult to recognise the requirements of the focused mothers and infants and realise the transformation of the design function, resulting in the deviation of the design from the requirements of mothers and infants.

To solve the above problems, innovative research has been conducted to explore the design of breastfeeding chairs in maternity rooms using a user-requirement-driven design method. In the research method, the Kano model, as a user requirement analysis method, can divide user requirements into different attributes and analyse the relationship with user satisfaction, realizing the correlation analysis between different requirements and mother and baby satisfaction. Constructed from the product's point of view, the Kano questionnaire asks both positive and negative questions about user requirements, analyses requirements that are positively correlated with user satisfaction and performs targeted analysis to effectively improve a product's user experience [18,19].

After determining the relationship between different requirements and maternal and infant satisfaction, it is necessary to recognise the importance of different requirements to improve product design efficiency. However, the Kano model cannot instantly rank the priority of user requirements. Determining the main requirements of a user is an important part of product design and can significantly improve the efficiency of meeting user requirements. The analysis hierarchy process (AHP) is a quantitative calculation and evaluation method used in multi-criteria decision-making. It can determine the weights of pertinent factors in an easy, effective, impartial, and thorough manner, and is feasible to statistically assess several aspects of the design to define the main user requirements and design focus by establishing hierarchical models and judgment matrices [20,21]. Using the Kano-AHP approach, we were able to better understand the correlation between maternal and infant requirements and breastfeeding chairs and recognise the focused maternal and infant requirements.

After obtaining the key user requirements, the key maternal and child requirements must be incorporated into the design functions of the breastfeeding chair program. The Kano model and the AHP method cannot directly offer product design guidance for satisfying user requirements. A design method applied to product decision-making called quality function deployment (QFD) converts abstract requirements into specific functional requirements. It is possible to develop an ideal design solution quickly and effectively by measuring user requirements using a quality home model and depicting the degree of connection between the user and functional requirements [22,23]. The entire derivation process can realise the analysis and transformation of mother and baby requirements; that is, by combining the Kano model, AHP, and QFD, key user requirements can be identified and transformed into product design functions to satisfy these requirements.

Kansei engineering is the study of the emotional design of products. However, Kansei Engineering is not necessary as functional investigation of the requirements of mothers and babies is lacking at this stage, considering the design of breastfeeding chairs. Therefore, a combination of the Kano-AHP-QFD methods was selected for this study.

Finally, the Kano-AHP-AD theoretical approach was used to derive the design function corresponding to the user requirements, which required design practice and an assessment of the feasibility of the design function. Fuzzy comprehensive evaluation (FCE) is an evaluation method that assesses the evaluated thing's affiliation level with several aspects comprehensively by combining fuzzy connection synthesis and fuzzy mathematics [24]. A fuzzy comprehensive evaluation method was used to compare the breastfeeding chair solutions for the maternity rooms with the original design solutions. This allows for a quantitative assessment and comparison of the scores of various solutions, thus completing user requirement-driven product design practice and plan testing [25].

Using a combination of these methods, this study established a complete design methodology for mother- and baby-friendly products. The method starts with an analysis of the mother and baby's requirements and satisfaction and establishes the core requirements of breastfeeding for mothers and babies through empirical research. Therefore, the derivation of mother and baby requirements for product design functions is further realised, and a fuzzy evaluation is adopted for design verification, which comprehensively completes the methodological process from user derivation to design verification.

2. Literature review

2.1. Kano model

Noriaki Kano, a professor at the Tokyo University of Technology, created the Kano model, a method used to comprehend customer goals and requirements. The model helps businesses identify which attributes increase customer satisfaction, which can cause dissatisfaction, and which attributes have a minimal influence on customer satisfaction. This is achieved by classifying the client requirements into multiple categories. The basic principle of the Kano model is that various requirements have different effects on customer satisfaction [26].

As shown in Fig. 2, the Kano model classifies the factors influencing user satisfaction into five categories based on the relationship between the various categories of requirements and user satisfaction [27]. Must-be requirements are those that customers take for granted when using a product; achieving this requirement will not make consumers happy, but failing to fulfil them will make users very dissatisfied. One-dimensional requirements and user satisfaction are directly correlated; the higher the degree of availability, the more satisfied the user, and vice versa. Attractive requirements are those that the user does not anticipate; the higher the degree of availability, the significantly increased user satisfaction, and failing to fulfil this requirement will not result in a decrease in user satisfaction. Reverse requirements are attributes that users do not want and would lower user satisfaction, whereas indifferent requirements have no influence on user satisfaction [28].

2.2. Analytic hierarchy process

Beginning in the early 1970s, American operations researcher Thomas L. Saaty proposed the analytic hierarchy process (AHP), a method for the quantitative evaluation of difficult decision-making situations. The AHP method builds a hierarchical structural model, which then quantitatively evaluates and ranks decision-making elements through pairwise comparisons. Decisions were made based

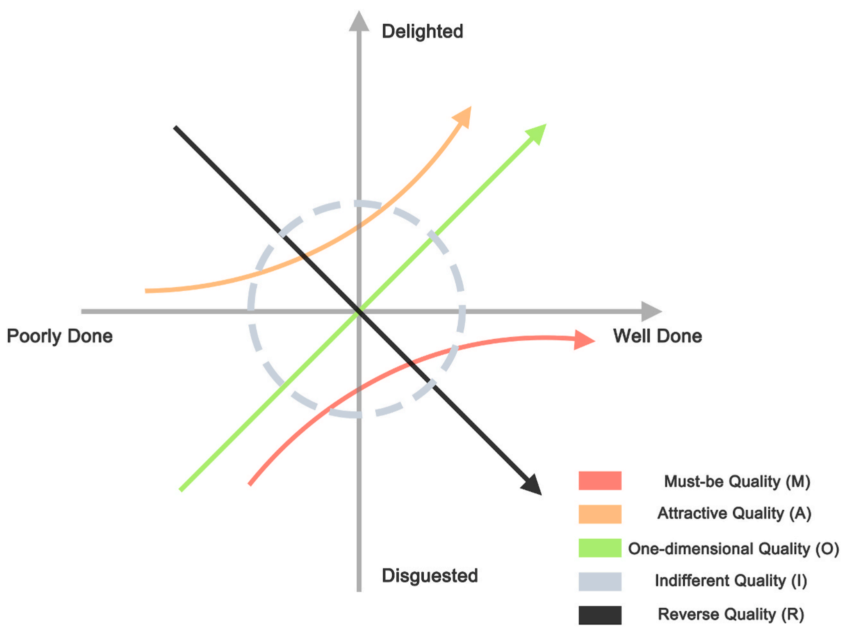

Fig. 2. Requirement attributes of the Kano model.

on the evaluation and ranking results. This process divides a complex decision-making problem into smaller and easier-to-analyse parts. Many disciplines, including management, economics, environmental assessment, and public policy, use the AHP extensively for decision analyses [29].

Before using the AHP method, it is essential to establish the decision objectives and the problems that need to be solved. The decision problem is divided into several layers, including objectives, policies, and programs. The elements in a level are compared two against two and given a score based on the degree to which they contribute to or are important to the objectives of the level before it. Based on this, a matrix of pairwise comparisons was applied to quantify the weight of each element in relation to the objective of the previous level. A consistency test was conducted to ensure that the scores were logical and consistent [30]. The analysis proceeded if the consistency ratio (CR) was accepted; otherwise, paired comparisons were reevaluated. Decision-making is based on the total weight of each option at the program level relative to the highest objective, which is ultimately determined by adding the weights of several levels [31].

2.3. Quality function deployment

Quality function deployment (QFD) is a systematic method of product development that assists businesses in converting user requirements into targeted product design functions to ensure that the end result fulfils user expectations [32]. A multidimensional matrix called the House of Quality serves as the central component of QFD, depicting and evaluating the relationship between product functions and user requirements to ensure that the final product fulfils user expectations [33].

To evaluate the design functions using the QFD method, the quality house must obtain the user requirements and weights from the AHP method. We selected particular design functions that can satisfy this requirement through market research and in-depth interviews and built an evaluation matrix to measure the relationship between the design functions and user requirements [34]. After evaluating and scoring the correlation strength of the design functions based on different user requirements and weights, design functions with higher scores are prioritised to guide the design and better fulfil user requirements.

2.4. Fuzzy comprehensive evaluation

The fuzzy comprehensive evaluation method is an evaluation method based on quantitative analysis, which is mainly used to deal with evaluation problems with uncertainty and ambiguity [35]. It is distinguished by lucid and methodical outcomes and is more adept at resolving ambiguous and challenging-to-quantify issues by converting qualitative assessment into quantitative analysis.

The fuzzy relationship matrix is formed by the evaluator determining the degree of affiliation (i.e. likelihood) of each evaluation object in relation to each evaluation level based on the particular result of each index, which is the first step in the FCE method [36]. A weight vector is formed by combining the weights derived from the analytic hierarchy process method with user requirements, which serve as an evaluation item in the product design. A fuzzy comprehensive evaluation was performed to determine the degree of affiliation of each design solution with each user requirement by combining the fuzzy evaluation matrix and weight vector, thus realizing the complete performance of analysing the design solutions [37].

3. Hypotheses

This study aimed to apply the Kano-AHP-QFD methodology to analyse the requirements of mother and baby users, with the goal of enhancing the user experience of breastfeeding chairs in maternity rooms and creating a mother-and-baby-friendly environment. This study integrates a user-requirement-driven methodology with mother-and-baby product design to construct a mother-and-baby-friendly product design strategy based on user requirements.

The following important concerns were addressed in this study to assist designers in comprehending the requirements of mother-and-child groups and creating products.

1) Systematically recognise the characteristics of different mother and baby requirements using the Kano model and analyse the impact of each mother and baby user requirement on user satisfaction.
2) The weight of each mother and child requirement was quantitatively assessed using the AHP method to derive a prioritised ranking of the different mother and child requirements in design practice.
3) Based on the weighted value of the mother and baby requirements as the evaluation standard, a QFD-quality house was adopted to score different design functions and obtain a highly relevant design function that can meet the requirements of the mother and baby.

4. Methodology

4.1. Field research on mother and infant requirements

To conduct data analysis, it is vital to gather raw user requirements through research before user requirements evaluation. The research team chose six public venues to distribute surveys and conduct in-depth user interviews with breastfeeding mothers to acquire more first-hand knowledge on the requirements of mothers and their babies. To guarantee the accuracy of the requirements gathered from the survey, participants in the maternity rooms who used breastfeeding chairs more than three times a month were chosen for the

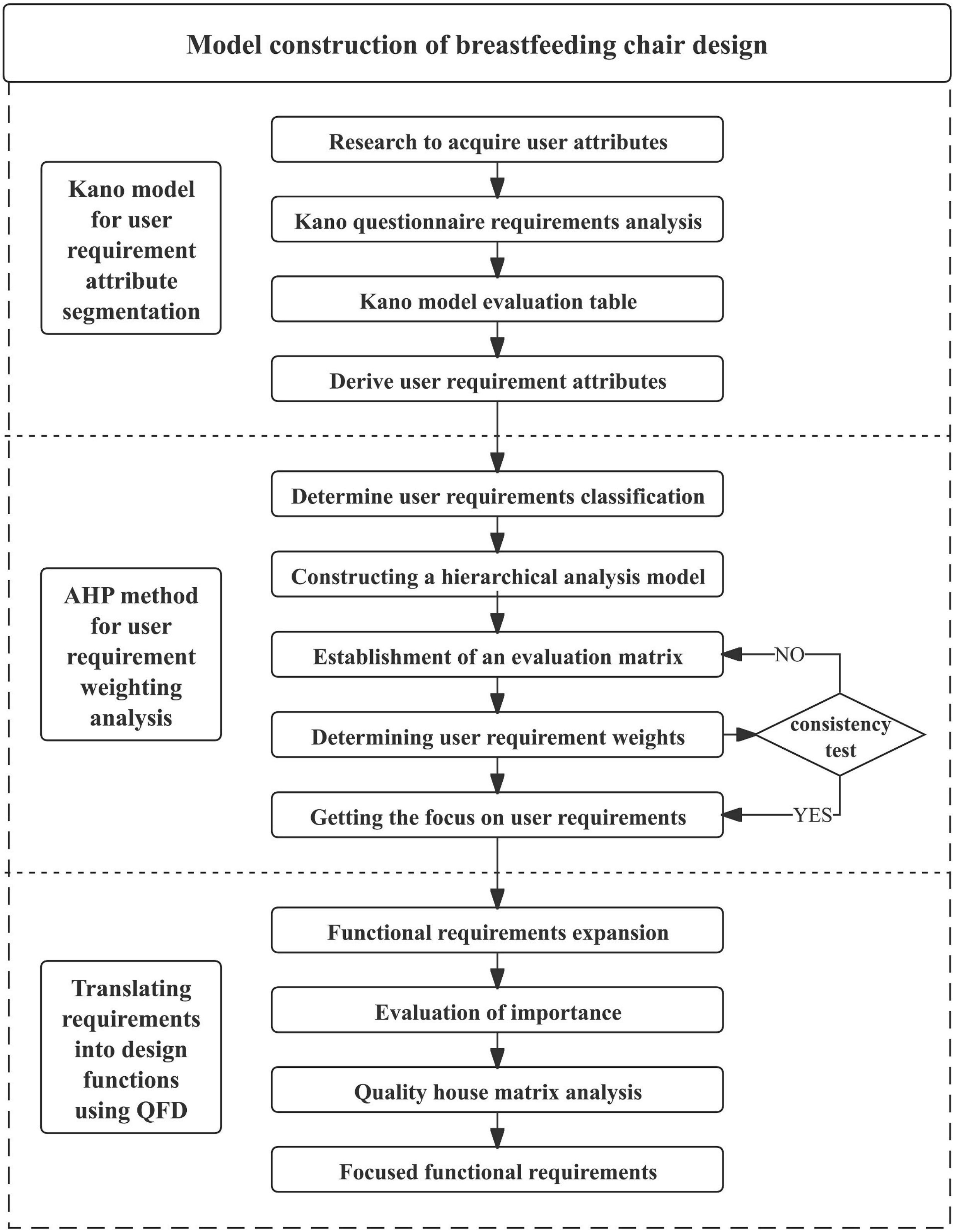

Fig. 3. Design framework.

study. The selection factors, along with exemplary public spaces, were as follows.

- Malls for shopping: Places where mothers and children go shopping and move around and where they do daily activities.
- Public Transportation Hubs: Associated with daily trip destinations and the commuting of mothers and children.
- Amusement parks: Amusement parks are associated with mother-and-child interactions and relaxation.
- Libraries: Linked to leisure and education for mothers and children, they serve as locations for everyday activities.
- Hospitals: Connected with medical care, maternity, and child health and serving as locations for standard medical treatment.
- Museums: Associated with mothers' and children's aesthetic education, museums serve as locations for daily activities.

4.2. Kano-AHP-AD method

After analysing the original mother and baby requirement indicators, to explore the connection between different requirements and mother and baby satisfaction and to understand the weight of each requirement to effectively transform the key user requirements into design functions, this study applied the Kano-AHP-QFD design methodology to conduct an in-depth user requirement analysis. Using the Kano model, we classified and assessed the attributes of maternal and infant requirements and systematically explored the relationship between each requirement and maternal and infant satisfaction. Using the AHP method, we quantitatively calculated the weights of each requirement and prioritised them. This helped to guide the product design more effectively. The QFD method enabled the conversion of maternal and infant requirements to breastfeeding chair design functions through the construction of a quality house, which ensures that the design of mother and baby products is centred on user requirements. The Kano-AHP–QFD design methodology framework shows significant advantages for its clarity of requirement attributes, well-defined weighting of key requirements, scientific and efficient design parameters, and comprehensive design process. Therefore, the original user requirement indicators from this research were incorporated into this methodology. The design framework is shown in Fig. 3.

4.2.1. Requirement attribute analysis via the Kano model

The Kano model is capable of asking positive and negative questions about the original user requirements to determine the correlation with user satisfaction. Therefore, the user requirements obtained from field research in different public places were used as the original indicators for the analysis. Breastfeeding women of various ages were issued a questionnaire created according to the requirements of mothers and babies from field research in public spaces. The attributes of the requirements of mothers and babies were computed based on the findings of subsequent steps..

1) The research team will create a Kano questionnaire for each screened mother-child requirement. The forward and reverse questions in the questionnaire can identify users' attitudes regarding whether they fulfil these requirements, as listed in Table 1.

2) Kano questionnaires were distributed to target users with the objective of guaranteeing that the research groups included mothers and babies of various ages and that the categorisation of user requirement attributes was appropriate. The research group included mothers and infants who used breastfeeding chairs three or more times a month.
3) With reference to the Kano result evaluation table [38], as listed in Table 2, the statistical data from the Kano questionnaire were compiled, and the user requirements were categorised into five types based on the maximum value of the proportion of categorised results. The must-be attribute requirement (M), attractive attribute requirement (A), one-dimensional attribute requirement (O), indifferent attribute requirement (I), and reverse attribute requirement (R) are listed in Table 2. The outcome was problematic if there were questionable attribute requirements (Q).

4) Following the identification of user requirements for different attributes in the design, the requirements of indifferent attributes are eliminated because they do not effect on user satisfaction, whereas the requirements of reverse attributes lower user satisfaction. The AHP method is based on mother and infant requirements and focuses on user requirements of must-be, one-dimensional, and attractive attribute categories [39].

4.2.2. Requirement weights computed via AHP

After the Kano model classifies the attributes of different maternal and infant requirements, a hierarchical model is constructed to assess the specific weights of each maternal and infant requirement according to the user requirements of the different classified

Table 1
Kano forward and reverse assessment questionnaire.

Questionnaire option		Like	Expect	Neutral	Tolerate	Dislike
User requirement 1	Forward: Fulfil user requirement 1	5	4	3	2	1
	Reverse: Not fulfil user requirement 1	5	4	3	2	1
User requirement 2	Forward: Fulfil user requirement 2	5	4	3	2	1
	Reverse: Not fulfil user requirement 2	5	4	3	2	1
…	…	…				
User requirement n	Forward: Fulfil user requirement n	5	4	3	2	1
	Reverse: Not fulfil user requirement n	5	4	3	2	1

Table 2
Kano attribute results assessment summary.

User requirement		Reverse problem				
		Like	Expect	Neutral	Tolerate	Dislike
Forward problem	Like	Q	A	A	A	O
	Expect	R	I	I	I	M
	Neutral	R	I	I	I	M
	Tolerate	R	I	I	I	M
	Dislike	R	R	R	R	Q

attributes. Retaining the must-be, one-dimensional, and attractive requirements in the Kano model as indicators, the AHP method was used to determine the comprehensive weights of each mother and baby requirement in the design of breastfeeding chairs and to derive the key mother and baby user requirements with the following steps.

1) The target layer of this study was set as the optimal maternity room breastfeeding chair design solution, whereas the criterion layer adopted the must-be (M), one dimensional (O), and attractive (A) attributes of the Kano model user requirement attributes. The sub-criteria layer then uses specific maternal and child requirements under each attribute type, with M_1 being the first requirement of the must-be attribute and M_n being the nth requirement of the must-be attribute. By analogy, O_1 is the first requirement of the desired attribute, and A_1 is the first requirement of the attractive attribute to construct the hierarchical model shown in Fig. 4 [40].

2) To guarantee that the research satisfied both theoretical and practical requirements, all invited theoretical researchers were acquainted with the AHP method in practice, and the designers of products for mothers and babies had over five years of professional experience. The objective of this group was to evaluate the indicators of the hierarchical scoring model.

3) The 1–9 scale method proposed by T.L. Saaty was used to establish the weight comparison questionnaire, and a two-by-two comparative scoring was conducted for the must-be, one-dimensional, and attractive requirements of breastfeeding chairs in maternity rooms. Second, each requirement within the different attributes was scored in a two-by-two comparison to arrive at the user-requirements questionnaire for the must-be, one-dimensional, and attractive attributes. Using the must-be requirements as an example, the M_1-M_n two-by-two comparison questionnaires to which they belonged are listed in Table 3. Similarly, the importance scores of each user-requirement indicator for different attributes were derived.

4) Using the geometric mean (square root method) [41], the weights of each user requirement indicator are calculated based on the scores and can be estimated as follows:

   To determine the scalar product (Z_i) for every layer, we multiply the values in each row of the judgment matrix.

$$Z_i = \prod_{j=1}^{m} W_{ij} \quad (i = 1, 2, \cdot \cdot \cdot, n) \tag{1}$$

where W_{ij} represents the factors in the ith row and jth column and m denotes the matrix order.

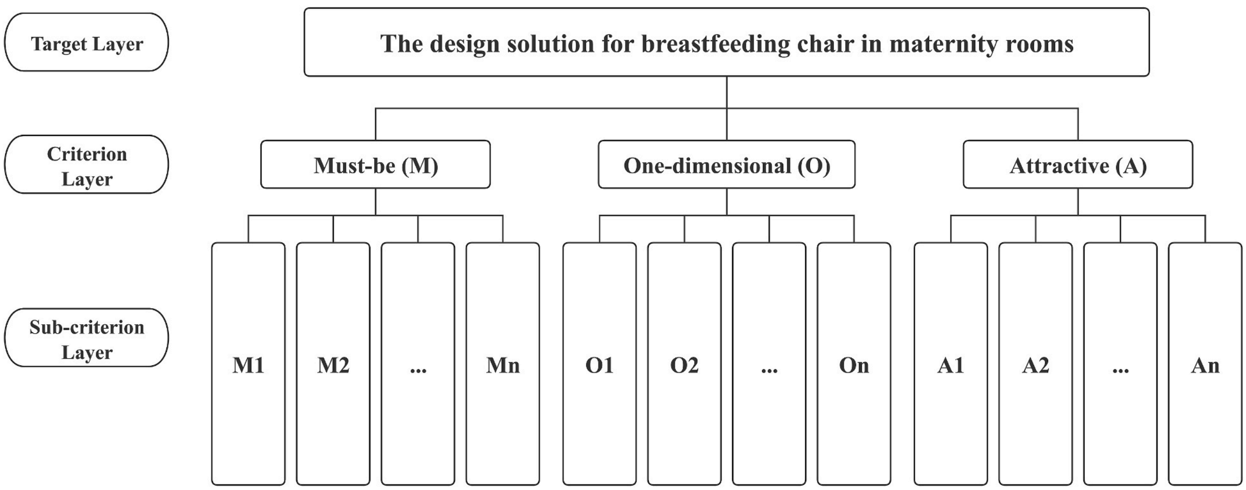

Fig. 4. Breastfeeding chair design hierarchical model.

Table 3
AHP weight comparison score assessment questionnaire.

User requirement	Weight comparison score									User requirement
M_1	9	7	5	3	1	3	5	7	9	M_1
M_1	9	7	5	3	1	3	5	7	9	M_2
…	…									…
M_1	9	7	5	3	1	3	5	7	9	M_n
…	…									…
M_n	9	7	5	3	1	3	5	7	9	M_n

The geometric mean (a_i) of Z_i was determined by elevating the sum of the scales of each layer, Z_i, to the mth power of the row's total factor.

$$a_i = \sqrt[m]{Z_i} \quad (i = 1, 2, \cdots, n) \tag{2}$$

For calculating the relative weights (ω_i), the data are standardized.

$$\omega_i = \frac{a_i}{\sum_{i=1}^{m} a_i} \tag{3}$$

Find the maximum characteristic root ($\lambda_{\max}$) by computing.

$$\lambda_{\max} = \frac{1}{m} \sum_{i=1}^{m} \frac{A_{W_i}}{\omega_i} \tag{4}$$

where m indicates the order and A_{Wi} stands for the ith component of the vector A_W.

Test for consistency of results (CI).

$$CI = \frac{(\lambda_{\max} - m)}{(m - 1)} \tag{5}$$

$$CR = \frac{CI}{RI} \tag{6}$$

where RI is the average random consistency index, CR is the consistency ratio, and m is the order matching the evaluation scale. The matrix passes the consistency test, and the weights are legitimate when $CR \leq 0.1$ [42].

5) To acquire the essential user requirement attributes for future design function derivation, the individual user requirements are ranked according to their total weight values.

4.2.3. *Requirement transformation function based on QFD*

After the AHP method is used to derive the weight of each maternal and child requirement, it can be used as an important numerical reference to evaluate the correlation between user requirements and design functions to derive the scores of each design function. After scoring the design functions obtained from the research, the higher the score, the better the design function meets the requirements of the users and improves their satisfaction. The requirements of mothers and babies were converted into design functions through QFD theory, and the degree of correlation between the requirements and the function matrix was evaluated using correlation analysis. This allowed the best optimisation solution to satisfy the mothers' and babies' requirements to be estimated in the subsequent steps.

1) Create a technical team for the product to investigate the primary user requirements resulting from the AHP. The QFD theory requires expert evaluation by experts with practical experience, primarily focusing on design function evaluation. To ensure the applicability of the design functions, a panel of experts, including engineers with over five years of production expertise in mother and child products and designers with experience in breastfeeding seat design, were asked to perform a correlation evaluation. The team then decides on the design functions of the breastfeeding chair that can address the primary requirements of the mothers and infants. The product design function includes a list of all the design functions that evolved from the baby and mother requirements.
2) The left wall value of the quality house was chosen by integrating the weights of the requirements of mothers and infants, which were calculated using the AHP method. These weights are then recorded in the user requirements weighting section.
3) Product design function and user requirements weighting should be linked. We then assessed the breastfeeding chair design functions and the requirements of mothers and infants based on this correlation. The User Requirements Weighting and Product Design Function sections are correlated in a matrix. The questionnaire is listed in Table 4; the results were correlated using a scale of 0, 1, 3, and 5 to indicate no correlation, weak correlation, medium correlation, and strong correlation, respectively. Using the must-be requirements as an example, the M_1-M_n user requirements belonging to it are filled in the user requirements weighting section, and the questionnaire is listed in Table 4. Similarly, all the scores of each user requirement indicator under the must-be attributes,

one-dimensional attributes, and attractive attributes are calculated, and the average value is filled into the correlation matrix, that is, the user requirements and product design functions relationship matrix of the quality house [43].

4) The design function scores for the breastfeeding chairs were accumulated by multiplying them with the weights of the corresponding layers of requirements for mothers and infants. These scores are then entered into the weighting of product design functions to assess the corresponding weights of each of the design functions and to guide the conceptual design of breastfeeding chairs. Based on the quality house framework proposed by Professors Yo Akao and Mizuno in Japan [44], the quality house framework for constructing a breastfeeding chair in a maternity room is shown in Fig. 5.

4.3. Design function guides conceptual design

After the correlation assessment by QFD, the design function with the highest score was used as a reference and guide for the design of the breastfeeding chair in the maternity rooms. To validate the design functions derived from the Kano-AHP-QFD method, we conducted a conceptual design of the breastfeeding chair based on higher-scoring design functions as a guideline and assessed whether it could improve the satisfaction of mothers and babies. The steps are as follows..

1) As a critical functional guide for future design, refer to the design functions with high correlation scores found via the QFD methods.
2) Existing breastfeeding chair solutions for maternity rooms were retrofitted, and the conceptual design of the modified breastfeeding chairs was validated by comparison with existing solutions. When choosing a prototype, the number of times a breastfeeding chair is used every day should be greater than 20. The largest shopping centre close to the team's research institution provided a breastfeeding chair for this study, which was utilised more than 20 times per day in the maternity room. This ensured that the referability of the study sample made it easier to complete and gauge user satisfaction.

4.4. Verification of breastfeeding chair satisfaction

After arriving at the conceptual design plan, to assess whether these high-scoring design functions applied to the breastfeeding chair can satisfy user requirements, all the requirement indicators under the must-be, one-dimensional, and attractive requirements after the division of the Kano model are selected as scoring criteria. The fuzzy comprehensive evaluation method is adopted to assess the user requirement satisfaction scores of the existing and conceptual breastfeeding chair designs, which is performed in the following steps.

1) As the benchmark for assessing how satisfied mothers and their infants feel with the breastfeeding chair design, the Kano model's must-be, one-dimensional, and attractive requirements serve as the evaluation index system.
2) The study's selection criteria included mothers and baby users with more than three sample usage experiences. Designers with more than three years of experience in creating products for mothers and babies were selected for co-analysis. On a scale of 0–100, they were asked to rank the two programs. As listed in Table 5, higher scores indicate that the program fulfilled the requirements of the mother and child. This was done to ensure that the study satisfied both the product practices and user criteria. The must-be requirements are M_1-M_n, the one-dimensional requirements are O_1-O_n, and the attractive requirements are A_1-A_n.

3) The matching rubric set was assigned based on various score intervals, and set $T = \{T_1, T_2, T_3, T_4\}$ was the result. T_1 indicates very like (90–100 scores), T_2 indicates like (75–90 scores), T_3 indicates normal (60–75 scores), and T_4 indicates dislike (0–60 scores) [45].
4) Rubric sets T_1, T_2, T_3, and T_4 were assigned 10, 8, 6, and 4 points, respectively. A fuzzy relationship matrix was created using the weights of each user requirement obtained from the AHP and the ratings assigned to the mother and baby satisfaction evaluation sets. A suitable fuzzy comprehensive evaluation operator was selected and scores were added to obtain the final score of the program [46].

Table 4
QFD correlation score assessment questionnaire.

User requirement	Correlation score				Design function
M_1	0	1	3	5	Design function 1
M_1	0	1	3	5	Design function 2
…	…				…
M_1	0	1	3	5	Design function n
…	…				…
M_n	0	1	3	5	Design function n

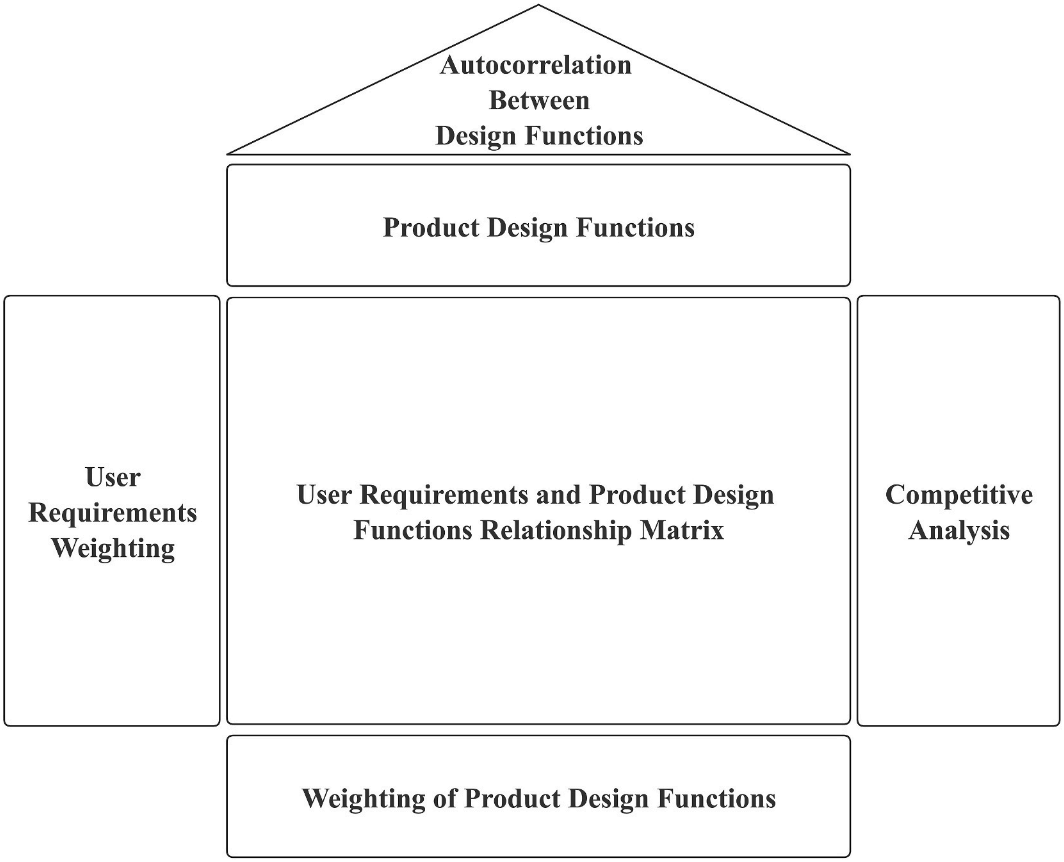

Fig. 5. Quality house framework model.

Table 5
FCE sample score assessment questionnaire.

User requirement	Sample A score				Sample B score			
M_1	0–60	60–75	75–90	90–100	0–60	60–75	75–90	90–100
…	…				…			
M_n	0–60	60–75	75–90	90–100	0–60	60–75	75–90	90–100
O_1	0–60	60–75	75–90	90–100	0–60	60–75	75–90	90–100
…	…				…			
O_n	0–60	60–75	75–90	90–100	0–60	60–75	75–90	90–100
A_1	0–60	60–75	75–90	90–100	0–60	60–75	75–90	90–100
…	…				…			
A_n	0–60	60–75	75–90	90–100	0–60	60–75	75–90	90–100

5. Results and discussion

5.1. Initial research on mother-and-baby requirements

Using open-ended questionnaires and in-depth interviews with breastfeeding women with babies in public locations such as Beijing Railway Station, Beijing Daxing Airport, the National Museum of China, and Tianjie Shopping Plaza, the research team collected firsthand information on the requirements and desires of mothers and babies regarding breastfeeding chairs. In total, 134 open-ended questionnaires were issued, 26 in-depth interviews were recorded, and 160 breastfeeding women were included in this study. The requirements of mothers and infants, which were highlighted by over half of those surveyed, were retained as initial user requirement indicators after a focus group consisting of five graduate students with backgrounds in the design was formed to screen the received requirement results. Table 6 lists the hierarchy of mother and baby requirements and mentions the following retention.

The results of the investigation demonstrated that when using breastfeeding chairs, mothers were generally worried about the requirements of comfort, safety, hygiene, and breastfeeding support. Subsequently, the initial requirements for the breastfeeding chair design and program development were based on the 15 requirements of mothers and children. In the Kano questionnaire, these 15 requirements served as the initial requirements for mothers and children.

5.2. The division of mother and baby requirements

The Kano questionnaires were created based on 15 initial user requirements gathered in the survey. The survey was thorough and obtained data on a total of six stages, as listed in Table 7, to ensure that the surveyed mothers and infants spanned various stages of breastfeeding. At this stage, 260 Kano positive and negative question surveys were distributed, and 248 valid questionnaires were confirmed. Table 8 lists the mother and baby requirements for each attribute. The maximum value of each requirement was categorised based on the Kano attribute result analysis table.

The Kano model attribute analysis indicates that easy maintenance, Space saving, and easy installation are indifferent requirements that do not affect user satisfaction. Consequently, the subsequent procedure does not consider all three requirements of mothers and infants. The design must fulfil the four requirements of safety, hygiene, durability, and comfort; failure to do so would decrease mother and baby satisfaction. One-dimensional requirements include adjustable size, breastfeeding support, temporary storage, and aesthetic design. User delight can be enhanced by meeting these requirements as much as possible. Attractive requirements include charging ports, lumbar heating, soothing music, and emergency calls. While addressing these requirements can significantly increase user satisfaction, failing to fulfil them will not decrease satisfaction.

5.3. Weigh the requirements of the mother and baby

The AHP method was applied to quantitatively evaluate the weights of numerous facets that constitute the requirements of mothers and infants after the attributes were classified using the Kano model. Fig. 6 shows the hierarchical model of a breastfeeding chair in a maternity room. The must-be, one-dimensional, and attractive attributes served as indicators for constructing the criterion layer, and the requirements of the mother and child under each attribute served as sub-criterion layers.

The members of user requirements scoring represent the two dimensions of industrial design theory research and mother and child product practice design to guarantee the establishment of the judgment matrix and the reliability of the scoring structure and ensure that the evaluation can meet the requirements of both product practice and theoretical research. A description of different user requirements is presented before the assessment. The evaluation involved the participation of 13 experts in industrial design and mother-and-child product research. These experts included three professors conducting research on furniture theory, four mother and child product designers, two product managers in the field of mother and child product design, and four doctoral students studying product design. Pairwise comparisons and scoring were performed using a 1–9 scale approach based on the importance of each requirement level. The scale-scoring concept states that a judgment matrix is created by computing an average. Tables 9 and 10 list the results of the solution and the consistency ratio. The geometric average approach (root method) was used to solve [47] and ascertain the weight values of the user requirements.

According to the AHP calculation result, the weight of mother and baby requirements estimated from the consistency test is effective, with the matrix $CR \leq 0.1$. The weight of the must-be requirements was higher in the criterion layer, and the requirements of mothers and infants should be considered. Among the must-be requirements, the importance is ordered by safety, hygiene, comfort, and durability; among the one-dimensional requirements, it is ranked by breastfeeding support, adjustable size, temporary storage, and aesthetic design; and among the attractive requirements, it is ranked by charging ports, lumbar heating, soothing music, and emergency calls.

Because weight dimensions have different attributes, it is challenging to directly compare the weights of every requirement for mothers and infants after they have been defined. Therefore, to prioritise the requirements of mothers and infants, the weights of the criteria and sub-criterion layers were multiplied to determine the relative weight values of the requirements in the same dimension. Table 11 lists the relative weight rankings of mother and baby requirements.

Table 6
Summary of user requirements and mentions.

User requirement	Number of mention	Frequency proportion
Comfort	146	91 %
Safety	140	88 %
Hygiene	139	87 %
Breastfeeding support	134	84 %
Adjustable size	133	83 %
Aesthetic design	126	79 %
Charging ports	121	76 %
Temporary storage	115	72 %
Durability	114	71 %
Emergency calls	106	66 %
Space saving	101	63 %
Lumbar heating	94	59 %
Soothing music	91	57 %
Easy maintenance	85	53 %
Easy Installation	82	51 %

Table 7
Summary of the proportion of months of breastfeeding.

Month of breastfeeding	Number of questionnaire	Percentage of number
2–3 months	38	15 %
4–5 months	45	18 %
6–9 months	37	15 %
10–11 months	57	23 %
12–24 months	36	15 %
Over 24 months	35	14 %

Table 8
Kano user requirements attribute assessment summary.

Requirement attribute	I	Q	A	M	R	O	User requirement
Indifferent	98	25	41	35	17	32	Easy maintenance
	86	18	52	43	21	28	Space saving
	119	26	32	27	23	21	Easy installation
Must-be	15	26	37	127	10	33	Safety
	32	44	26	104	17	25	Hygiene
	39	27	52	93	14	23	Durability
	18	19	25	126	23	37	Comfort
One-dimensional	19	22	67	35	21	84	Adjustable size
	47	35	27	29	15	95	Breastfeeding support
	21	27	39	54	33	74	Temporary storage
	13	21	43	39	29	103	Aesthetic design
Attractive	21	38	92	39	43	15	Charging ports
	31	42	74	45	19	37	Lumbar heating
	19	39	85	27	34	44	Soothing music
	13	33	121	39	18	24	emergency calls

5.4. *Design functions derived from the requirements*

Following the AHP method's calculation of the relative weight of each mother's and child's requirements, this weight can be utilised as a single benchmark for analysing the significance of the design functions in later phases. To better comprehend user pain points and psychological expectations, it is necessary to describe requirements in terms of distinct maternal and infant requirements during the design generation process. For example, the "safety" in the requirements of mothers and infants can be considered the user's actual requirement for "safety during use". Through this process, we could better analyse the functional connections between maternal and infant requirements. Drawing on this information, five graduate students studying design conducted functional research and product analysis by seeking breastfeeding chair-related products in the market. The main user requirements were renamed, and the design functions were inferred with the guidance of researchers and furniture designers who were members of the AHP evaluation team. Table 12 lists design functions with high-importance evaluations that were selected to be effectively translated into matching functional requirements for breastfeeding chairs. Similar design functions are incorporated in the quality screening because some user requirements can be satisfied by a combination of different design functions.

Using the QFD theory, the House of Quality model is constructed based on the conversion result of the user requirement-design function [48]. A panel of specialists comprising five designers with experience in breastfeeding chair design and three engineers with more than five years of production experience in mother-and-child products was tasked with conducting a correlation evaluation. The correlation strength in the requirement function matrix was divided into three types: weak, medium, and strong. The three types are denoted by the symbols "△", "□", and "■", respectively, and have corresponding scores of 1, 3, and 5 points [49]. Table 13 lists the correlation results and is blank if there is no association.

The relative weights of the mother and baby requirements calculated above were added to the matrix to evaluate the design function scores more accurately and objectively, which in turn determined the relevance scores of the different design functions. The ultimate score of the design function is determined using a cumulative calculation that multiplies the relevance score by the associated column requirement weight. The scoring procedure using F_1 as an example is as follows:

$$F_1 = M_1 \times 5 + M_4 \times 3 + O_4 \times 1 \tag{7}$$

Following the computation of all the design function relevance scores, the design function was ranked and divided into three levels. Level 1 was assigned to the score range of 1–2, Level 2 to the range of 0.5–1, and Level 3 to the range of 0–0.5. The sorting results are listed in Table 14. The first- and second-level design functions, or the functions listed 1 through 13, are prioritised in the design of breastfeeding chairs for maternity rooms to increase user satisfaction [50].

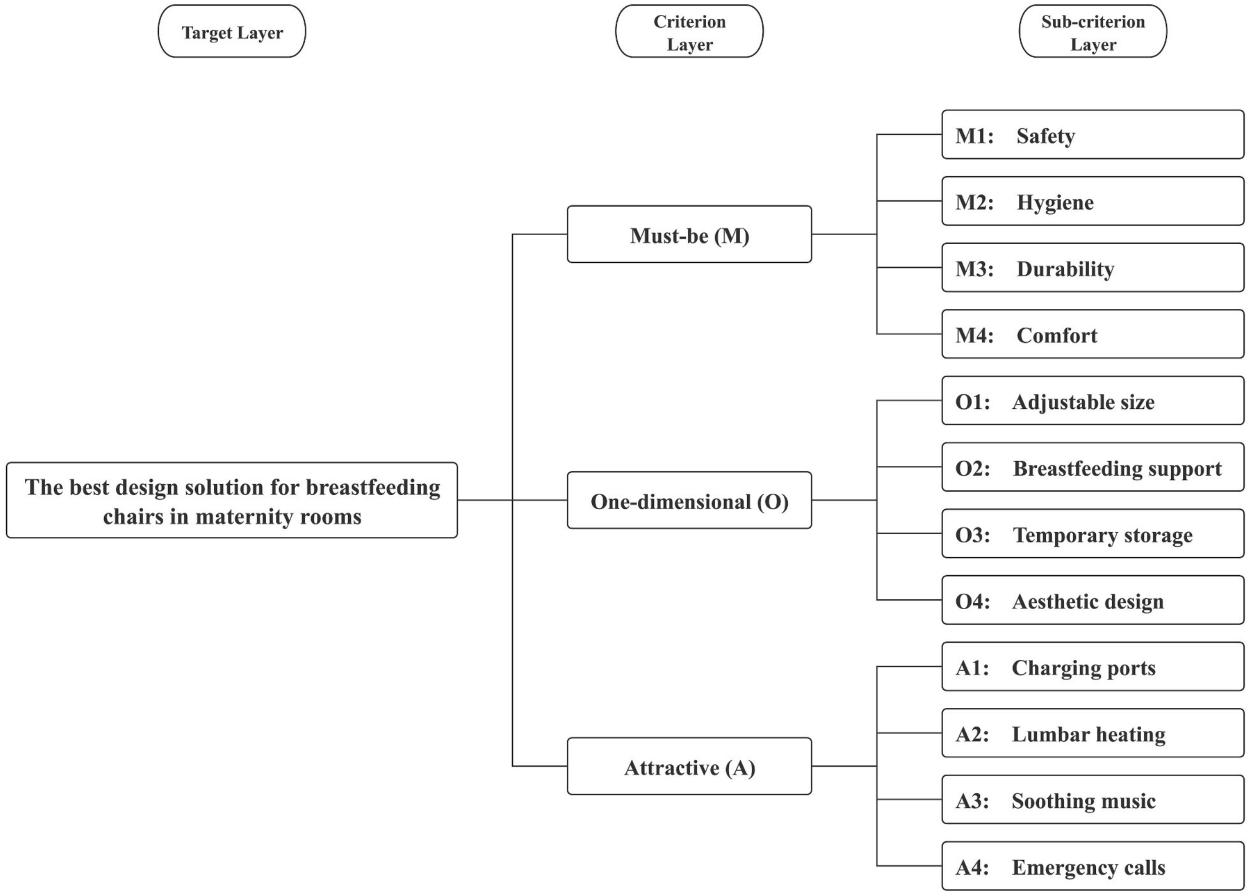

Fig. 6. Hierarchical model of breastfeeding chair design.

Table 9
Criterion layer weight assessment summary.

Criterion layer	Comparison matrix			Weight	*CR*
Must-be requirement	1	2	3	0.5396	0.0088
One-dimensional requirement	1/2	1	2	0.2970	
Attractive requirement	1/3	1/2	1	0.1634	

Table 10
Sub-criteria layer weight assessment summary.

Criterion layer	Sub-criterion layer	Comparison matrix				Weight	*CR*
Must-be requirement	M_1	1	2	4	2	0.4297	0.0304
	M_2	1/2	1	3	2	0.2827	
	M_3	1/4	1/3	1	1/3	0.0877	
	M_4	1/2	1/2	3	1	0.1999	
One-dimensional requirement	O_1	1	1/2	2	3	0.2776	0.0116
	O_2	2	1	3	4	0.4668	
	O_3	1/2	1/3	1	2	0.1603	
	O_4	1/3	1/4	1/2	1	0.0953	
Attractive requirement	A_1	1	2	5	3	0.4832	0.0054
	A_2	1/2	1	3	2	0.2717	
	A_3	1/5	1/3	1	1/2	0.0882	
	A_4	1/3	1/2	2	1	0.1569	

Table 11
User requirement relative weight ranking summary.

Requirement number	User requirement	Relative weight	Rank
M_1	Safety	0.2319	1
M_2	Hygiene	0.1525	2
O_2	Breastfeeding support	0.1386	3
M_4	Comfort	0.1079	4
O_1	Adjustable size	0.0824	5
A_1	Charging ports	0.0790	6
O_3	Temporary storage	0.0476	7
M_3	Durability	0.0473	8
A_2	Lumbar heating	0.0444	9
O_4	Aesthetic design	0.0283	10
A_4	Soothing music	0.0256	11
A_3	Emergency calls	0.0144	12

Table 12
Summary of user requirements translated into design functions.

User requirement	User requirement explained	Design function
M_1	Safety during use	Avoid sharp corners F_1
		Anti-slip treatment F_2
M_2	Easy to clean and disinfect	Anti-fouling surface materials F_3
M_3	Robust construction and materials	Solid material F_4
		Structurally sound and reasonable F_5
M_4	Comfortable user experience	Seat ergonomics F_6
		Cushion comfort F_7
O_1	Suitable for different body sizes	Adjustable size seat F_8
O_2	Supporting the body during breastfeeding	Seat ergonomics F_6
		Breastfeeding support structure F_9
O_3	Placement space for mother and child items	Storage space F_{10}
O_4	The product appearance is beautiful and coordinated	Structurally sound and reasonable F_5
		Harmonious proportions and curves F_{11}
A_1	Power charging function	Charging Socket F_{12}
A_2	Lumbar thermostatic heating function	Constant-temperature heating lumbar support F_{13}
A_3	Music playback function	Integrated Speaker F_{14}
A_4	Emergency calls to staff	Emergency call button F_{15}

Table 13
Quality house model score assessment summary.

User requirement		Design function														
Requirement	Weight	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
M_1	0.2319	■	■	□	□	□		△		△		△				△
M_2	0.1525			■								□				
M_3	0.0473				■	■						△				
M_4	0.1079	□	△	△			■	■	□	■	□		□	□	△	
O_1	0.0824						□		■							
O_2	0.1386				△	□	■	□	△	■				△		
O_3	0.0476										■					
O_4	0.0283	△				△	△					■				
A_1	0.0790												■			
A_2	0.0444													■		
A_3	0.0144														■	
A_4	0.0256															■

5.5. Design function guides conceptual design

Based on the QFD calculations of highly relevant design functions, the design should primarily consider the first- and second-level design functions. Specifically, anti-fouling surface materials, avoid sharp corners, seat ergonomics, breastfeeding support structures, and other design functions. We chose to modify the design of the breastfeeding chair using the design in the maternity room of the Tianjie shopping centre, which is the largest area close to the research institution, to enable better data measurement and comparative experimentation. Numerous individuals pass through this area, and the research team can easily conduct controlled investigations due to the breastfeeding chairs in the maternity rooms, which are frequently used and close to the research institution. Fig. 7 shows the selected samples.

Table 14
Design function weight ranking summary.

Priority	Design function	Score	Rank
First level	Anti-fouling surface materials F_3	1.57	1
	Avoid sharp corners F_1	1.51	2
	Seat ergonomics F_6	1.51	3
	Breastfeeding support structure F_9	1.46	4
	Structurally sound and reasonable F_5	1.38	5
	Anti-slip treatment F_2	1.27	6
	Cushion comfort F_7	1.19	7
	Solid material F_4	1.07	8
Second level	Harmonious proportions and curves F_{11}	0.88	9
	Adjustable size seat F_8	0.87	10
	Charging Socket F_{12}	0.72	11
	Constant-temperature heating lumbar support F_{13}	0.68	12
	Storage space F_{10}	0.56	13
Third level	Emergency call button F_{15}	0.36	14
	Integrated Speaker F_{14}	0.18	15

The current design of breastfeeding chairs has the basic functionality for breastfeeding; however, it fails to support the waist or legs, which makes it difficult to nurse for extended periods of time. Moreover, the fabric used in these chairs is easily stained, which lowers its hygiene in a public shopping centre setting where a lot of people frequent. Therefore, as shown in Figs. 8 and 9, the conceptual improvement design scheme of the breastfeeding chair in the maternity rooms was implemented in accordance with the aforementioned design function requirements. The specific product design scheme is as follows.

1) Anti-fouling surface materials: The breastfeeding chair's surface is made of PU leather that has been coated with anti-fouling film. This material offers superior comfort, improved waterproof, anti-fouling, and anti-ageing qualities.
2) Avoid sharp corners: The chair design uses an arc treatment to minimize unintentional bumps and scratches during breastfeeding.
3) Seat ergonomics: Ergonomic dimensions were considered when designing the chair. Sizes overall: 110 cm high, 70 cm broad, and 72 cm deep. The dimensions of the seat are 50 cm deep, 66 cm wide, and 41 cm high [51].
4) Breastfeeding support structure: Provide a breastfeeding support cushion and footstool to offer excellent support during the cradle, cross, and football breastfeeding positions.
5) Structurally sound and reasonable: A suitable chair angle was chosen to guarantee the stability of the force, and the chair shell was built using an integrated moulding technique to maintain the integrity of the breastfeeding chair construction.
6) Anti-slip treatment: To prevent slipping, raise the material's friction level at the support and add more braided material above the footrest.
7) Cushion comfort: The interior of the cushion is filled with a high-density sponge to ensure better cushioning and comfort.
8) Solid material: The ABS material used to make the shell has the benefits of being inexpensive, strong, and resistant to heat.

Fig. 7. Improved design prototype for a breastfeeding chair.

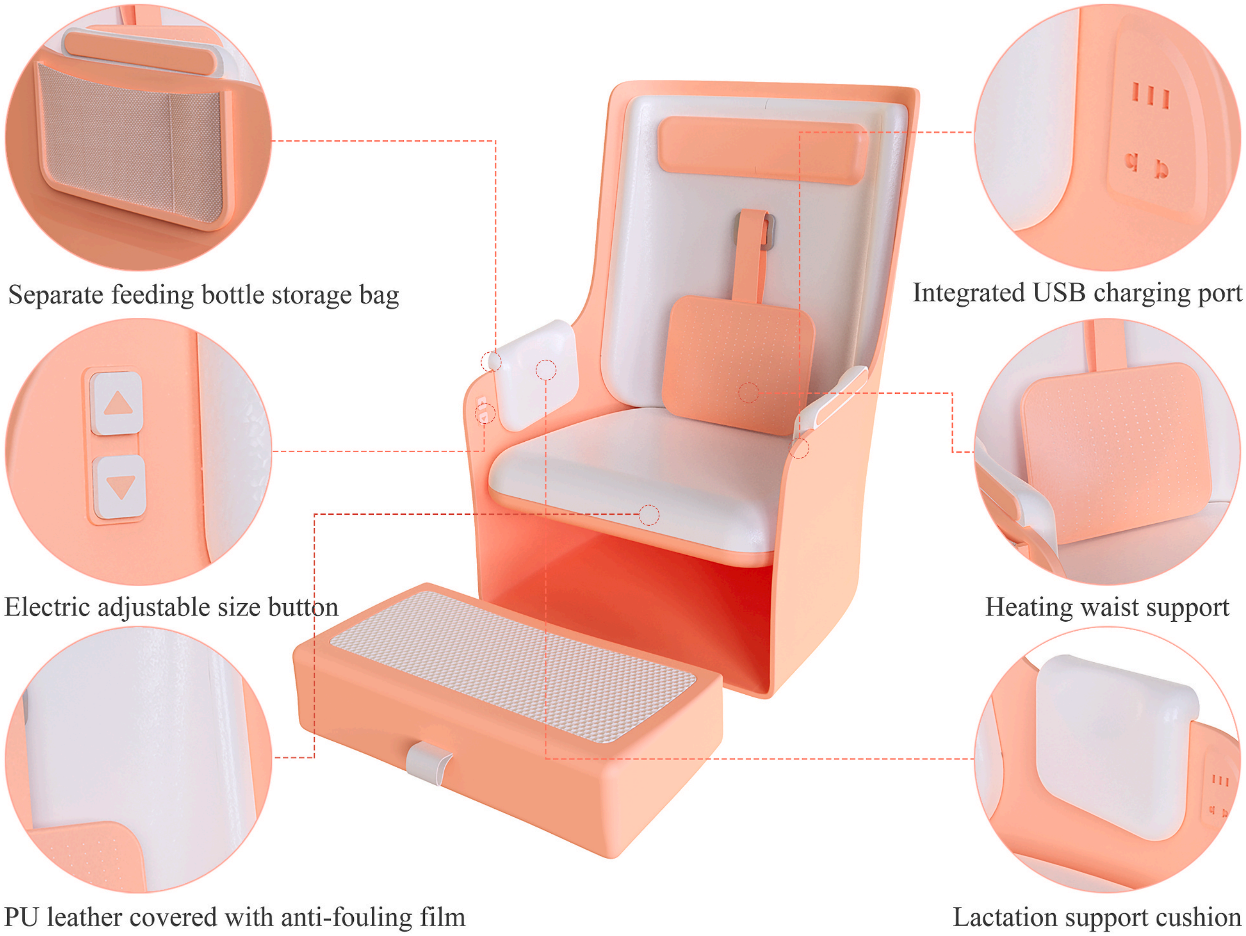

Fig. 8. Breastfeeding chair conceptual design.

9) Harmonious proportions and curves: Warm, gentle pink hues have a calming psychological effect on people, and bezier curves are created in Rhino software to guarantee smooth and well-coordinated curves [52].
10) Adjustable size seat: By pressing a button, the integrated electric lifting structure may raise and modify the chair's angle to accommodate users of varying sizes.
11) Charging Socket: A USB interface is incorporated into the armrest, and multiple jacks are available to accommodate the charging requirements of devices like cell phones, breast pumps, and milk warmers.
12) Constant-temperature heating lumbar support: The waist maintains a steady temperature. In winter, hot compresses help relieve discomfort in a sedentary mother and increases body warmth during breastfeeding.
13) Storage space: Arrange a multipurpose hanging bag that can be used to hold other baby and maternal items, bottles, and infant garments during breastfeeding.

As shown in Fig. 8, the conceptual design of the breastfeeding chair places a separate feeding bottle storage bag on the right side of the mother for easy access to nursing items at any time. The chair is equipped with an electric adjustable size button, allowing the mother to adjust the height of the seat as needed during breastfeeding to accommodate mothers of different body types. The surface of the chair is covered with PU leather and an anti-fouling film, ensuring durability and ease of cleaning even in high-traffic areas. Additionally, an integrated USB charging port is located on the inside, facilitating the charging of nursing items and electronic devices. Moreover, the chair is equipped with a heating waist support and a lactation support cushion, providing a comfortable and stable nursing experience for the mother.

5.6. Analysis of breastfeeding chair design satisfaction

The verification of the satisfaction of mothers and infants with the design function followed a conceptual design, and this verification was necessary to assess the feasibility of the study approach. Therefore, a fuzzy comprehensive assessment method was employed to create a questionnaire for assessing user demand satisfaction. Fig. 10 shows Sample B, the original breastfeeding chair in

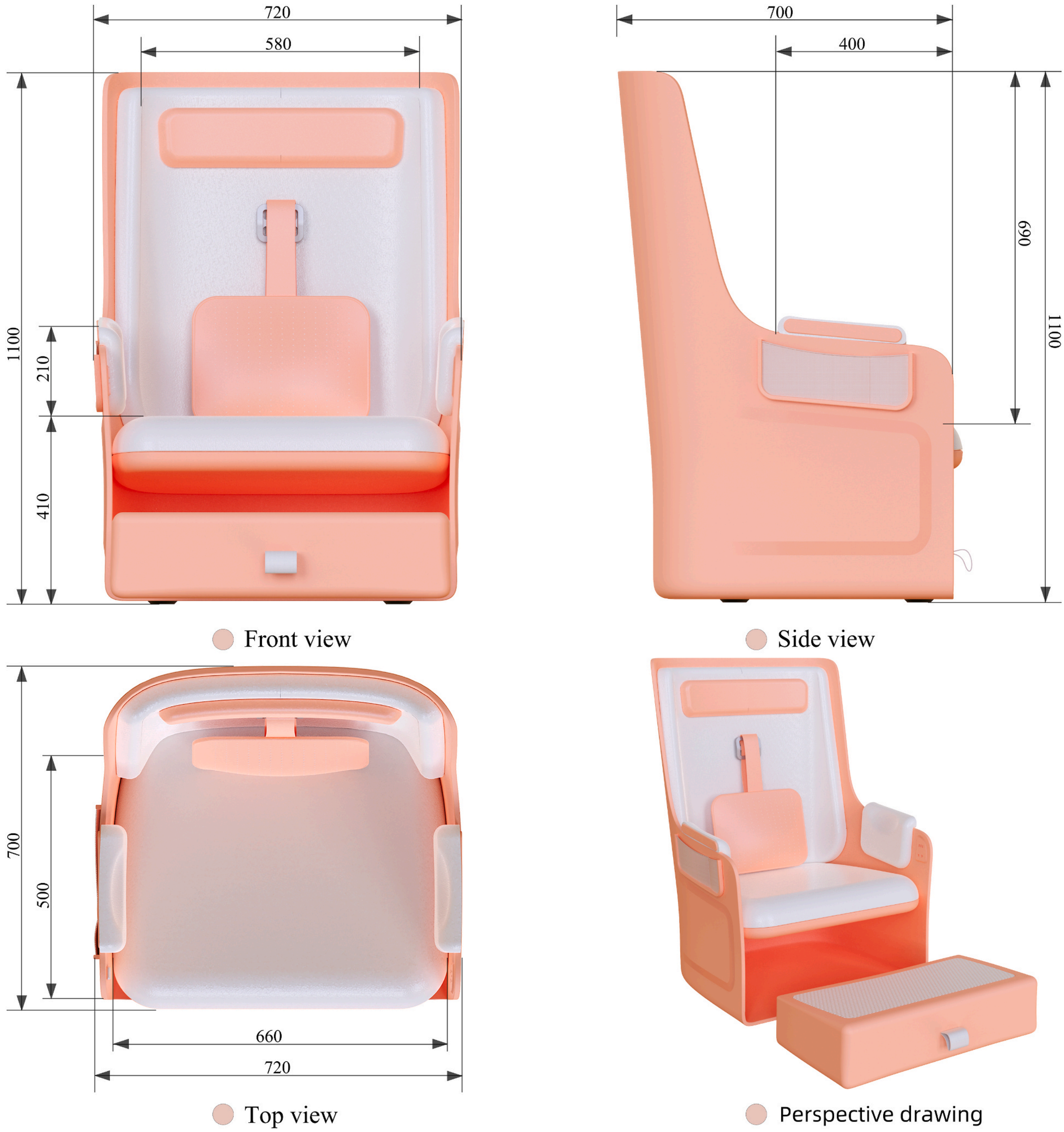

Fig. 9. Breastfeeding chair concept design: three views.

the maternity rooms, which corresponds to the enhanced conceptual design scheme of Sample A in the survey questionnaire.

The research team interviewed people using breastfeeding chairs in the maternity room of the Tianjie shopping centre, Sample B. They evaluated the user requirement indicators and offered their thoughts. Users who have used Sample B of the breastfeeding chair more than three times were asked to rate both Samples A and B together to assess the validity of the functional requirements and ensure the reliability of the mothers' evaluations [53].

Mothers completed 15 questionnaires, and five were sent to designers of products for mothers and babies. According to the survey results, T_1 denotes very like (90–100 points), T_2 denotes like (75–90 points), T_3 denotes normal (60–75 points), and T_4 denotes dislike (0–60 points). Table 15 lists the results of the normalisation of the final vote of each scheme.

T_1, T_2, T_3, and T_4 in the evaluation set were assigned 10, 8, 6, and 4 points, respectively, to calculate the fuzzy comprehensive evaluation value for each scheme. Subsequently, using a bounded operator, the relative weights of each index listed in Table 15 were

Fig. 10. Design scheme and sample selection of a breastfeeding chair.

multiplied and accumulated with the normalised result matrix of Sample A. Consider Sample A's calculation method as an example. T_1 had a very like set of comments, meaning that its score ranged from 90 to 100 points. Sample A very like score of 7.907 [54] was computed using the following method:

$$T_1 = 10(M_1 \times 0.85 + M_2 \times 0.8 + M_3 \times 0.85 + \ldots + A_4 \times 0) \quad (8)$$

A final comprehensive value of 9.350 was obtained by multiplying the fuzzy comprehensive evaluation value with the Sample A assignment score. Fig. 11 shows this result. Similarly, Sample B had a score of 7.572. Consequently, design scheme A > B in the ranking of scheme scores, and user satisfaction increased by 23 % over the original scheme. It can be concluded that a breastfeeding chair

Table 15
Summary of the vote normalisation results.

User requirement	Relative weight	Sample A				Sample B			
		T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
M_1	0.2319	0.850	0.150	–	–	0.750	0.200	0.050	–
M_2	0.1525	0.800	0.200	–	–	0.350	0.550	0.100	–
M_3	0.0473	0.850	0.150	–	–	0.500	0.350	0.150	–
M_4	0.1079	0.800	0.150	0.050	–	0.700	0.300	–	–
O_1	0.0824	0.800	0.050	0.100	0.050	0.650	0.350	–	–
O_2	0.1386	0.900	0.100	–	–	–	0.150	0.600	0.250
O_3	0.0476	0.700	0.100	0.150	0.050	–	–	–	1.000
O_4	0.0283	0.650	0.300	0.050	–	0.450	0.350	0.150	0.050
A_1	0.0790	0.850	0.150	–	–	–	–	–	1.000
A_2	0.0444	0.800	0.200	–	–	–	–	0.200	0.800
A_3	0.0144	–	–	–	1.000	–	–	–	1.000
A_4	0.0256	–	–	–	1.000	–	–	–	1.000

created using this approach can address issues and satisfy the requirements of mothers and their infants.

In conclusion, we can obtain the following results.

1) Mothers are generally concerned about the requirements for comfort, safety, hygiene, and breastfeeding support in breastfeeding chairs. According to the Kano model attribute analysis, easy maintenance, space saving, and easy installation were found to not affect user satisfaction in breastfeeding chair design. Although the inclusion of requirements such as comfort, durability, hygiene, and safety does not increase user happiness, its absence dramatically reduces user happiness. It can increase user happiness by satisfying the requirements for breastfeeding support, adjustable size, temporary storage, and aesthetic design, and vice versa. Although satisfying requirements such as emergency calls, lumbar heating, soothing music, and charging ports can significantly boost user happiness, failing to meet similar requirements does not have the opposite effect.
2) The weight calculation of the AHP method indicated that safety, hygiene, breastfeeding support, and comfort were user requirements with a higher relative weight priority. These requirements are strongly related to the primary factors determining how well mothers and infants breastfeed. Prioritising high-weight requirements in the design can help increase user satisfaction.
3) Design functions with higher scores had a better correlation with the requirements of mothers and baby users, as determined by deriving the design functions using QFD. Breastfeeding mothers and their infants can be more effectively satisfied by design functions, such as anti-fouling surface materials, avoid sharp corners, seat ergonomics, and breastfeeding support structures, to encourage breastfeeding among women and their children and establish a comfortable setting for all parties.

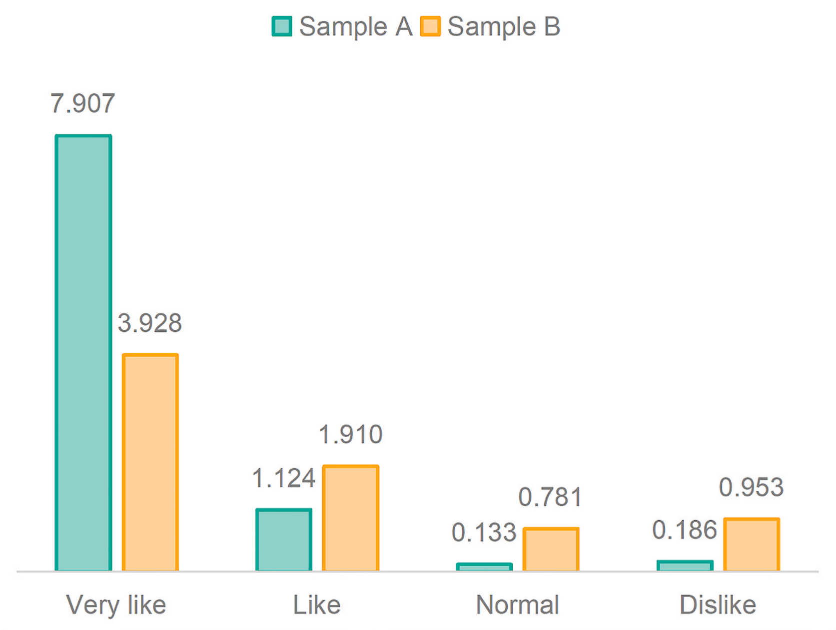

Fig. 11. Fuzzy comprehensive evaluation value of breastfeeding chair design.

6. Conclusions

This study proposes an approach for designing breastfeeding chairs for maternity rooms based on the Kano-AHP-QFD theory. Through an analysis of user requirements, this approach identifies critical requirements that should be incorporated into design functions. It also successfully raised the user satisfaction levels for breastfeeding chairs in maternity rooms by 23 %. We can identify the major variables influencing the breastfeeding experience using this design method and precisely determine the functions and weight values necessary for the design of breastfeeding chairs in maternity rooms. It is an advantageous practical guide for the next mother-child-friendly product design and has significant theoretical value for defining mother-child-friendly product design standards.

However, there are still some limitations in practical research. (1) The privacy issues of maternal and infant requirements increase the difficulty of the research, limiting the breadth and depth of the data; (2) existing design practices lack a detailed study on human body data and the range of motion of breastfeeding mothers, which may limit the design's ergonomic adaptability; and (3) research has mainly focused on breastfeeding chairs rather than the optimisation of the environment of the entire maternity room, and there is a lack of analysis of the relationship between other factors and the satisfaction of mothers and babies.

Therefore, future research could explore the following directions: (1) raising public awareness of the importance of mother and baby products and enhancing privacy protection, (2) conducting more ergonomic research on breastfeeding women to develop more appropriate mother and baby products, and (3) expanding the scope of the study to include the entire environmental design of the maternity rooms to optimise the room layout and environmental factors.

Ethical statement

Ethical review and approval were not required for the study on human participants in accordance with local legislation and institutional requirements.

Human experiments

Identifies the institutional and/or licensing committee that approved the experiments, including any relevant details. Confirms that all experiments were performed in accordance with relevant guidelines and regulations. Confirms that informed consent was obtained from all participants. All of the experimental procedures involving humans were conducted in accordance with the institutional guidelines of Guangxi Arts University, China.

Data availability statement

The data underlying this article cannot be shared publicly due to the privacy of the individuals that participated in the study. The data will be shared, on reasonable request, with the corresponding author.

CRediT authorship contribution statement

Zhizheng Liu: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Chi Zhang:** Investigation. **Xiran Ji:** Software. **Xinyue Yi:** Writing – review & editing. **Jian Yao:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Appendix A. Supplementary data

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