Kansei-Driven Redesign of Luohan Beds Using an Integrated LDA–GRA–AHP–QFD Approach

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To address contemporary users' Kansei requirements for traditional Luohan beds and adapt traditional furniture to modern lifestyles, this study proposes a redesign method integrating Kansei Engineering (KE), Latent Dirichlet Allocation (LDA), Grey Relational Analysis (GRA), the Analytic Hierarchy Process (AHP), and Quality Function Deployment (QFD). LDA was applied to cleaned online user reviews to identify six Kansei requirement categories: Luxurious and Gorgeous, Traditional Chinese Classical, Elegant and Literati-Refined, Zen-Inspired Serene, Minimalist and Plain, and Exquisite Craftsmanship. The Minimalist and Plain and Traditional Chinese Classical categories received greater user attention. Next, 40 representative samples were selected from 89 Luohan beds and decomposed into seven design attributes, yielding a coding system comprising 149 morphological features. GRA was then used to identify the morphological features strongly associated with each Kansei requirement, while AHP was employed to determine their importance weights. These results were integrated into a QFD House of Quality (HoQ) to prioritize key combinations of morphological features for redesign. The resulting design was preliminarily evaluated by experts and users in terms of Kansei matching and design feasibility. The integrated LDA–GRA–AHP–QFD approach effectively translates natural-language user reviews into weighted Kansei requirements and subsequently into actionable morphological features of design attributes.

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INTRODUCTION

The Luohan bed is a representative type of furniture with multiple functional attributes within the traditional Chinese furniture system. It is neither a single-purpose bed nor an ordinary seat; rather, it integrates practical, ritual, and spatial functions by accommodating activities such as sitting, lying, reclining, receiving guests, appreciating objects, and displaying objects. In traditional Chinese interiors, the Luohan bed was commonly placed in halls, studies, or inner rooms. It served not only as a piece of furniture for daily rest but also as an artifact that contributed to the organization of spatial order, bodily posture, and ritual relationships. Its three-sided railings, front and side aprons supporting the bed platform, waist, legs, and broad, flat bed platform collectively constitute the morphological characteristics that distinguish it from chairs, couches, conventional beds, and modern sofas. Wang (1986) systematically classified Ming- and Qing-dynasty furniture and demonstrated that Chinese classical furniture should not be understood as a

collection of isolated objects but rather as an artifact system closely associated with traditional patterns of living, structural craftsmanship, and aesthetic order. Handler (2001) similarly argued that the typological significance of Chinese classical furniture should be understood in relation to bodily posture, patterns of use, and spatial relationships.

However, as the Luohan bed has entered contemporary living environments, its original functional, spatial, and aesthetic relationships have undergone substantial changes. Modern living rooms, studies, and tea rooms place greater emphasis on furniture scale, ease of use, spatial adaptability, and visual lightness. The substantial volume, enclosed configuration, and display-oriented character of traditional Luohan beds constitute distinctive cultural identifiers, yet these characteristics may also limit their compatibility with contemporary residential environments. Clunas (1997) noted that the meaning of furniture derives not only from its materials, craftsmanship, and form but also from its position within interior displays, modes of viewing, and contexts of use. Therefore, the contemporary transformation of the Luohan bed should not be limited to the reproduction of traditional formal symbols; rather, it should also account for contemporary usage scenarios, spatial relationships, and user perceptions.

In recent years, several studies have examined the morphological characteristics and Kansei evaluation of Luohan beds. Liu *et al.* (2021) investigated the relationship between morphological design attributes and perceptual imagery in Ming-style Luohan beds, demonstrating that variations in design attributes can influence users' Kansei perceptions of traditional furniture. So and Bang (2024) analyzed the structural forms, decorative characteristics, and materials of 57 Qing-dynasty Luohan bed specimens, demonstrating that Qing-dynasty Luohan beds placed greater emphasis on screen-like enclosures, decorative expression, and morphological order. Chen and Guan (2025) further introduced Kansei Engineering (KE) into the study of Ming-style Luohan beds and explored approaches to Kansei prediction and its application to furniture design. Collectively, these studies provide an important foundation for the morphological analysis, typological understanding, and Kansei evaluation of Luohan beds. Meanwhile, research on the contemporary redesign of traditional furniture has advanced in areas such as form generation, cultural-symbol extraction, Kansei evaluation, and intelligent optimization. Nevertheless, existing studies have rarely established an integrated framework connecting users' natural-language expressions of Kansei requirements, component-level morphological coding of design attributes, and subsequent design translation. In particular, insufficient attention has been paid to how Kansei requirements can be systematically mapped onto the component-level morphological coding of design attributes of Luohan beds, including the front railing, side railing, front apron, side apron, waist, legs, and bed platform.

In current design practice, many Luohan bed redesigns seek to achieve a "Neo-Chinese" aesthetic primarily through pattern simplification, material substitution, or localized proportional adjustments. Although such approaches can reduce the visual heaviness of traditional furniture to some extent, they often remain at the level of surface styling. Users' requirements for Luohan beds are not limited to functional considerations, such as suitability for sitting or lying and physical comfort; they also encompass integrated perceptions of cultural imagery, visual order, spatial atmosphere, craftsmanship, and aesthetic style. Therefore, the contemporary redesign of Luohan beds should begin with users' Kansei requirements and establish systematic relationships between these Kansei requirements and specific design attributes.

KE provides a suitable theoretical and methodological basis for addressing this issue. Nagamachi (1995) defined KE as a consumer-oriented product development technology whose core objective is to translate users' feelings, impressions, and preferences toward a product into concrete design elements. Schütte *et al.* (2004) further demonstrated that KE can systematically translate users' subjective perceptions and requirements into product properties and design parameters. For Luohan beds, which combine distinctive cultural characteristics with a complex component structure, KE can facilitate the identification of users' affective perceptions of traditional furniture while providing a methodological framework for design attribute identification, form optimization, and design translation.

At the same time, the development of e-commerce platforms and social media has enabled large volumes of user-generated evaluations to be recorded in natural-language form. These online reviews capture users' spontaneous expressions when viewing, purchasing, and using products. Compared with traditional questionnaires based on researcher-defined evaluation vocabularies, online reviews can provide a complementary data source for identifying Kansei requirements spontaneously expressed by users. Mudambi and Schuff (2010) noted that online reviews can provide consumers with diagnostic product information. Decker and Trusov (2010) demonstrated that online product reviews can be used to estimate consumers' preferences regarding product attributes. Archak *et al.* (2011) further showed that textual reviews can reveal the influence of product features on consumers' product evaluations. In the context of Luohan beds, expressions such as "Chinese style," "classical," "minimalist," "Zen-inspired," and "exquisite craftsmanship" provide an empirical basis for extracting Kansei requirements from naturally occurring user-generated content.

Accordingly, the present study develops a user-driven redesign method for Luohan beds within the KE framework by integrating Latent Dirichlet Allocation (LDA), Grey Relational Analysis (GRA), the Analytic Hierarchy Process (AHP), and Quality Function Deployment (QFD) to translate users' Kansei requirements into design strategies based on specific design attributes and their component forms. First, online user reviews of Luohan beds are collected, and LDA is applied to identify and extract Kansei requirements from the review corpus. Second, representative Luohan bed samples are collected and screened, and their forms are decomposed into seven design attributes—front railing, side railing, front apron, side apron, waist, leg, and bed platform. The morphological variations of each design attribute are then classified and coded to establish a component-level morphological coding system. Third, GRA is used to quantify the relationships between the component forms of each design attribute and the Kansei requirements, thereby identifying component forms that are strongly associated with specific Kansei requirements. AHP is then employed to construct a hierarchical structure of Kansei requirements and determine their relative importance weights through expert pairwise comparisons. Finally, the identified component forms and the importance weights of the Kansei requirements are incorporated into the QFD House of Quality (HoQ) to establish systematic mappings between Kansei requirements and design attributes, determine key component-form combinations and design priorities, and develop a corresponding Luohan bed redesign proposal.

The main contributions of this study are as follows:

1) User-driven extraction of Kansei requirements. Online user reviews are introduced as a data source for deriving Kansei requirements from users' spontaneous natural-language expressions, thereby reducing reliance on predefined Kansei words or expert-defined evaluation vocabularies.

2) Component-based morphological representation of design attributes. Luohan beds are decomposed into seven component-level design attributes, and the morphological variations of each design attribute are systematically classified and coded. This representation transforms the overall furniture form into analyzable design attributes and component forms, enabling explicit relationships between Kansei requirements and specific component forms to be identified.

3) Integrated quantitative redesign framework. LDA, GRA, AHP, and QFD are integrated into a continuous process of Kansei requirement extraction, component-form association analysis, Kansei requirement weighting, and design-priority translation, providing a quantitative methodological framework for the contemporary redesign of Luohan beds.

LITERATURE REVIEW

Kansei Engineering and User-oriented Furniture Design

KE is a user-oriented design methodology centered on users' perceptions, emotional responses, and psychological needs. Its fundamental aim is to translate users' subjective impressions, emotional experiences, and aesthetic preferences regarding a product into identifiable, analyzable, and applicable design information. Nagamachi (1995) defined KE as a consumer-oriented product development technology, emphasizing the systematic translation of users' feelings and impressions of a product into concrete design elements. Schütte *et al.* (2004) further indicated that KE can systematically relate users' subjective perceptions and requirements to product properties and design parameters, thereby supporting design decision-making. Compared with conventional design approaches that primarily emphasize function, structure, or craftsmanship, KE places greater emphasis on users' integrated perceptual and emotional experiences, including aesthetic judgments, cultural associations, experiences of use, and emotional responses. In furniture design, therefore, KE provides a methodological basis for relating users' Kansei perceptions to design attributes such as form, material, color, proportion, decoration, and structural configuration, thereby supporting user-oriented design decisions.

In recent years, the application of KE in furniture design research has continued to expand, with research objects extending from general furniture products to more specific categories, including traditional Chinese furniture, rosewood furniture, Neo-Chinese furniture, children's furniture, and elderly-oriented furniture. Lin *et al.* (2024) conducted perceptual semantic experiments on Ming-style, Qing-style, and modern Chinese-style solid wood furniture to compare users' affective responses to different furniture styles. They further decomposed furniture forms into morphological elements and established relationships between these elements and users' affective responses, demonstrating that differences in furniture style and morphological characteristics can significantly influence user perception. Lei *et al.* (2024) combined KE with psychological and physiological measurement techniques in a study of Ming-style chairs. Representative Kansei words and typical furniture samples were selected for perceptual evaluation, demonstrating the potential of multisource perceptual data for analyzing users' responses to traditional furniture forms. Hao and Guan (2025) applied KE to the evaluation of furniture for children's consultation spaces, focusing on children's aesthetic and emotional preferences regarding furniture forms. Yang *et al.* (2025) integrated KE with deep learning methods to investigate users' emotional responses and the optimization of traditional Chinese Jiaoyi

(folding chair) form design. Collectively, these studies demonstrate that KE is applicable not only to the affective evaluation of furniture products but also to the identification of Kansei requirements across specific user groups and furniture categories.

In the transformation of traditional cultural elements, KE has increasingly been employed to investigate the relationships among cultural symbols, form elements, and user perceptions. Jing *et al.* (2024) combined KE with shape grammar to explore the innovative application of diagonal-ridge elements derived from classical Suzhou-style architecture to furniture design. Through Kansei word screening, perceptual evaluation, and factor analysis, they identified representative cultural imagery and translated it into furniture design alternatives. Wang *et al.* (2025) examined the translation of cultural symbols and user perceptions in Neo-Chinese furniture, emphasizing that contemporary Chinese-style furniture design should not only preserve recognizable cultural symbols and aesthetic characteristics but also enhance user experience and emotional resonance. These studies suggest that the contemporary transformation of traditional furniture should extend beyond the direct transplantation of cultural symbols or the reproduction of decorative motifs. More importantly, it should consider whether the cultural meanings conveyed through these design features can be effectively perceived, understood, and accepted by contemporary users.

In terms of user requirement translation and design decision-making, KE has increasingly been integrated with GRA, AHP, QFD, fuzzy theory, machine learning, and intelligent optimization methods to improve the systematic and actionable nature of the design process. Fu *et al.* (2024) integrated KE with hesitant fuzzy QFD in rosewood furniture design to translate consumer requirements into engineering characteristics, thereby supporting systematic design decision-making oriented toward users' affective needs. Zhou *et al.* (2023) combined GRA with KE to investigate the relationships between users' Kansei perceptions and the morphological characteristics of electric recliner chairs, providing a quantitative approach to furniture form analysis and optimization. Lee *et al.* (2023) integrated KE with fuzzy theory to examine the relationships among Kansei-related design attributes, user requirements, and perceptual evaluations in the form design of Taiwanese wooden seating furniture. Liu and Luo (2025) developed an SD–FA–QFD methodological framework for the redesign of Ming-style warped tables, extracting users' Kansei requirements and translating them into design priorities for key furniture components. Collectively, these studies demonstrate a broader methodological shift in furniture-related KE research from standalone Kansei evaluation toward integrated frameworks that connect user perceptions and requirements with product forms and subsequent design decisions.

Overall, existing studies have demonstrated the applicability of KE to furniture design, with an increasing tendency to integrate it with physiological measurement, shape grammar, GRA, QFD, fuzzy theory, machine learning, and other computational methods. However, two research gaps remain particularly relevant to the contemporary redesign of traditional furniture with complex component structures, such as the Luohan bed. First, many existing studies obtain Kansei information through predefined Kansei words, expert input, or structured perceptual evaluation, whereas users' spontaneous natural-language expressions derived from real-world consumption and use contexts remain comparatively underexplored as a source for identifying Kansei requirements. Second, previous studies have frequently examined overall furniture forms, style imagery, or morphological elements, while the systematic relationships between users' Kansei requirements and specific component forms have received comparatively limited attention. This issue is

particularly important for Luohan beds because their overall morphological expression is jointly determined by multiple design attributes, including the front railing, side railing, front apron, side apron, waist, leg, and bed platform. To address these gaps, the present study adopts KE as its theoretical framework and integrates LDA, GRA, AHP, and QFD to establish a continuous process encompassing the extraction of Kansei requirements from users' natural-language reviews, the morphological coding and screening of component forms, the analysis of relationships between Kansei requirements and component forms, and the translation of these relationships into design priorities, thereby supporting the user-oriented redesign of Luohan beds.

User Need Mining and LDA Topic Modeling

In user-oriented design research, accurately identifying user needs is a fundamental prerequisite for product positioning, design decision-making, and scheme optimization. Traditional KE studies usually obtain users' Kansei requirements through questionnaires, user interviews, expert evaluation, or the semantic differential method. Although these approaches facilitate the formation of structured data, the evaluation dimensions are often predefined by researchers and are therefore susceptible to subjective experience, sample selection, and Kansei vocabulary screening. For products with complex cultural semantics and multi-level perceptual characteristics, relying solely on predefined vocabularies or expert judgment may fail to fully capture users' natural expressions in real use contexts.

With the development of e-commerce platforms, social media, and online review systems, users generate large amounts of natural-language text during product viewing, purchasing, and use. These user-generated contents record consumers' direct evaluations of product form, function, material, quality, cultural imagery, and use experience, and have gradually become an important data source for product need mining and design improvement. Existing studies have shown that online reviews can reveal consumers' preferences and value judgments regarding product attributes, and can be used for user need identification, satisfaction analysis, and design optimization (Decker and Trusov 2010; Archak *et al.* 2011). In recent years, online reviews have been widely applied to product need identification, satisfaction analysis, and design optimization. Zhang *et al.* (2023) combined text mining with the Kano model to identify and classify user needs from initial and follow-up reviews, showing that online reviews can help researchers capture dynamic user needs and changes in satisfaction. Miao *et al.* (2023) used consumer online reviews as data sources and combined text analysis with LDA topic modeling to explore the role of user reviews in supporting product design strategy optimization. Cheng *et al.* (2025) further systematically integrated online reviews into the product design improvement process, indicating that user reviews can support not only need identification but also scheme generation and design decision-making.

LDA, proposed by Blei *et al.* (2003), is a classical unsupervised topic model. It represents a document collection as a probabilistic mixture of multiple latent topics and identifies latent semantic structures in texts through word co-occurrence relationships. Compared with simple high-frequency word statistics, LDA is more suitable for processing unstructured texts, such as online reviews, which are large in scale, dispersed in expression, and semantically overlapping. For product design research, LDA can extract latent concerns from users' natural-language expressions, helping researchers identify user need themes and providing a data basis for subsequent need classification, design positioning, and scheme optimization.

In the field of product design, LDA has been used for user review mining, customer need identification, and design element translation. Huang *et al.* (2022) combined the LDA topic model with interval grey QFD and proposed an LDA–IGQFD method to extract customer needs and market competition information from online reviews and further translate them into engineering characteristics for new product development. The study indicates that LDA not only can extract review topics, but it also can be integrated with design methods, such as QFD, to realize the translation from user needs to product design elements. Wang *et al.* (2023) combined LDA, LightGBM, and QFD to construct a data-driven product specification recommendation and optimization process, further demonstrating that topic models can work together with machine learning and QFD to support product decision-making. Yang *et al.* (2024) used LDA to analyze online reviews in eco-innovative product design, extracting user needs related to environmental functions, appearance, human–computer interaction, and service experience, and further integrating TRIZ and KE for design innovation. These studies show that LDA can serve as a front-end tool for user need mining in the early stage of product design and can be combined with KE, QFD, TRIZ, and machine learning to form a more complete design transformation process.

However, LDA primarily identifies latent semantic topics within user-generated text and does not directly quantify the strength of relationships between Kansei requirements and specific component forms. Therefore, additional methods are required to analyze these relationships and translate the resulting insights into actionable design decisions. In product design research, LDA is thus more appropriately positioned as a front-end tool for user requirement mining rather than as a standalone method for translating user requirements into specific design attributes or component forms.

For traditional furniture with strong cultural characteristics, such as the Luohan bed, user requirements expressed in online reviews may encompass not only functional concerns related to practicality, comfort, and durability but also Kansei perceptions associated with cultural imagery, aesthetic atmosphere, and craftsmanship. Such perceptions may be expressed through terms such as “Chinese style,” “classical,” “elegant,” “Zen-inspired,” “plain,” and “exquisite craftsmanship.” Reliance solely on predefined Kansei words may therefore constrain the identification of spontaneous and context-dependent expressions found in naturally occurring user-generated content. Accordingly, within the KE framework, the present study employs LDA to identify latent semantic topics from online user reviews of Luohan beds. These topics are subsequently interpreted and consolidated into representative Kansei requirements, which serve as inputs for GRA-based analysis of relationships between Kansei requirements and component forms and subsequent QFD-based design translation. In this way, the study establishes a continuous research process encompassing natural-language user requirement identification, Kansei requirement formulation, component-form association analysis, and design-priority translation.

GRA, AHP, and QFD in Product Design Translation

Once users’ Kansei requirements have been identified, product design research needs to establish systematic relationships between these requirements and specific design attributes and their component forms. For traditional furniture, overall product form is typically composed of multiple design attributes, each of which may exhibit several morphological variations. If all component forms are directly incorporated into the design translation process, the number of design variables may become excessive, resulting in an

overly complex relationship matrix and making it difficult to identify the component forms most relevant to users' Kansei requirements. Therefore, prior to QFD-based design translation, it is necessary to evaluate the relationships between Kansei requirements and component forms and identify those with stronger associations.

GRA originates from grey system theory and is suitable for evaluating relationships in systems characterized by limited data, multiple factors, and incomplete information. Deng (1989) proposed that, when system information is insufficient or relationships among factors are uncertain, their relational degrees can be evaluated by comparing the geometric similarity or proximity of data sequences. Compared with statistical correlation methods that generally rely on stronger assumptions regarding sample size and data distributions, GRA can evaluate the relative relational degrees among factors under limited-data conditions. It has therefore been applied to design evaluation, design variable screening, and multi-criteria decision-making. In the present study, GRA is used to quantify the relational degrees between Kansei requirements and the component forms associated with different design attributes, thereby identifying component forms that are strongly associated with specific Kansei requirements for subsequent design translation.

AHP proposed by Wind and Saaty (1980), is a multi-criteria decision-making method that integrates qualitative judgments with quantitative analysis. It decomposes a complex decision problem into a hierarchical structure and uses pairwise comparisons to construct judgment matrices from which the relative weights of evaluation criteria are derived. Consistency analysis is subsequently performed to assess the logical coherence of the pairwise judgments. In product design research, AHP has been widely used to determine the relative importance of user requirements, design attributes, and engineering characteristics, thereby providing a quantitative basis for design decision-making (Kwong and Bai 2002). In the present study, AHP is specifically employed to determine the relative importance weights of the identified Kansei requirements.

QFD provides a systematic mechanism for translating customer requirements into technical or engineering characteristics and subsequently prioritizing design actions. Govers (1996) noted that QFD is fundamentally customer-oriented and employs a matrix-based structure to connect customer requirements, technical characteristics, and design decisions. Subsequent studies have integrated QFD with multi-criteria decision-making, fuzzy theory, and grey system methods to improve customer requirement weighting, relationship evaluation, and the prioritization of engineering characteristics (Karsak *et al.* 2003; Karsak 2004).

In recent years, the integration of GRA and QFD has been increasingly applied to product form design, user requirement translation, and multi-criteria design decision-making. Wang and Yang (2023), for example, combined GRA with fuzzy QFD in the design and development of wickerwork lamps. Their approach employed GRA to evaluate relationships among relevant design factors and subsequently incorporated the evaluation results into a fuzzy QFD framework to support product design decision-making. Related studies have further demonstrated the potential of grey-system-based approaches to improve the quantitative evaluation of relationships between customer requirements and technical or design characteristics, thereby supporting more systematic product design translation.

AHP has also been widely integrated with QFD to support requirement weighting and design prioritization. In their review of QFD research, Chan and Wu (2002) identified AHP as an important multi-criteria decision-making approach used in conjunction with QFD to support the weighting and prioritization of customer requirements and technical

characteristics. By structuring expert judgments through pairwise comparisons and consistency analysis, AHP provides a systematic means of deriving relative importance weights for subsequent QFD analysis. More recent integrated AHP–QFD studies have extended this approach to diverse user-oriented design contexts. Kürüm Varolgüneş *et al.* (2021), for example, applied AHP and QFD to thermal hotel design, linking weighted customer requirements with relevant design criteria through the HoQ. Bao *et al.* (2025) proposed an integrated GT–Kano–AHP–QFD framework for the sustainable design of parent–child interactive seating in urban children's parks, illustrating the potential of multi-method integration for complex user requirement analysis and design decision-making. Fan and Wang (2025) similarly applied an AHP–QFD approach to sustainable gift packaging design to quantify customer requirement weights and identify priority design characteristics.

Meanwhile, methodological extensions of conventional QFD have focused particularly on addressing uncertainty in expert judgments, the fuzziness of linguistic evaluations, and the robustness of technical-characteristic prioritization. Han *et al.* (2023), for example, developed a QFD approach incorporating multi-granular unbalanced linguistic information and a consensus-reaching process to improve relationship evaluation. Wang *et al.* (2023) incorporated social network analysis and interval-valued 2-tuple Pythagorean fuzzy linguistic information into QFD to support the prioritization of engineering characteristics. Shi *et al.* (2024) employed an entropy-weighted fuzzy QFD approach to improve the translation of customer requirements into technical characteristics for remanufactured products. Mao *et al.* (2025) further integrated linguistic distribution assessment with the CRITIC method to enhance relationship evaluation and the prioritization of engineering characteristics. Collectively, these studies demonstrate an ongoing shift toward more robust and uncertainty-aware QFD models for complex design decision-making.

The application of QFD has also expanded to intelligent product design and increasingly complex user requirement scenarios. Liang *et al.* (2024) incorporated customer evaluation, competitive learning, and cost-related considerations into a QFD-based framework for intelligent product design, while Zhu and Husin (2025) proposed a multidimensional requirement-oriented QFD approach to reduce the complexity of relationship matrices in scenarios involving heterogeneous user requirements. Overall, QFD has evolved beyond the use of a single HoQ matrix toward an integrative design decision framework capable of incorporating user requirements, multidimensional evaluations, technical or design characteristics, and prioritization mechanisms. The integration of GRA can further support this process by providing quantitative relational information before design translation and prioritization.

Overall, existing studies indicate that GRA, AHP, and QFD can perform complementary functions within product design translation. GRA can quantify relational degrees between user requirements and product-related variables under conditions involving multiple factors and limited information; AHP can determine the relative importance weights of user requirements; and QFD can integrate requirement importance and relationship information to establish a structured pathway from user requirements to design priorities. In the present study, these methodological roles are specifically adapted to the component-based redesign of Luohan beds. GRA is first employed to evaluate the relational degrees between the six identified Kansei requirements and the component forms associated with the seven design attributes, thereby identifying component forms with stronger associations with specific Kansei requirements. AHP is subsequently used to

determine the relative importance weights of the six Kansei requirements. Finally, the GRA-derived relational information and AHP-derived Kansei requirement weights are incorporated into the HoQ to determine the relative priorities of component forms and identify key component-form combinations. Through this integrated process, users' Kansei requirements are systematically translated into actionable design priorities for the redesign of Luohan beds.

EXPERIMENTAL

Research Framework

This study adopts KE as its theoretical foundation and takes the Luohan bed as the research object to develop a systematic redesign process integrating LDA, GRA, AHP, and QFD. The overall research process follows the sequence of natural-language user requirement mining–component-level morphological coding–component-form association analysis and screening–Kansei requirement weighting–QFD-based design translation–redesign generation and evaluation. The aim is to identify Kansei requirements from users' natural-language reviews and systematically translate them into specific component forms and design priorities for the redesign of Luohan beds. The overall research framework is illustrated in Fig. 1, and the specific steps are described as follows:

(1) *Extraction of users' Kansei requirements*. Within the KE framework, online user reviews related to Luohan beds are collected through web crawling and subjected to text preprocessing, including text cleaning, word segmentation, and stop-word removal. LDA is then employed to identify latent semantic topics within the review corpus. Based on the representative words and semantic characteristics of the extracted topics, the topics are interpreted and consolidated into six Kansei requirements: Luxurious and Gorgeous Style, Traditional Chinese Classical Style, Elegant and Literati-Refined Style, Zen-Inspired Serene Style, Minimalist and Plain Style, and Exquisite Craftsmanship Style. These Kansei requirements serve as the user-side inputs for subsequent component-form association analysis, requirement weighting, and design translation.

(2) *Luohan bed sample screening and morphological coding of design attributes*. Luohan bed image samples are collected and screened according to sample completeness, morphological representativeness, and component identifiability, resulting in 40 representative samples. Based on the structural composition and morphological characteristics of Luohan beds, each sample is decomposed into seven design attributes: front railing, side railing, front apron, side apron, waist, leg, and bed platform. The morphological variations of each design attribute are subsequently classified and coded to establish a component-level morphological coding system, thereby transforming the overall furniture form into analyzable design attributes and component forms.

(3) *Component-form association analysis and screening*. GRA is employed to quantify the relational degrees between the component forms associated with the seven design attributes and the six Kansei requirements. This analysis addresses the large number of coded component forms and provides a quantitative basis for identifying those that are more strongly associated with users' Kansei requirements. The component forms are ranked and screened according to their grey relational grades (γ), and those exhibiting stronger associations with the Kansei requirements are retained. The selected component forms subsequently serve as the product-side inputs for QFD-based design translation.

(4) *Kansei requirement weighting and QFD-based design translation*. AHP is employed to construct a hierarchical model of the six Kansei requirements. Expert pairwise comparisons are used to establish judgment matrices and determine the relative importance weights of the Kansei requirements, followed by consistency analysis to assess the logical coherence of the pairwise judgments. Subsequently, QFD is used to construct the HoQ, in which the six Kansei requirements and their AHP-derived importance weights constitute the customer requirement inputs, while the highly associated component forms identified through GRA constitute the corresponding product-side characteristics. The GRA-derived relational information is incorporated into the relationship matrix of the HoQ. By integrating the importance weights of the Kansei requirements with the relational degrees between Kansei requirements and component forms, the absolute and relative priorities of the component forms are calculated, thereby identifying key component-form combinations and design priorities for the redesign of Luohan beds.

(5) *Redesign generation and evaluation*. Based on the QFD-derived component-form priorities and key component-form combinations, a Luohan bed redesign proposal is developed and subsequently evaluated by experts and target users. A total of 35 participants are recruited, including five furniture design professionals and 30 target users. A 10-point Likert scale is used to evaluate the redesign proposal with respect to the six Kansei requirements, morphological rationality, and design feasibility. The evaluation results are used to assess whether the proposed redesign effectively reflects the identified Kansei requirements and whether the prioritized component forms can support the intended morphological expression of the Luohan bed. The results also provide empirical evidence for evaluating the effectiveness of the proposed LDA–GRA–AHP–QFD integrated redesign framework.

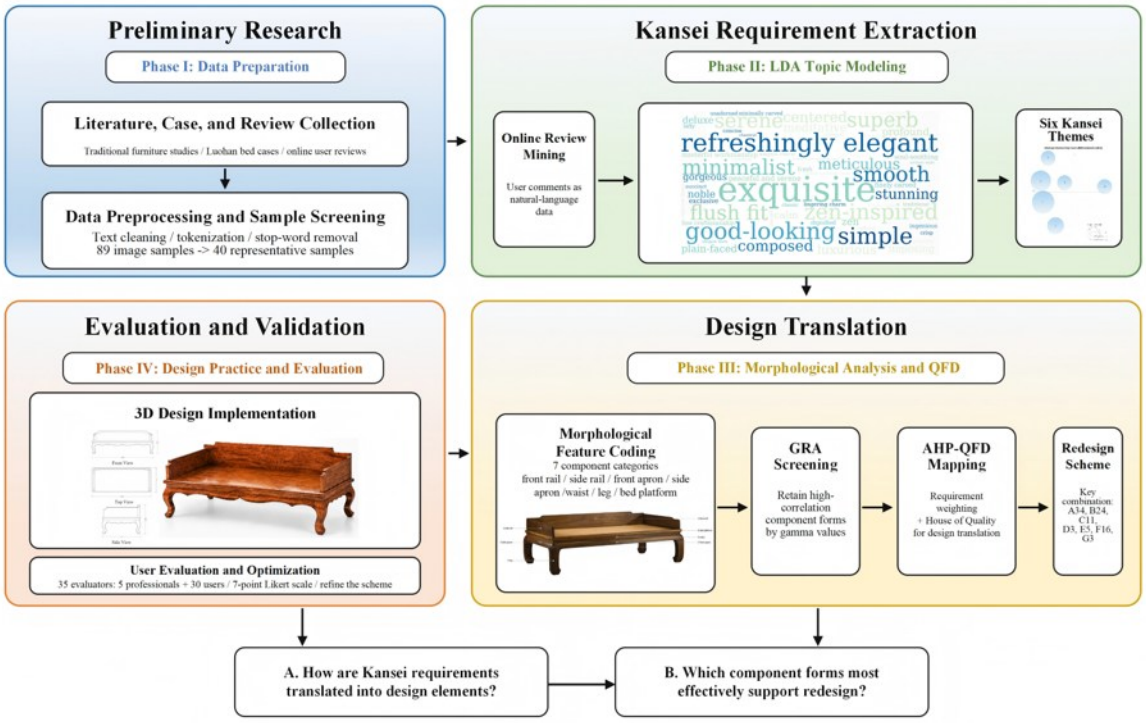


Fig. 1. Design framework

Data Collection

Text data collection

To obtain contemporary users' perceptions of and requirement expressions for Luohan beds, this study used "Luohan bed" and "Chinese-style Luohan bed" as search keywords to collect user review data from Taobao, furniture brand websites, social media comments, and other relevant online texts. The collected texts mainly covered users' evaluations of Luohan beds in terms of form style, use function, spatial adaptability, material and color, decorative details, cultural imagery, and purchase preferences.

The data were collected from December 2025 to February 2026. In the initial collection stage, a total of 18,759 raw text entries were obtained. Because online texts contained duplicate reviews, advertising statements, invalid characters, logistics-related comments, price discussions, and content weakly related to the design features of Luohan beds, the research team cleaned and screened the raw texts. The specific preprocessing procedures included removing characters with no semantic contribution, duplicate sentence segments, and invalid texts; using the jieba word segmentation tool for Chinese word segmentation and correcting the segmentation results according to Luohan bed-related professional terms; removing common function words, conjunctions, and modal particles based on a stop-word list; and retaining only one text entry with complete expression and clear design-related information when highly repetitive or semantically similar comments were identified.

After cleaning, deduplication, and manual review, 14,538 valid text entries were finally obtained. The processed text data were used for subsequent LDA topic modeling, providing the data basis for extracting user Kansei requirement themes for Luohan beds.

Luohan Beds Sample Collection

To establish the basis for analyzing the morphological features of Luohan beds, this study further collected image samples of Luohan beds. The samples were mainly obtained from professional publications on traditional furniture, such as *Research on Ming-style Furniture* and *Illustrated Handbook of Chinese Classical Furniture*, publicly available image resources released by institutions such as the Palace Museum, furniture brand websites, product images from e-commerce platforms, auction records, and other relevant online image materials.

In the initial collection stage, 89 image samples of Luohan beds were obtained, as shown in Fig. 2. To reduce the influence of image background, color differences, and presentation styles on subsequent morphological analysis, the research team first removed duplicate images, images with incomplete subjects, and images with obvious color interference. Photoshop was then used for background weakening, unified cropping, size adjustment, and numbering to form a relatively consistent image sample set. The image processing was used only to standardize visual presentation and did not alter the main contour, component proportions, or decorative features of the Luohan beds.

To improve the rigor of sample screening and ensure adequate morphological coverage, an expert consensus procedure was employed. Eight experts participated in the screening process, including three university professors specializing in Chinese classical furniture design and craftsmanship, three senior furniture designers, and two industry practitioners with experience in the traditional furniture market. Based on the objectives of the morphological analysis, four screening criteria were established: structural integrity, image quality, morphological diversity, and completeness of component information. Each expert independently evaluated the candidate samples according to these criteria. A sample

was retained when at least 75% of the experts (*i.e.*, at least six of eight) considered it eligible. Samples for which the experts did not initially reach sufficient agreement were subsequently reviewed through panel discussion until a final consensus was reached.



Fig. 2. Initial image samples of Luohan beds

The specific screening criteria were as follows: (1) the main structure of the Luohan bed was sufficiently complete to allow clear identification of the seven design attributes, including the front railing, side railing, front apron, side apron, waist, leg, and bed platform; (2) image quality was sufficient to distinguish morphological proportions, component boundaries, structural details, and decorative features; (3) the candidate sample set exhibited sufficient morphological diversity in terms of railing forms, apron forms, leg forms, decorative characteristics, and overall proportions; and (4) samples exhibiting substantial morphological duplication, severe occlusion, obvious perspective distortion, or incomplete structural information were excluded.

Following independent expert evaluation, panel discussion, and final review by the research team, 40 representative Luohan bed samples were retained for subsequent morphological analysis, as shown in Fig. 3. The screening process focused primarily on structural characteristics, proportional relationships, and decorative forms, while color was excluded as a screening criterion to minimize the influence of chromatic differences on the subsequent analysis of morphological characteristics. The final sample set encompassed a diverse range of morphological configurations, including plain, framed, openwork-carved, screen-style, three-sided enclosed, and simplified modern forms. These samples provide morphological coverage of both traditional Luohan bed forms and their contemporary transformations and constitute the sample basis for the subsequent decomposition and

coding of design attributes and their component forms, as well as the GRA-based analysis of relationships between component forms and Kansei requirements.



Fig. 3. Selected representative samples of Luohan beds

LDA-Based Kansei Requirement Extraction for Luohan Beds

Determination of the optimal number of topics

Based on the cleaned user review corpus, LDA was employed to identify latent semantic topics related to users' perceptions and evaluations of Luohan beds. Because the number of topics must be specified prior to model estimation, the selection of the topic number should not rely solely on subjective judgment. If the number of topics is too small, semantically distinct user concerns related to form, style, craftsmanship, material, and spatial atmosphere may be merged into overly broad topics. Conversely, an excessively large number of topics may fragment semantically related content into multiple overlapping topics, reducing topic distinctiveness and interpretability and complicating the subsequent formulation of Kansei requirements. Therefore, LDA models with different numbers of topics were iteratively estimated and compared. The final topic number was determined by jointly considering model perplexity, topic coherence, and semantic interpretability, thereby balancing statistical model performance with the meaningful interpretation of the extracted topics in the context of Luohan bed design.

Perplexity measures how well the model fits the textual data. In general, a lower perplexity indicates a better representation of the latent topic structure. It is calculated as follows,

$$\text{Perplexity}(D) = \exp\left\{-\frac{\sum_{d=1}^{M} \log P\,(W_d)}{\sum_{d=1}^{M} N_d}\right\} \quad (1)$$

where D denotes the test text set, M denotes the number of test documents, W_d denotes the set of terms in the d-th document, $P(W_d)$ denotes the probability of the model generating this document, and N_d denotes the number of terms in the d-th document.

To avoid potential bias caused by relying solely on perplexity, the topic coherence metric C_V was also introduced to evaluate the semantic consistency among keywords within each topic. This metric primarily assesses the co-occurrence and semantic associations among keywords belonging to the same topic and can be expressed as,

$$C_V = \frac{2}{M(M-1)} \sum_{m<n} \log \frac{P(w_m, w_n) + \varepsilon}{P(w_m)P(w_n)} \quad (2)$$

where M is the number of keywords selected for each topic; w_m and w_n are keywords within the same topic; $P(w_m, w_n)$ denotes their co-occurrence probability; $P(w_m)$ and $P(w_n)$ denote their individual occurrence probabilities; and ε is a smoothing constant. In general, a higher C_V value indicates stronger semantic consistency among keywords within a topic and greater topic stability.

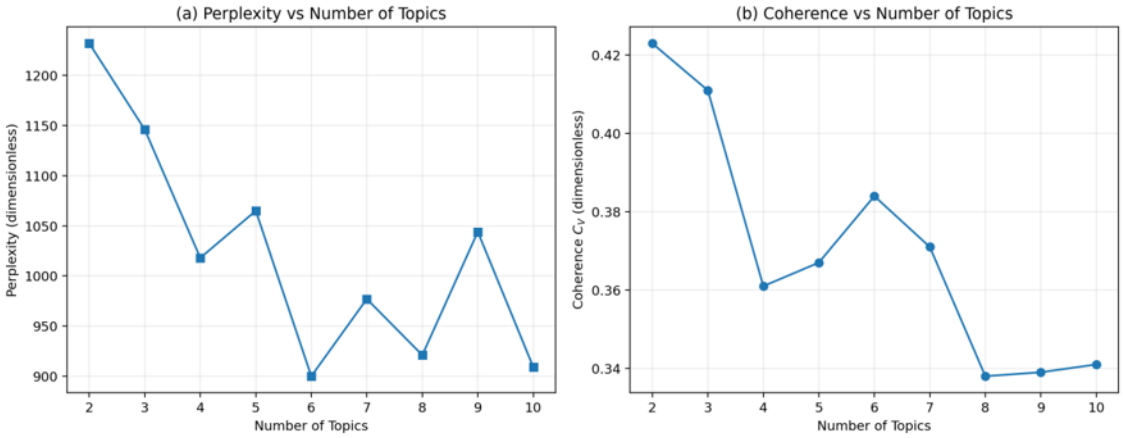


Fig. 4. Perplexity and coherence scores of the LDA model with different numbers of topics

The LDA model was estimated with the number of topics ranging from $K = 2$ to $K = 10$, and the corresponding variations in perplexity and topic coherence were compared, as shown in Fig. 4. As illustrated in Fig. 4(a), perplexity generally decreased as the number of topics increased, with a particularly pronounced decline from $K = 2$ to $K = 4$. Within the tested range, perplexity reached its minimum at $K = 6$. Beyond $K = 6$, the perplexity values fluctuated rather than showing a consistent further decrease, suggesting that increasing the number of topics did not provide a clear improvement in model fit.

As shown in Fig. 4(b), the C_V coherence scores were relatively high at $K = 2$ and $K = 3$. However, manual examination of the corresponding topic-word distributions indicated that these low-dimensional solutions merged several semantically distinct aspects of users' perceptions, including traditional Chinese style, literati refinement, Zen-inspired serenity, minimalist aesthetics, and craftsmanship. At $K = 6$, the C_V coherence score increased markedly compared with $K = 4$ and $K = 5$ and reached a local maximum. More importantly, examination of the representative words associated with each topic indicated that the six-topic solution provided comparatively distinct and interpretable semantic boundaries. When K was increased beyond 6, topic coherence generally declined, accompanied by greater semantic overlap or fragmentation among the extracted topics.

Considering model perplexity, C_V coherence, and semantic interpretability together, K = 6 was therefore selected as the final topic number for the LDA model.

Topic Visualization and Kansei Requirement Interpretation

After determining the final topic number (K = 6), pyLDAvis was used to visualize the LDA results. As shown in Fig. 5, the intertopic distance map represents topic prevalence by circle size and intertopic dissimilarity by the distance between circles. Fig. 6 presents the distribution of high-frequency terms in the review corpus, providing supplementary information for interpreting the extracted topics and subsequently formulating the Kansei requirements.

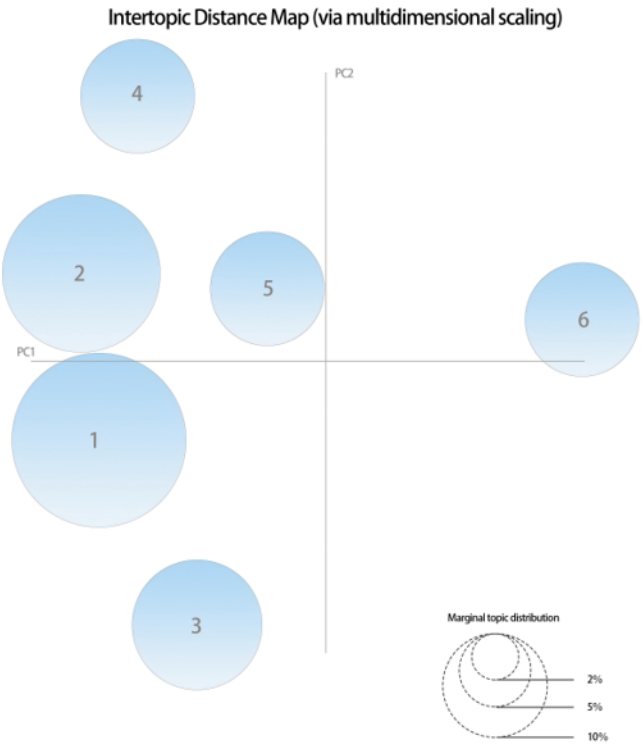


Fig. 5. Intertopic distance map of the LDA model

As shown in the intertopic distance map, the six topics exhibit a relatively distinct distribution in the two-dimensional semantic space, with limited overall overlap, indicating a reasonable degree of differentiation among the identified topics. Some topics are positioned relatively close to one another, suggesting partial semantic similarity in users' descriptions of Chinese-style characteristics, traditional imagery, minimalist forms, and craftsmanship. In contrast, the relatively isolated topics represent more distinct semantic dimensions associated with Kansei requirements, such as a Zen-inspired atmosphere, a luxurious aesthetic, and craftsmanship-related perceptions. The high-probability terms displayed on the right, including *Chinese-style*, *practical*, *minimalist*, *aesthetic*, *exquisite*, *traditional*, and *refined*, show relatively high salience across the topic model. Overall, the topic distribution and associated high-probability terms suggest that users' evaluations of Luohan beds encompass multiple perceptual dimensions, including traditional Chinese cultural characteristics, practical functionality, simplicity of form, aesthetic qualities, craftsmanship, and traditional imagery.

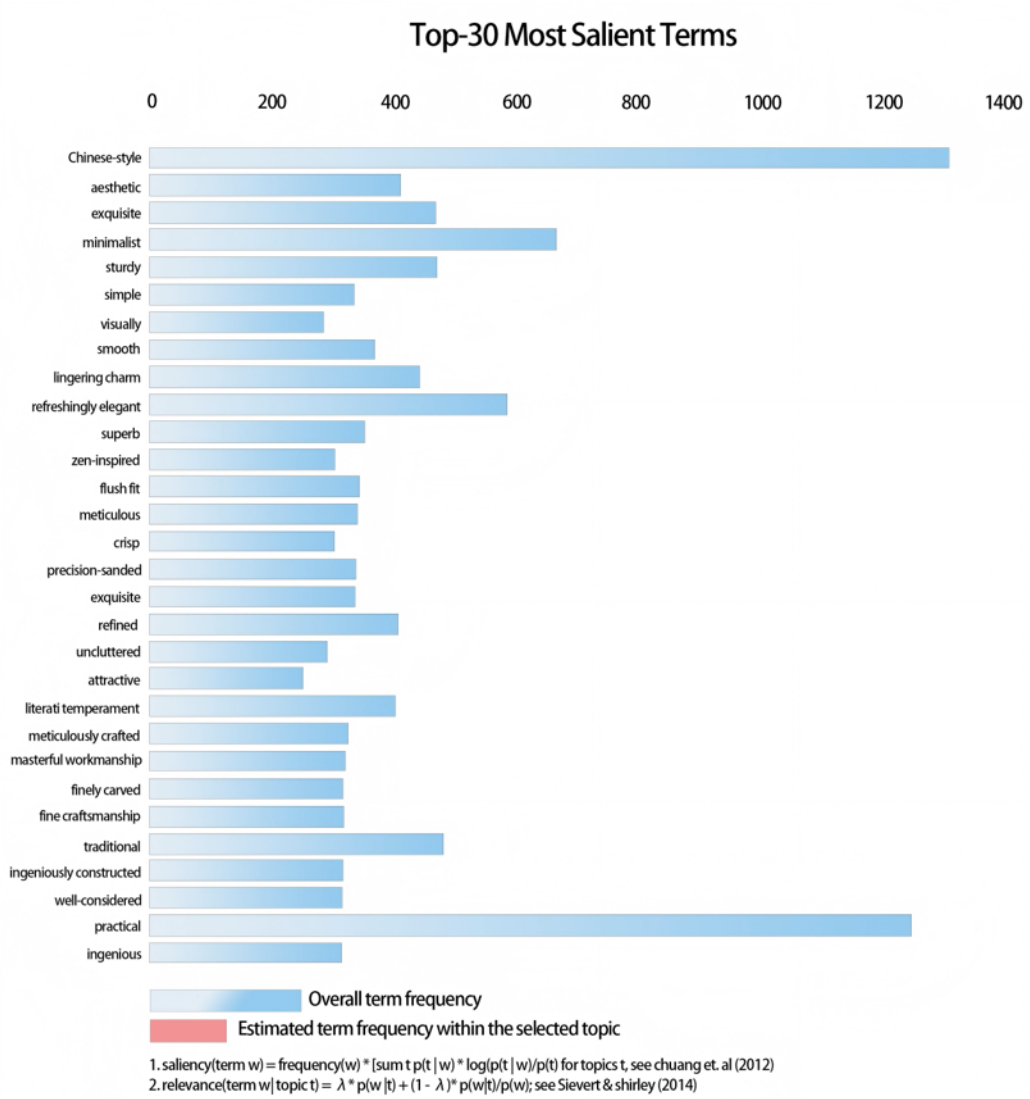


Fig. 6. Distribution of the top 30 most salient terms in the LDA model

Because the high-probability terms generated by LDA include not only Kansei words reflecting users' subjective perceptions but also functional terms, product-component terms, and noise, further screening was conducted during topic interpretation by considering both term probabilities and the semantic contexts of the original reviews. Priority was given to Kansei words reflecting stylistic imagery, aesthetic evaluation, cultural perception, user experience, and craftsmanship, such as *Chinese-style*, *classical*, *refined*, *Zen-inspired*, *minimalist*, and *exquisite*. Terms describing functional perceptions with explicit experiential implications, such as *comfortable*, *stable*, and *safe*, were also retained. In contrast, component-related terms, general descriptive terms, and non-design-related terms without explicit Kansei implications, such as *accessories*, *track*, *appear*, *contact*, and *time*, were excluded. Semantically similar Kansei words were subsequently interpreted and consolidated according to their contexts in the original reviews to reduce semantic redundancy and improve the interpretability of the identified Kansei requirements.

The Kansei word cloud generated based on the above screening criteria is shown in Fig. 7. The most prominent Kansei words are primarily associated with semantic dimensions such as *Chinese-style*, *classical*, *refined*, *Zen-inspired*, *minimalist*, and

craftsmanship. These results indicate that users' Kansei requirements for Luohan beds extend beyond preferences for visual appearance and encompass multiple dimensions, including perceptions of traditional Chinese cultural characteristics, aesthetic qualities, simplicity of form, user experience, and craftsmanship.



Fig. 7. Word cloud of screened Kansei words from Luohan bed reviews

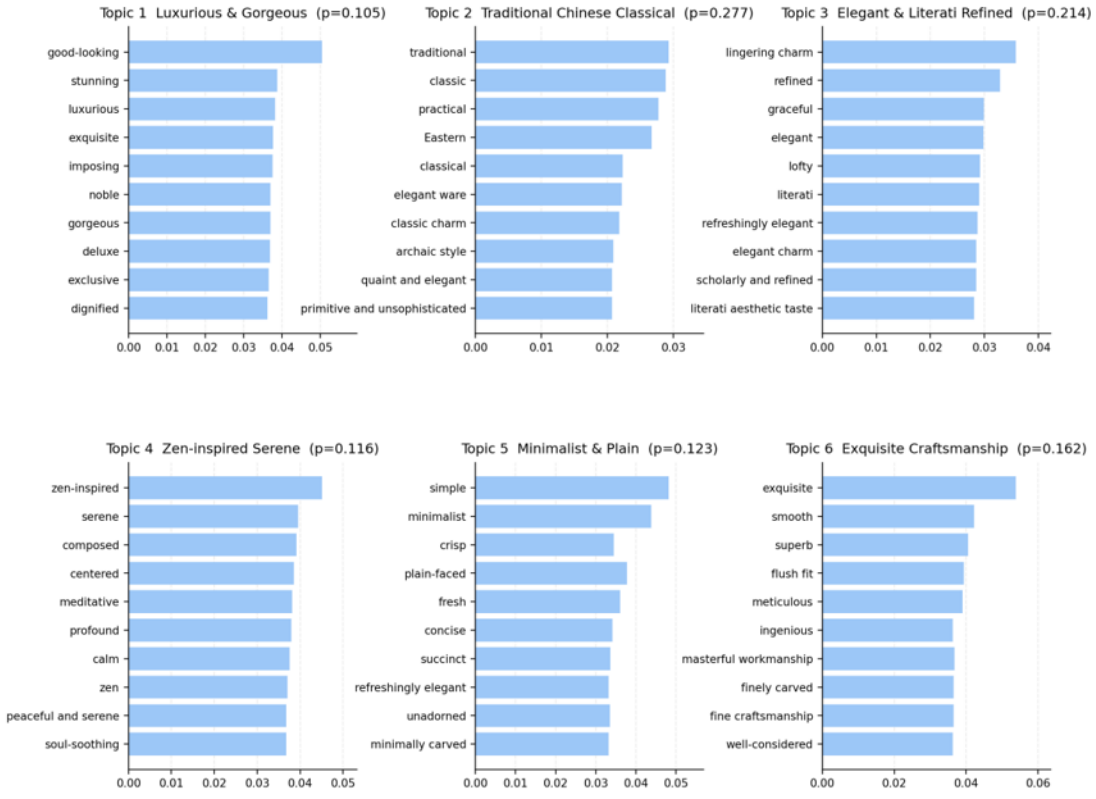


Fig. 8. Top keywords across the six LDA topics

By integrating the high-probability terms, their semantic contexts in the original reviews, and the semantic coherence within each topic, the six topics were interpreted and labeled. Accordingly, six Kansei requirement categories for Luohan beds were identified: U1 Luxurious & Gorgeous, U2 Traditional Chinese Classical, U3 Elegant & Literati-Refined, U4 Zen-Inspired & Serene, U5 Minimalist a & Plain, and U6 Exquisite Craftsmanship.

As shown in Fig. 8, the mean topic probabilities for U1 to U6 were 0.105, 0.277, 0.215, 0.117, 0.123, and 0.162, respectively. U2 Traditional Chinese Classical exhibited the highest mean topic probability, followed by U3 Elegant and Literati-Refined and U6 Exquisite Craftsmanship. These results indicate that traditional Chinese characteristics, refined aesthetic qualities, and craftsmanship constitute the most prominent semantic dimensions in the current review corpus. Detailed results are presented in Table 1.

Table 1. LDA Topic Labels and High-frequency Keywords of Luohan Beds

Category No.	Mean Prob.	Theme Label	High-frequency Keywords
Topic 1	0.105	Luxurious & Gorgeous Style	Good-looking, stunning, luxurious, exquisite, imposing, noble, gorgeous, deluxe, exclusive, dignified
Topic 2	0.277	Traditional Chinese Classical Style	Traditional, classic, practical, Eastern, classical, elegant ware, classic charm, archaic style, quaint and elegant, primitive and unsophisticated
Topic 3	0.214	Elegant & Literati Refined Style	Lingering charm, refined, graceful, elegant, lofty, literati, refreshingly elegant, elegant charm, scholarly and refined, literati aesthetic taste
Topic 4	0.116	Zen-inspired Serene Style	Zen-inspired, serene, composed, centered, meditative, profound, calm, zen, peaceful and serene, soul-soothing
Topic 5	0.312	Minimalist & Plain Style	Simple, minimalist, crisp, plain-faced, fresh, concise, succinct, refreshingly elegant, unadorned, minimally carved
Topic 6	0.162	Exquisite Craftsmanship Style	Exquisite, smooth, superb, flush fit, meticulous, ingenious, masterful workmanship, finely carved, fine craftsmanship, well-considered

Morphological Feature Coding

The Luohan bed integrates multiple functions, including sitting, lying, reclining, and display, and its overall form comprises several structural components, such as railings, aprons, the waist, legs, and the bed platform. To investigate the relationships between its morphological features and users' Kansei requirements, 40 representative Luohan bed specimens were decomposed and coded. The decomposition adopted in this study follows the structural logic of traditional Ming–Qing furniture while incorporating a modular approach to morphological analysis. Ming–Qing furniture is primarily characterized by frame structures and component-based construction, in which components such as railings, aprons, waists, legs, and bed platforms perform relatively distinct structural and decorative functions, as shown in Fig. 9. Accordingly, the Luohan bed was decomposed into the seven design attributes described above, allowing its overall form to be represented as a set of

identifiable and analyzable morphological units and providing a basis for subsequent morphological feature classification and coding.

Based on this decomposition, the morphological variations observed within each design attribute across the 40 samples were further classified to establish a morphological feature coding system. The coding follows the format "design attribute code + serial number," where A denotes Front Railing, B denotes Side Railing, C denotes Front Apron, D denotes Side Apron, E denotes Waist, F denotes Leg, and G denotes Bed Platform. Each code represents a specific morphological feature within the corresponding design attribute; for example, A1 represents the first morphological feature of Front Railing, B1 represents the first morphological feature of Side Railing, and F1 represents the first morphological feature of Leg. Through this coding scheme, the complex forms of Luohan beds were transformed into structured and identifiable morphological features, providing the data foundation for the subsequent GRA, AHP, and QFD analyses.



Fig. 9. Morphological decomposition of the Luohan bed

A total of 149 morphological features were identified and coded in this study, forming the morphological feature coding system for Luohan beds, as shown in Fig. 10. Among the seven design attributes, Front Railing comprises 34 morphological features (A1–A34), including plain-panel, openwork-carved, assembled-frame, inset-panel, arch-opening, and patterned decorative forms. Side Railing comprises 32 morphological features (B1–B32), which generally correspond to those of Front Railing but differ in scale, decorative density, and compositional arrangement. Front Apron comprises 28 morphological features (C1–C28), including straight, curved, Kuimen-style, carved, and simplified forms. Side Apron comprises 19 morphological features (D1–D19), primarily reflecting variations in the form and decorative characteristics of the side structure. Waist comprises six morphological features (E1–E6), primarily reflecting variations in molding and hierarchical organization within the middle section of the bed structure. Leg comprises 26 morphological features (F1–F26), including straight, curved, hoof-shaped, inward-curved, and other forms. Bed Platform comprises four morphological features (G1–G4), primarily differentiated by frame configuration, platform form, and overall thickness.

Through this coding process, the complex overall forms of Luohan beds were transformed into identifiable, comparable, and quantifiable morphological features. The resulting coding system preserves the morphological variations within each design attribute while providing a structured data basis for subsequent analyses: GRA was used to examine the relationships between morphological features and users' Kansei requirements, AHP was employed to determine the relative importance weights of the Kansei requirements,

and QFD was used to integrate the Kansei requirements and morphological features within the HoQ and determine their design priorities.

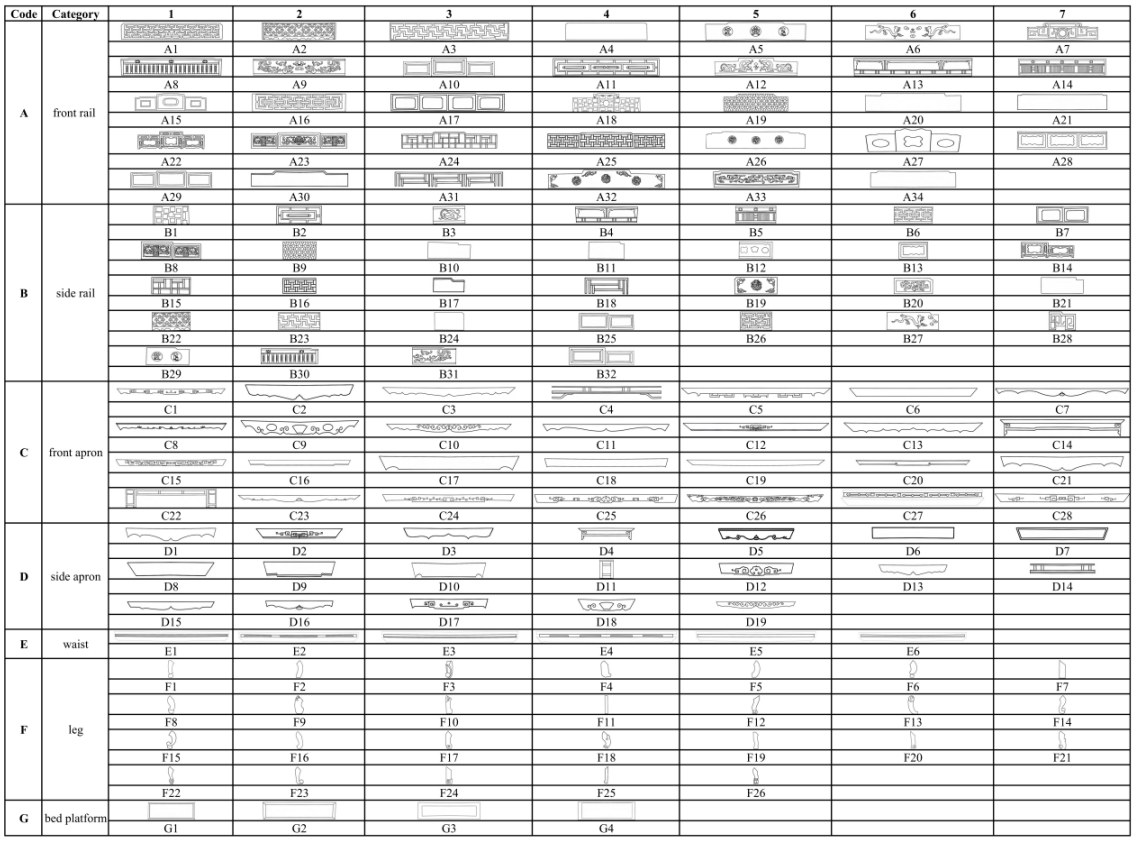


Fig. 10. Morphological feature coding table of Luohan beds

GRA

Given the limited number of Luohan bed specimens and the substantial morphological differences among the coded features in terms of structure, ornamentation, and visual characteristics, conventional correlation-based methods may not adequately characterize the relationships between users' Kansei requirements and individual morphological features. GRA evaluates the relational strength between factors by comparing the similarity or proximity of their data sequences and is applicable to analytical problems involving limited data and incomplete information. Therefore, in this study, the six Kansei requirements were used as the evaluation dimensions, while the 149 coded morphological features served as the objects of analysis. GRA was employed to quantify the grey relational degree between each morphological feature and each Kansei requirement, thereby identifying the morphological features with stronger relationships to the Kansei requirements for subsequent integration into the HoQ.

To obtain the evaluation data required for GRA, a Kansei evaluation experiment was conducted based on the six Kansei requirements identified in the preceding LDA analysis. The evaluation objects comprised the 149 coded morphological features of the Luohan bed, and the evaluation dimensions corresponded to the six Kansei requirements (U1–U6). Given the strong cultural, morphological, and visual-aesthetic characteristics of traditional Chinese furniture, 30 participants were recruited, including 10 professionals with backgrounds in furniture design or industrial design and 20 general users. The

professionals evaluated the morphological features with consideration of form characteristics, structural proportions, and traditional furniture aesthetics, whereas the general users provided evaluations based on their visual perceptions and affective responses. The resulting evaluation data were subsequently used to calculate the grey relational degrees between the morphological features and the six Kansei requirements.

Participants rated the degree of correspondence between each component form and each Kansei need using a five-point semantic differential scale, where 1 indicated the lowest degree of correspondence and 5 indicated the highest. The ratings of all participants were aggregated for each Kansei-need dimension, and the mean rating for each component form was calculated and used as the original evaluation data for GRA. Specifically, the mean evaluation value of the i-th component form with respect to the k-th category of users' Kansei needs is denoted as $x_i(k)$.

First, the evaluation results of each component form across the six categories of users' Kansei needs were organized into comparison sequences,

$$X_i = \{x_i(1), x_i(2), \dots, x_i(n)\}, \qquad i = 1,2, \dots, m \tag{3}$$

where X_i denotes the evaluation sequence of the i -th component form code, $x_i(k)$ represents the evaluation value of that component form with respect to the k-th category of users' Kansei needs, and n denotes the number of Kansei-need dimensions. In this study, n=6.

To determine the proximity of each component form to users' needs, the optimal value for each Kansei-need dimension was used to construct the reference sequence,

$$X_0=\{x_0(1),x_0(2),\dots,x_0(n)\} \tag{4}$$

where X_0 denotes the ideal reference sequence, and $x_0(k)$ denotes the reference value under the k -th user Kansei requirement dimension.

To eliminate the influence of differences in numerical scales across evaluation dimensions, the original evaluation data were normalized using min–max normalization. Since all evaluation criteria in this study were benefit-type criteria, with higher values indicating a stronger correspondence between a component form and users' Kansei needs, the normalization was performed as follows:

$$x_i'(k) = \frac{x_i(k) - \min x_i\,(k)}{\max x_i\,(k) - \min x_i\,(k)} \tag{5}$$

where $\max x_i\,(k)$ and $\min x_i\,(k)$ denote the maximum and minimum values, respectively, among all component forms for the k-th Kansei-need dimension. After normalization, the reference sequence can be expressed as:

$$X_0'=\{1,1\dots,1\} \tag{6}$$

The absolute difference between the normalized reference sequence and each comparison sequence was then calculated as:

$$\Delta_i(k) = |x_0'(k) - x_i'(k)| \tag{7}$$

Based on these differences, the grey relational coefficient was calculated as,

$$\xi_i(k) = \frac{\Delta_{min}+\rho\Delta_{\max}}{\Delta_i(k)+\rho\Delta_{\max}} \tag{8}$$

where Δ_{min} and $\Delta_{\max}$ denote the minimum and maximum absolute differences across all comparison sequences and Kansei-need dimensions, respectively, and ρ is the distinguishing coefficient, conventionally set to 0.5. A larger grey relational coefficient indicates a stronger association between a component form and the corresponding category of users' Kansei needs.

The grey relational coefficients across the six Kansei-need dimensions were subsequently summed to obtain the overall grey relational score for each component form,

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n} \xi_i\,(k) \tag{9}$$

where γi denotes the cumulative Grey relational score of the *i*-th component form. A higher overall score indicates a stronger overall correspondence between the component form and users' Kansei needs.

To ensure that the morphological features incorporated into the HoQ exhibited sufficiently strong overall relationships with users' Kansei requirements, a screening threshold was established based on the cumulative grey relational score. Because six Kansei requirements were considered in this study, an average grey relational coefficient of 0.500 across the six requirements corresponds to a cumulative grey relational score of 6×0.500=3.000.

Accordingly, γ=3.000 was adopted as the screening threshold. For each morphological feature (i), its cumulative grey relational score, γ_i, was calculated by summing its grey relational coefficients across the six Kansei requirements. A morphological feature satisfying $\gamma_i \geq 3.000$ was considered to exhibit a sufficiently strong overall relationship with the Kansei requirements and was therefore retained for subsequent QFD analysis. Based on this criterion, 67 coded morphological features were retained, as presented in Table 2.

Table 2. Screening Results of Luohan Bed Component Forms Based on Grey Relational Analysis

Code	T1	T2	T3	T4	T5	T6	Comprehensive γ Value
A2	4.000	4.250	2.750	1.875	3.000	3.750	3.271
A3	3.250	4.125	3.750	3.000	2.000	4.000	3.354
A4	4.250	2.000	3.000	3.625	3.375	1.875	3.021
A5	3.875	3.875	4.125	4.375	2.875	4.125	3.875
A6	4.250	2.000	3.125	3.500	1.875	4.375	3.188
A8	4.375	3.125	4.000	1.250	3.250	3.250	3.208
A10	3.125	4.375	1.750	3.000	3.875	3.000	3.188
A12	2.000	3.750	2.500	3.625	4.250	4.125	3.375
A14	3.875	2.000	2.000	4.000	4.000	4.250	3.354
A19	1.625	3.500	3.500	3.250	2.875	4.250	3.167
A22	4.250	3.000	3.500	2.750	2.375	2.625	3.083
A24	3.625	3.125	2.625	4.125	4.375	3.000	3.479
A26	4.375	2.875	2.000	4.000	3.125	3.125	3.250
A34	3.000	4.625	4.000	2.875	2.500	2.250	3.208
B2	3.500	4.000	2.250	3.875	4.000	4.000	3.604
B3	4.000	3.875	2.000	4.125	3.000	2.375	3.229
B4	4.000	3.000	2.250	2.875	3.250	2.875	3.042
B7	2.625	4.500	2.000	3.000	2.625	4.125	3.146
B10	2.500	4.000	2.750	3.125	3.500	3.250	3.188
B16	3.125	2.875	2.250	3.625	4.125	4.000	3.333

Code	T1	T2	T3	T4	T5	T6	Comprehensive γ Value
B17	2.125	3.250	3.125	3.875	2.875	2.750	3.000
B18	2.875	3.750	2.750	4.125	3.750	1.875	3.188
B19	3.125	4.125	3.000	4.375	2.000	3.000	3.271
B20	4.000	4.000	3.875	2.250	4.125	4.000	3.708
B21	2.125	4.375	3.875	4.000	4.250	4.250	3.812
B24	2.750	3.250	3.375	3.750	4.125	2.125	3.229
B25	4.250	3.750	3.250	2.000	3.625	4.125	3.500
B26	3.750	3.750	3.125	3.000	4.000	2.000	3.271
B27	2.125	4.375	3.000	4.125	4.250	4.125	3.667
B28	3.000	3.750	2.375	4.000	2.875	3.250	3.208
C1	4.125	3.250	3.250	3.375	2.125	4.250	3.396
C2	3.625	3.250	2.250	4.000	1.875	3.000	3.000
C4	2.500	3.750	4.125	1.875	2.875	4.250	3.229
C5	2.625	3.250	1.875	4.250	4.375	1.875	3.042
C8	1.750	1.875	2.625	3.625	4.000	4.375	3.042
C11	2.625	2.125	3.875	4.625	4.000	1.875	3.188
C13	2.875	3.875	2.750	3.250	4.125	3.000	3.312
C15	3.875	3.000	3.150	1.750	2.375	4.000	3.025
C16	3.875	3.125	3.250	2.625	2.500	4.375	3.292
C19	3.250	3.125	3.050	3.875	2.500	2.250	3.008
C20	4.375	3.000	3.000	4.000	3.000	3.125	3.417
C27	4.375	2.500	4.125	2.500	4.125	4.000	3.604
C28	3.250	2.875	2.875	4.000	4.000	1.750	3.125
D3	1.750	4.250	3.875	2.375	2.750	4.000	3.167
D5	3.750	1.750	4.250	3.875	3.000	2.000	3.104
D8	3.000	4.000	2.000	3.750	3.875	1.875	3.083
D15	2.375	3.000	4.125	2.250	3.875	4.125	3.292
D17	3.500	2.750	4.000	3.875	2.250	3.750	3.354
D18	2.875	4.125	3.375	3.875	3.125	4.000	3.562
E1	3.000	2.125	3.500	4.250	3.250	3.250	3.229
E5	1.850	4.125	3.125	3.125	3.375	3.875	3.246
F7	3.875	2.625	3.750	3.000	2.500	4.375	3.354
F8	1.625	3.875	3.875	4.000	1.875	2.750	3.000
F10	4.125	2.750	1.875	2.375	4.250	3.000	3.062
F12	3.125	3.875	4.000	1.750	3.125	4.000	3.312
F13	3.250	3.875	4.125	4.125	2.000	1.875	3.208
F14	4.250	2.125	2.500	3.875	2.375	3.000	3.021
F15	3.750	4.250	2.000	3.250	3.375	3.875	3.417
F16	3.000	3.750	4.125	4.375	4.000	4.125	3.896
F17	2.625	1.750	3.000	4.000	4.375	4.250	3.333
F19	3.125	3.000	4.250	3.625	4.125	3.500	3.604
F21	3.125	4.125	3.500	2.625	4.000	2.250	3.271
F22	3.000	3.250	2.375	3.875	3.125	4.375	3.333
F25	3.000	1.625	3.875	3.625	4.125	3.875	3.354
G2	2.750	3.875	2.750	2.875	2.750	3.875	3.146
G3	3.125	4.500	2.000	2.125	3.875	3.750	3.229
G4	3.875	4.000	2.250	2.875	4.125	3.250	3.396

The screening results show that relatively large numbers of morphological features were retained for Front Railing, Side Railing, Front Apron, and Leg, suggesting that users' Kansei evaluations may be particularly responsive to morphological variations in these design attributes. Specifically, Front Railing and Side Railing contribute directly to the

perceived sense of enclosure, cultural identity, and overall visual style of the Luohan bed. Front Apron contributes to the decorative rhythm and structural layering of the lower portion of the bed, whereas Leg is associated with perceptions of support, stability, and stylistic expression.

Through GRA-based screening, the original 149 coded morphological features were reduced to 67 retained morphological features. This screening reduces the complexity of the subsequent QFD relationship matrix while ensuring that the morphological features incorporated into the HoQ are empirically associated with users' Kansei requirements. Based on these results, a QFD relationship matrix between the six Kansei requirements and the retained morphological features was subsequently constructed to translate users' Kansei requirements into design priorities for the morphological features.

AHP

To avoid directly equating the topic distributions derived from LDA with the relative importance of the Kansei requirements, AHP was employed during the QFD construction stage to determine the importance weights of the six Kansei requirements. The six Kansei requirements—U1 Luxurious & Gorgeous, U2 Traditional Chinese Classical, U3 Elegant & Literati-Refined, U4 Zen-Inspired Serene, U5 Minimalist & Plain, and U6 Exquisite Craftsmanship—were defined as the criteria layer of the AHP hierarchy. Eight experts with experience in furniture design, traditional furniture research, or product design practice were invited to perform pairwise comparisons of the six Kansei requirements. Using Saaty's 1–9 scale, each expert provided 15 pairwise judgments regarding the relative importance of the six Kansei requirements for the contemporary redesign of the Luohan bed. Specifically, values of 1, 3, 5, 7, and 9 represent equal, moderate, strong, very strong, and extreme importance, respectively; values of 2, 4, 6, and 8 represent intermediate judgments between adjacent levels, and reciprocal values represent judgments in the opposite direction.

The pairwise comparison results of the eight experts are presented in Tables 3 to 5. To reduce the influence of individual differences in expert judgments on the group-level results, an individual judgment matrix was first constructed for each expert and subjected to a consistency test. Of the eight individual judgment matrices, seven met the predefined consistency criterion and were retained for subsequent analysis, whereas the remaining matrix was excluded. The pairwise judgments from the seven retained matrices were then aggregated using the geometric mean method to obtain the aggregated group judgment matrix.

Table 3. Pairwise Comparison Results of Eight Experts for Six Kansei Requirements (Part 1)

Expert	U1/U2	U1/U3	U1/U4	U1/U5	U1/U6
E1	1/3	1/2	1	1/3	1
E2	1/4	1/2	1	1/4	1/2
E3	1/3	1/2	1	1/3	1/2
E4	1/3	1	1	1/4	1/2
E5	1/3	1/2	1	1/3	1/2
E6	1/2	1/2	1/2	1/4	1/2
E7	1/3	1/3	1	1/3	1
E8	1/2	1/2	1	1/3	1/2

Table 4. (continued). Pairwise comparison results of eight experts for six Kansei requirements (Part 2)

Expert	U2/U3	U2/U4	U2/U5	U2/U6	Expert
E1	1	2	1	3	E1
E2	1/2	3	1/2	2	E2
E3	1	2	1/2	3	E3
E4	1	2	1	2	E4
E5	1/2	2	2	2	E5
E6	1	2	2	2	E6
E7	1	2	1	2	E7
E8	2	2	1	2	E8

Table 5. (continued). Pairwise comparison results of eight experts for six Kansei requirements (Part 3)

Expert	U3/U4	U3/U5	U3/U6	U4/U5	U4/U6
E1	2	1/2	1	1/3	1
E2	2	1/2	1	1/3	1
E3	2	1	2	1/3	1
E4	2	1/2	1	1/3	1
E5	2	1/3	1	1/3	1
E6	2	1/2	1	1/4	2
E7	2	1	1	1/3	1
E8	2	1/2	1	1/4	1

To assess the consistency of the expert judgments, the maximum eigenvalue λ_{max}, consistency index (CI), and consistency ratio (CR) were calculated for each of the eight individual judgment matrices. The results of the consistency tests are presented in Table 6. Seven of the eight individual judgment matrices yielded (CR < 0.10), indicating acceptable consistency and were therefore retained for subsequent group aggregation. The remaining judgment matrix did not meet the predefined consistency criterion and was excluded from the group-level analysis.

Table 6. Consistency Test Results of the Eight Individual Expert Judgment Matrices

Expert	λ_{max}	CI	CR	Expert	λ_{max}
E1	6.112	0.022	0.018	E1	6.112
E2	6.246	0.049	0.040	E2	6.246
E3	6.139	0.028	0.022	E3	6.139
E4	6.153	0.031	0.025	E4	6.153
E5	6.469	0.094	0.076	E5	6.469
E6	6.476	0.095	0.077	E6	6.476
E7	6.108	0.022	0.017	E7	6.108
E8	6.115	0.023	0.019	E8	6.115

Note: The consistency requirement is satisfied when $\mathrm{CR} < 0.10$.

Considering potential differences among the judgments of the eight experts, the geometric mean method was employed to aggregate the individual judgment matrices. Each element a_{ij} in the aggregated group judgment matrix was calculated as follows,

$$a_{ij} = (\prod_{k=1}^{8} a_{ij}^{(k)})^{\frac{1}{8}} \quad (10)$$

where $a_{ij}^{(k)}$ denotes the judgment made by the *k*-th expert regarding the relative importance of the *i*-th Kansei requirement compared with the *j*-th Kansei requirement. Based on this procedure, the aggregated group judgment matrix for the six Kansei requirements was obtained, as shown in Table 7.

Table 7. Aggregated Judgment Matrix for the Six Kansei Requirements

Kansei requirement	U1	U2	U3	U4	U5
U1	1.000	0.356	0.518	0.917	0.299
U2	2.810	1.000	0.917	2.104	1.000
U3	1.929	1.091	1.000	2.000	0.565
U4	1.091	0.475	0.500	1.000	0.310
U5	3.342	1.000	1.769	3.224	1.000
U6	1.682	0.452	0.917	0.917	0.493

Subsequently, the normalized weights of the six Kansei requirements were calculated using the eigenvector method. The rationality and consistency of the aggregated group judgment matrix were then evaluated using the consistency index (CI) and consistency ratio (CR), calculated as follows,

$$A\boldsymbol{w} = \lambda_{\max}\boldsymbol{w}, \sum_{i=1}^{6} \boldsymbol{w}_i = 1 \quad (11)$$

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} \quad (12)$$

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \quad (13)$$

where $\lambda_{\max}$ denotes the maximum eigenvalue of the judgment matrix, and *n* denotes the order of the judgment matrix, with n=6 in this study. RI represents the average random consistency index, which is 1.24 when n=6. The calculation results showed that the aggregated group judgment matrix yielded $\lambda_{\max}$ =6.102, CI =0.020, and CR =0.016. Since CR <0.10, the aggregated group judgment matrix passed the consistency test.

Table 8. AHP Weights and Ranking of the Six Kansei Requirements

Code	Kansei requirement	Weight	Rank
U1	Luxurious & Gorgeous	0.084	6
U2	Traditional Chinese Classical	0.231	2
U3	Elegant & Literati-refined	0.180	3
U4	Zen-inspired & Serene	0.101	5
U5	Minimalist & Plain	0.278	1
U6	Exquisite Craftsmanship	0.126	4

Note: $\lambda_{\max} = 6.076$, $\mathrm{CI} = 0.015$, $\mathrm{RI} = 1.24$, and $\mathrm{CR} = 0.012 < 0.10$.

The AHP results (Table 8) showed that Minimalist and Plain received the highest weight (0.278), followed by Traditional Chinese Classical (0.231) and Elegant and Literati-

Refined (0.180). The weights of Exquisite Craftsmanship, Zen-Inspired and Serene, and Luxurious and Gorgeous were 0.126, 0.101, and 0.084, respectively. These results indicate that, in expert decision-making for the contemporary redesign of the Luohan bed, restrained and minimalist formal expression, recognizable traditional Chinese characteristics, and an elegant aesthetic are assigned relatively high design priorities, whereas elaborate and luxurious ornamentation is given a comparatively lower priority.

QFD

After determining the importance weights of the six Kansei requirements using AHP, the 67 morphological features retained through GRA-based screening were incorporated into the HoQ to construct the relationship matrix between the Kansei requirements and the morphological features. The 67 retained morphological features were organized according to seven design attributes: A, Front Railing; B, Side Railing; C, Front Apron; D, Side Apron; E, Waist; F, Leg; and G, Bed Platform. Five experts with expertise in traditional furniture design practice and Ming-style furniture were subsequently invited to evaluate the relationship strength between each retained morphological feature and each of the six Kansei requirements, thereby establishing the QFD relationship matrix.

Relationship strength was represented using a symbolic scoring scheme. A strong relationship was denoted by ▲ and assigned a score of 9, a moderate relationship by ○ and assigned a score of 3, a weak relationship by □ and assigned a score of 1, and no evident relationship was assigned a score of 0. The normalized AHP importance weights of the six Kansei requirements were then incorporated into the HoQ. The absolute weight of the (j)-th morphological feature was calculated as follows,

$$W_j = \sum_{i=1}^{m} w_i R_{ij} \tag{14}$$

where W_j denotes the absolute weight of the j-th component form, w_i represents the AHP weight of the i-th Kansei requirement, R_{ij} denotes the relationship strength between the i-th Kansei requirement and the j-th component form, and m is the number of Kansei requirements, with m=6 in this study. To facilitate comparison across different component forms, the relative weight was further calculated as follows:

$$P_j = \frac{W_j}{\sum_{j=1}^{n} W_j} \times 100\% \tag{15}$$

where P_j denotes the relative weight of the j-th component form, and n represents the number of component forms incorporated into the QFD House of Quality, with n=67 in this study. A higher relative weight indicates a higher design priority for the corresponding component form in satisfying the weighted Kansei requirements.

Based on the HoQ calculation results, the absolute weights, relative weights, and overall rankings of the 67 retained morphological features were determined. Within each design attribute, the morphological feature with the highest absolute weight was selected as the priority morphological feature for redesign. Accordingly, the priority combination of morphological features for the Luohan bed redesign was identified as A34, B24, C11, D3, E5, F16, and G3, as presented in Table 9. The recalculated House of Quality results are presented in Table 10.

Table 9. Key Component Selection Results of Luohan Bed Based on QFD

Component category	Selected code	Absolute weight	Relative weight (%)
A	A34	6.222	2.046
B	B24	7.722	2.539
C	C11	7.488	2.462
D	D3	7.112	2.338
E	E5	7.436	2.445
F	F16	8.496	2.793
G	G3	7.560	2.485

Table 10. QFD House of Quality Model Between User Requirements and Component Forms of Luohan Beds

Design requirements	Demand factors	U1	U2	U3	U4	U5	U6	Absolute weight	Relative weight (%)	Rank
	AHP weight	0.084	0.231	0.180	0.101	0.278	0.126			
A	A2	▲	▲	□		○	○	4.227	1.39	34
	A3	○	▲	○	○	□	▲	4.586	1.51	27
	A4	▲	□	○	○	○		2.664	0.88	58
	A5	○	○	▲	▲	□	▲	4.886	1.61	25
	A6	▲	□	○	○		▲	2.964	0.97	52
	A8	▲	○	▲		○	○	4.281	1.41	32
	A10	○	▲		○	○	○	3.846	1.26	43
	A12	□	○	□	○	▲	▲	4.896	1.61	24
	A14	○	□	□	▲	▲	▲	5.208	1.71	20
	A19		○	○	○	□	▲	2.948	0.97	53
	A22	▲	○	○	□	□	□	2.494	0.82	59
	A24	○	○	□	▲	▲	○	4.914	1.62	23
	A26	▲	□	□	▲	○	○	3.288	1.08	50
	A34	○	▲	▲	○	○	▲	6.222	2.05	16
B	B2	○	▲	□	○	▲	▲	6.450	2.12	14
	B3	▲	○	□	▲	○	□	3.498	1.15	48
	B4	▲	○	□	□	○	□	2.690	0.88	56
	B7	□	▲	□	○	□	▲	4.058	1.33	37
	B10	□	▲	□	○	○	○	3.858	1.27	42
	B16	○	□	□	○	▲	▲	4.602	1.51	26
	B17	□	○	○	○	□	□	2.024	0.67	66
	B18	□	○	□	▲	○		2.700	0.89	55
	B19	○	▲	○	▲	□	○	4.436	1.46	30
	B20	▲	▲	○	□	▲	▲	7.112	2.34	9
	B21	▲	▲	▲	○	▲	○	7.638	2.51	3
	B24	□	▲	▲	○	▲	▲	7.722	2.54	2
	B25	▲	○	○	□	○	▲	4.058	1.33	37
	B26	○	○	○	○	▲	□	4.416	1.45	31
	B27	□	▲	○	▲	▲	▲	7.248	2.38	7
	B28	○	○	□	▲	□	○	2.690	0.88	56
C	C1	▲	○	○	○	□	▲	3.704	1.22	46
	C2	○	○	□	▲		○	2.412	0.79	60
	C4	□	○	▲		□	▲	3.809	1.25	44
	C5	□	○		▲	▲		4.188	1.38	35
	C8	□	□	○	▲	▲		4.266	1.40	33
	C11	○	▲	▲	▲	▲	□	7.488	2.46	5
	C13	○	○	○		□	▲	2.897	0.95	54

Design requirements	Demand factors	U1	U2	U3	U4	U5	U6	Absolute weight	Relative weight (%)	Rank
	AHP weight	0.084	0.231	0.180	0.101	0.278	0.126			
	C15	○	○	○	□	□	▲	2.998	0.99	51
	C16	○	○	○	○	□	□	2.192	0.72	63
	C19	▲	▲	▲	○	○	▲	6.726	2.21	11
	C20	▲	□	▲	□	▲	▲	6.344	2.09	15
	C27	○	□	□	▲	▲		4.074	1.34	36
	C28	▲	□	□	○	□	□	1.874	0.62	67
D	D3	▲	▲	○	□	▲	▲	7.112	2.34	9
	D5	○	▲	□		▲	□	5.139	1.69	21
	D8	□	○	▲	□	○	▲	4.466	1.47	29
	D15	▲	□	□			▲	2.301	0.76	61
	D17	□	▲	○	○	○	▲	4.974	1.64	22
	D18	▲	▲	▲	○	○	▲	6.726	2.21	11
	E1	○	□		○	▲	○	3.666	1.21	47
	E5	▲	▲	▲	□	▲	○	7.436	2.44	6
E	C1	▲	○	○	○	□	▲	3.704	1.22	46
	C2	○	○	□	▲		○	2.412	0.79	60
F	F7		○	○	▲		□	2.268	0.75	62
	F8	▲	□		□	▲	○	3.968	1.30	41
	F10	○	○	▲		○	▲	4.533	1.49	28
	F12	○	○	▲	▲	□		3.752	1.23	45
	F13	▲	□	□	○	□	○	2.126	0.70	64
	F14	○	▲	□	○	○	○	4.026	1.32	39
	F15		▲	▲	▲	▲	□	7.236	2.38	8
	F16	○	▲	▲	▲	▲	▲	8.496	2.79	1
	F17	○	○	▲	○	▲	○	5.748	1.89	17
	F19	○	▲	○	□	▲	□	5.600	1.84	18
	F21	○	○	□	○	○	▲	3.396	1.12	49
	F22	○		○	○	▲	○	3.975	1.31	40
	F25	▲	○			□	○	2.105	0.69	65
G	G2	○	▲		○	▲	○	5.514	1.81	19
	G3	▲	▲	□	▲	▲	▲	7.560	2.49	4
	G4	○	▲	▲		▲		6.453	2.12	13

Note: Strong correlation is marked as ▲ and assigned a value of 9; moderate correlation is marked as ○ and assigned a value of 3; weak correlation is marked as □ and assigned a value of 1; and no obvious correlation is assigned a value of 0.

RESULTS AND DISCUSSION

Design Practice

Based on the results of the integrated LDA–GRA–AHP–QFD analysis, a redesign of the Luohan bed was developed. The preceding analysis identified six Kansei requirements: U1 Luxurious & Gorgeous, U2 Traditional Chinese Classical, U3 Elegant & Literati-Refined, U4 Zen-Inspired Serene, U5 Minimalist & Plain, and U6 Exquisite Craftsmanship. According to the AHP results, U2 Traditional Chinese Classical, U3 Elegant & Literati-Refined and U5 Minimalist & Plain received relatively high importance weights, indicating that the contemporary redesign of the Luohan bed should emphasize both formal simplicity and adaptability to contemporary living environments while preserving the recognizable characteristics of traditional Chinese furniture.

According to the final QFD results (Table 11), the priority morphological feature within each of the seven design attributes was identified as A34, B24, C11, D3, E5, F16, and G3, corresponding to Front Railing, Side Railing, Front Apron, Side Apron, Waist, Leg, and Bed Platform, respectively. These priority morphological features were integrated to establish the core morphological configuration of the redesigned Luohan bed. While retaining the characteristic three-sided enclosure of the traditional Luohan bed, the redesign reorganizes the morphological relationships among the seven design attributes to reduce visual complexity while preserving the recognizability of the traditional furniture typology. Through this integration, the design achieves greater formal coherence and adaptability to contemporary living environments while responding to the identified Kansei requirements.

Table 11. Design Translation of Key Luohan Bed Components Based on QFD Results

Component	Selected code	Design Implication
Front railing	A34	Simplified enclosure / cultural recognition
Side railing	B24	Spatial enclosure / visual continuity
Front apron	C11	Reduced decoration
Side apron	D3	Side visual coherence
Waist	E5	Proportional transition
Leg	F16	Stable but lighter support
Bed platform	G3	Flat and usable surface

The proposed design is presented in Fig. 11 through the top, front, and side views, together with an overall rendering, providing a comprehensive representation of the Luohan bed's overall proportions and the morphological configuration of its principal design attributes. The design retains the characteristic three-sided enclosure of the traditional Luohan bed to preserve its typological identity. At the same time, the morphological features of the Front Railing, Side Railing, Front Apron, Side Apron, and Leg are simplified by reducing dense carving and elaborate ornamentation, resulting in a clearer, more restrained, and visually lighter overall appearance.



Fig. 11. Design rendering of the redesigned Luohan beds

Design Evaluation

To evaluate the extent to which the redesigned Luohan bed corresponded to the identified Kansei requirements, 35 participants were recruited, including five professionals with research or practical experience in traditional Chinese furniture, furniture design, or product design and 30 target users. The target users were selected based on their prior knowledge of, experience with, purchasing experience of, or sustained interest in Chinese-style furniture, ensuring that they possessed sufficient familiarity to evaluate the stylistic characteristics, formal aesthetics, spatial atmosphere, and craftsmanship of the Luohan bed.

The evaluation included two design alternatives: a baseline Luohan bed and the redesigned Luohan bed developed using the integrated LDA–GRA–AHP–QFD approach. To minimize the potential influence of presentation format on participants' evaluations, both alternatives were presented against a white background using images that clearly illustrated their overall proportions and the morphological configurations of the principal design attributes, including the railings, aprons, waist, legs, and bed platform, as shown in Fig. 12. All 35 participants independently evaluated both design alternatives.



Fig. 12. Luohan bed schemes used for design evaluation: (a) baseline Luohan bed; (b) redesigned Luohan bed

The evaluation criteria corresponded to the six Kansei requirements identified in the preceding analysis: U1 Luxurious & Gorgeous, U2 Traditional Chinese Classical, U3 Elegant & Literati-Refined, U4 Zen-Inspired & Serene, U5 Minimalist & Plain, and U6 Exquisite Craftsmanship. A 10-point rating scale was employed, where 1 indicated that the design "does not exhibit the corresponding Kansei requirement at all," and 10 indicated that it "exhibits the corresponding Kansei requirement to a very high degree." To compare the perceptual profiles of the two design alternatives across the six Kansei requirements, the ratings provided by the 35 participants were aggregated, and the mean scores for the baseline and redesigned Luohan beds were calculated separately for each Kansei requirement. The resulting mean scores were visualized using a radar chart to facilitate comparison between the two designs.

As shown in Fig. 13, the redesigned Luohan bed achieved higher mean evaluation scores across the six Kansei requirements than the baseline design. Relatively larger increases were observed for U2 Traditional Chinese Classical, U3 Elegant and Literati-refined, and U5 Minimalist and Plain. Overall, the evaluation results suggest that the redesigned Luohan bed better corresponded to the identified Kansei requirements, particularly in terms of traditional Chinese characteristics, minimalist expression, and perceived craftsmanship. These findings provide preliminary design-level evidence supporting the applicability of the integrated LDA–GRA–AHP–QFD approach to the contemporary redesign of traditional furniture.

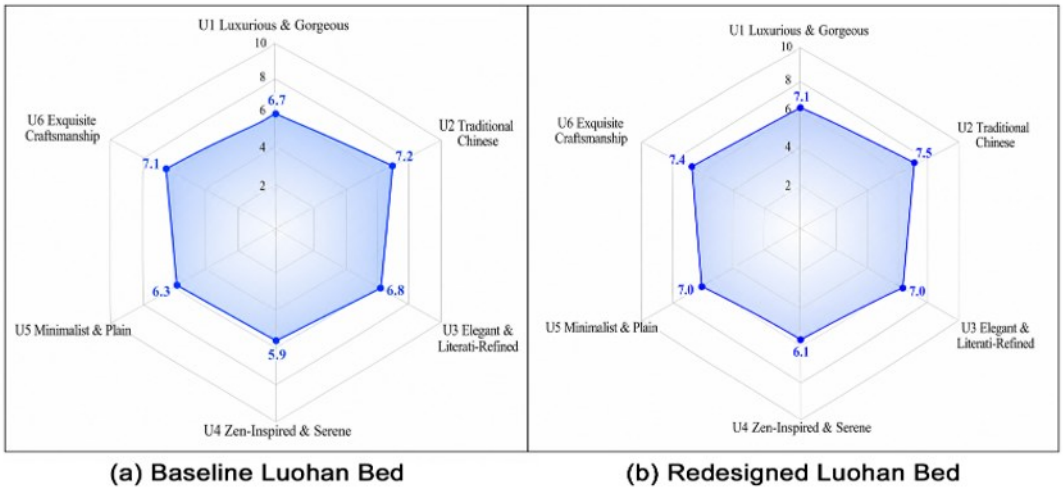


Fig. 13. Kansei evaluation profiles of the Luohan bed schemes based on 35 participants: (a) baseline Luohan bed; (b) redesigned Luohan bed.

DISCUSSION

This study developed an integrated LDA–GRA–AHP–QFD approach within the KE framework to translate Kansei requirements extracted from online user reviews into morphological features and design priorities for Luohan bed redesign. The results reveal a dual orientation in contemporary users' Kansei requirements: preserving the traditional identity of the Luohan bed while improving its simplicity and adaptability to contemporary living environments. According to the AHP results, U5 Minimalist & Plain and U2 Traditional Chinese Classical received relatively high importance weights. This suggests that contemporary redesign should not merely reproduce traditional ornamentation but should coordinate the proportions, decorative density, and visual relationships among the design attributes to balance traditional identity with contemporary aesthetics.

Methodologically, LDA enabled Kansei requirements to be identified from natural-language user reviews, reducing reliance on predefined Kansei vocabularies. GRA screened the original 149 morphological features to 67 retained morphological features based on their relationships with the Kansei requirements, while AHP determined the importance weights of the six Kansei requirements. QFD subsequently integrated these results to determine design priorities, resulting in the priority combination of A34, B24, C11, D3, E5, F16, and G3. This integrated process provides a systematic and traceable pathway from user-generated Kansei information to specific morphological features.

The design evaluation showed that the redesigned Luohan bed achieved higher mean scores across the six Kansei requirements than the baseline design, particularly for U2 Traditional Chinese Classical, U3 Elegant & Literati-Refined, and U5 Minimalist & Plain. These results provide preliminary evidence that component-level morphological control can support the preservation of traditional furniture identity while responding to contemporary aesthetic requirements.

This study still had several limitations. First, the user reviews were mainly collected from online platforms and may be influenced by platform characteristics, consumption contexts, and review motivations. Second, the naming of LDA topics still requires

interpretation based on keywords and contexts, which inevitably involves a certain degree of subjective judgment. Third, although the 40 Luohan bed samples and 149 morphological codes covered the main form types, they cannot fully represent all variations across different historical periods, regional styles, and craftsmanship traditions. In addition, the sample size in the design evaluation was limited; therefore, the results are more suitable as preliminary evidence rather than conclusive proof of large-scale market acceptance or long-term use experience. Future research may expand data sources and introduce eye-tracking, physiological measurement, virtual reality evaluation, or physical prototype testing to further verify the influence of component forms on users' Kansei judgments and use experience.

CONCLUSIONS

1. Latent Dirichlet allocation (LDA)-based analysis of online user reviews identified six Kansei requirements for Luohan beds: U1 Luxurious & Gorgeous, U2 Traditional Chinese Classical, U3 Elegant & Literati-Refined, U4 Zen-Inspired & Serene, U5 Minimalist and Plain, and U6 Exquisite Craftsmanship. The analytical hierarchy process (AHP) was subsequently used to determine their importance weights, with U5 Minimalist & Plain and U2 Traditional Chinese Classical receiving relatively high weights. These results highlight the importance of balancing traditional identity with formal simplicity and contemporary adaptability in Luohan bed redesign.
2. Forty representative Luohan bed samples were decomposed into seven design attributes and coded into 149 morphological features. Grey relational analysis (GRA) was used to quantify the relationships between these morphological features and the six Kansei requirements. Using a cumulative grey relational score of $\gamma \geqslant 3.000$ as the screening criterion, 67 morphological features were retained for subsequent quality function deployment (QFD) analysis, reducing the complexity of the relationship matrix while preserving features closely associated with the Kansei requirements.
3. QFD integrated the AHP-derived importance weights of the Kansei requirements with the relationships between the Kansei requirements and the GRA-screened morphological features. The priority morphological feature within each design attribute was identified, resulting in the combination A34, B24, C11, D3, E5, F16, and G3 for the Luohan bed redesign.
4. The proposed redesign retained the characteristic three-sided enclosure of the traditional Luohan bed while simplifying excessive carving and ornamentation. The design evaluation showed higher mean scores for the redesigned Luohan bed across the six Kansei requirements than for the baseline design, indicating an improved balance between traditional identity and contemporary aesthetic preferences. These results provide preliminary support for the applicability of the integrated LDA–GRA–AHP–QFD approach.
5. Overall, the integrated KE–LDA–GRA–AHP–QFD framework was found to provide a systematic and quantitative pathway from Kansei requirement identification and weighting to morphological feature screening, design prioritization, and redesign. By linking users' Kansei requirements with specific morphological features, the

framework supports the contemporary redesign of Luohan beds and provides a transferable methodological reference for other types of traditional Chinese furniture with complex morphological structures and cultural characteristics.

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