

Redesign of the Ming-Style ‘Warped Table’ Based on Kansei Needs of Contemporary Users Using an SD–FA–QFD Method

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For contemporary users’ emotional demands and the promotion of Ming-style furniture, which has cultural value, this paper studies the Ming-style ‘Warped Table’. A systematic re-design process is provided, consisting of Kinaesthetic Engineering (KE), Semantic Differential (SD), Factor analysis, Likert-weighted scoring, and Quality Function Deployment (QFD). Affective assessment was carried out by using SD questionnaires and text mining. Perceptual factor analysis yielded four major dimensions of perception, including ‘Material Warmth’ (29.9%), ‘Functional Serenity’ (25.4%), ‘Resilient Grace’ (22.9%), and ‘Fluid Elegance’ (21.9%). Relative importance was computed by the Likert Weighting method. Afterwards, a ‘sensory demand–design element’ mapping model was created with QFD, in which 7.9% were table-top and 7.2% legs as significant design elements. Modular redesign has been carried out, maintaining the traditional stylistic language “simple, elegant, and graceful” together with the mortise-and-tenon craft, but with new manufacturing logic and user sensory desires. The methodology realizes quantitative analysis and parametric translation of traditional furniture imagery, greatly improving the product’s cultural and emotional display, and gives a series of system references for related design work.

DOI: 10.15376/biores.20.4.10082-10105

Keywords: Ming-style ‘warped’ table; Kansei engineering; Semantic Differential; Factor Analysis; Likert method; Quality Function Deployment

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INTRODUCTION

Since the 21st century, the paradigm of cultural heritage research has shifted from ‘static preservation’ to ‘living transmission’. As outlined in UNESCO’s Convention for the Safeguarding of the Intangible Cultural Heritage, traditional craftsmanship should be integrated with contemporary user experiences and practical needs. The organization stresses that ‘the interaction and perception of people and heritage’ needs to become ‘a central component of cultural heritage research’ (Heritage and Rii 2020). Driven by this, the perspective on traditional furniture research is making big changes all around the world.

To advance the inheritance and innovation of traditional Chinese furniture within contemporary contexts, researchers have undertaken multidimensional explorations centered on form generation, aesthetic evaluation, and intelligent design, yielding preliminary outcomes. For instance, Xue and Chen (2024) used morphological grammar theory and the method of establishing a ‘furniture gene bank’ to innovatively reconstruct traditional Ming-

style ‘Warped Table’. They used questionnaire surveys to show that the design could be done, and they said it should mix changing how things look and what people want the product to do. Bai *et al.* (2024) conducted a questionnaire investigation and data analysis to formulate an ergonomic plan for Ming-style chair design from six angles, namely the chair itself, the aesthetic, safety, comfort, utility, and production. Xia *et al.* (2023) utilized the method of DCGAN and CAD techniques to extract main morphological characteristics from physical pictures of Ming-style furniture, thus obtaining design ideas for combining contemporary styles with ancient ones.

As for research on digital transformation and user-centered traditional furniture design, the above research is a valuable reference, but research on the ‘Warped Table’ as a representative Ming-style furniture in terms of cultural connotation, user emotions, and ‘emotion design’ mapping is still insufficient. In China’s traditional furniture system, Ming-style furniture has gained fame for its brief contours, sturdy frames, and rich cultural relevance; it boasts a high honorific place in world furniture design history. The Ming-style ‘Warped Table’ is one of the classics of the Ming-style furniture. It is characterized by unique decoration and structure. There is a little slope upwards on the table-tops at both ends. It is like eave wings rising upwards, which symbolizes auspiciousness. This embodies the unity between heaven and humanity (Cui *et al.* 2025). The overall shape is simple but rhythmically expressive, often featuring unadorned surfaces or shallow relief carvings (Suhadolnik 2023). It represents a kind of aesthetic of ‘simplify not to be poor’. Structurally speaking, the ‘warped table’ applies mortise and tenon structure. This means that it is joined closely together without any nailing nor glue. This brings together both practicality and the zenith of artistic craft.

The present work is a study of a Ming-style ‘warped table’, based on KE theory. A ‘perceptual imagery –design element’ mapping model is established, aiming to reveal the relational pathway between user perceptual cognition and designed products. The research included four stages: Firstly, collecting emotional experiences while using ‘Warped table’ through questionnaires for the target group; Secondly, transforming the emotional data into numeric information with the help of SD and Likert Scale; Thirdly, analyzing the emotional data with FA to distill the internal structure of sense needs; Fourthly, mapping between users emotional needs and design elements with QFD. This study provides a theoretical basis for the modern renovation of the ‘warped table’. This approach can help to create and preserve traditional furniture that is suitable for contemporary society.

In addition, this research employed the modular design idea and disassembles the ‘Warped Table’ structure into typical elements comprised of table-top, yatiao, yatou, chengzi and leg. The procedures followed basic mortise-and-tenon rules but explored flexibility and optimization paths for modern industry production. Such a strategy not only greatly improves the batch processing efficiency and assembly flexibilities of the components, but it also makes full use of advanced manufacturing technologies such as CNC to maintain as much as possible of those key structural features and cultural meanings contained in the traditional mortise and tenon craftsmanship. Thus, it can give good technical support for both modern presentation and passing on of traditional craftsmanship in a sustainable manner.

This research is mainly about:

(1) Pioneering the integration of KE and QFD methodologies in the design of Ming-style ‘Warped Table’ furniture, enabling the quantitative modelling of emotional requirements.

(2) Proposing of a modular redesign framework for Ming-style ‘Warped Table’, advancing the integration of traditional structural techniques with modern manufacturing logic.

(3) Established a systematic translation mechanism linking emotion, design, and manufacturing, charting a path for the re-creation of traditional craftsmanship in the digital era.

(4) Addressing the contemporary imperative of ‘heritage preservation and innovation’ in traditional furniture, expanding the theoretical boundaries of cultural heritage design methodologies.

LITERATURE REVIEW

Applications of Kansei Engineering in Furniture Design

Kansei Engineering (KE), introduced by Nagamachi (1995), is a user-oriented design methodology. Its core lies in taking user needs as the foundation, transforming consumers’ subjective perceptions and emotional experiences into quantifiable data, and systematically integrating them into the product design process (Schütte *et al.* 2004). By constructing a mapping relationship between ‘emotions and design elements,’ KE not only enhances the human-centered quality of products but it also shifts design decisions from a purely functional orientation to an emotion-driven approach, thereby effectively addressing users’ deeper psychological and emotional needs.

In recent years, KE has been widely used in many fields: transportation industry, home appliances industry, clothing industry, and furniture industry, showing an inter-disciplinary integration trend. In the transportation sector, Kikumoto *et al.* (2021) incorporated KE with human factors engineering methodologies to improve the placement of automotive seat adjustment levers. The group used a Semantic Differential Scale to collect subjective information from participants of different genders and heights, utilizing LOES regression and the random forest algorithm to develop a mathematical model connecting various lever positions and user satisfaction. Within the household appliances sector, Wang *et al.* (2021) applied KE to guide the aesthetic design of portable desktop air purifiers. Affective features are extracted through SD and FA, and the mapping from design variables to affective imagery is constructed by means of partial correlation analysis. Design proposal practicalities were eventually confirmed effective. Within apparel design, Wei *et al.* (2025) constructed an affective clothing evaluation framework with the SD method, converting traditional symbols into intelligent recommendation systems efficiently. Thus, KE has demonstrated potential for use in interdisciplinary contexts. In furniture design, Jing *et al.* (2024) integrated KE with morphological syntax to translate the sloping ridge elements of ‘flying eaves and ridges’ of Suzhou-style residential architecture into a furniture design language. This approach, alongside affective vocabulary gave way to a few design proposals for evaluation. Zhou *et al.* (2023) used KE along with grey relational analysis to create a mapping model that connects design parts with emotions evoked by imagery. Then they used fuzzy logic optimization methods to make an electric recliner work better. Lei *et al.* (2024) combined the thinking of KE with psychophysiological measuring ways, taking the Ming-style official’s hat chair as the example to look into how the design parts of a chair can change the way the person feels when using it.

In summary, the application of KE in furniture design is progressively expanding from the level of visual form to encompass multi-sensory experiences and psychophysiological responses, propelling furniture design towards higher levels of emotional

integration and intelligence. Building upon this, this paper introduces KE as a theoretical foundation, aiming to achieve precise alignment between users' subjective affective needs and key design elements of the 'Warped Table' (such as table-top, yatiao, yatou, chengzi, and leg). It further explores the deep-seated connection mechanisms between traditional craftsmanship language and modern aesthetic psychology, providing systematic theoretical support and practical pathways for the affective redesign of traditional furniture.

Summary of Methods Employed in Related Studies

In the use of Kansei Engineering oriented design studies, Kansei Engineering oriented design studies use the semantic differential (SD), factor analysis (FA), Likert scale, and quality function deployment (QFD). These four together can comprise a systematic link chain from the generation of emotional images to the transformation of design elements, not only quantifying users' affective demands, but also providing an engineering route for product design driven by emotions. Its preliminary success can be seen from some studies.

Firstly, as the quantitative starting point for sensory imagery in affective design, the SD scale was originally proposed by Osgood *et al.* (1957). He built several pairs of bipolar adjectives such as 'good–bad', 'soft–sharp', 'traditional–modern' to evaluate people's emotions about a particular target. Such an approach is good for the evaluation of aesthetic and cultural values of products such as furniture. Its simplicity of operation and widespread applicability are its advantages. In KE studies, SD scale is usually adopted as the main way of getting emotional information at first. For example, Dasmeh *et al.* (2024) compared differences in subjective rating distributions between discrete and analogue SD scales, suggesting that different SD scale types may introduce systematic biases. González *et al.* (2024) combined the SD scale with PCA and logistic regression to quantify users' emotional responses to video game controller designs, establishing a mapping model between emotional evaluations and geometric parameters. Gao *et al.* (2024) combined SD methods with pair-wise comparison and physiological indicators, namely skin conductance and heart rate, to show important connections between material properties (friction coefficient, surface roughness) and people's psychological and physiological reactions, as expressed in their emotions. Yohanny and Mulyono (2025) applied the SD scale and PCA as affective vocabulary classification in train carriage design. And then together with cluster analyses, a linear shape, green color themes, and pine woods were incorporated into the design.

Secondly, FA is often used as a common post-SD action to produce shorter lists of representatives latent variables from long lists of emotional states. FA looks at how each factor is related to each other within a set of factors. In this way, it extracts a reduced number of factors that expose the structure and dimensions for emotional cognition. Choi *et al.* (2024) applied FA to classify adjectives to 2 factors 'stability' and 'preference', thereby improving explainable of emotional dimension. Choudhury *et al.* (2023) applied a semi differential scale to evaluate teachers' attitude towards less-favored students. Three main beliefs were extracted by means of FA to evaluate the structural validity of the instrument. Bing *et al.* (2025) used FA to filter out affective factors, used SD+TOPSIS to optimize affective vocabulary, and then used a KE-GAN fusion to propose product designs that align well with user emotional needs.

After the important emotional triggers have been determined, a Likert scale is used to determine just how much someone would prefer one design solution to another. The

Likert scale was developed in 1932 by Likert (1932), and it is a common attitude measurement in psychology and social sciences as well as design. It is mainly concerned with creating multilevel rating scales to determine how much agreeing or liking a particular statement or attribute there is among the respondents. Compared with merely dividing into yes and no, the Likert scale reflects a finer difference of attitude. For instance, Restuputri *et al.* (2022) combined the Likert scale with conjoint analysis to pinpoint preference attributes for last-mile delivery services (such as ‘goods integrity,’ and ‘delivery personnel’s attitude’) which are regarded as factors that determine customers’ satisfaction. Zhang *et al.* (2023). By using Likert scales together with implicit measurement method (*e.g.* EEG, Eye-Tracking), the authors uncover user’s emotional response characteristics during their product form perception process, thereby making form design evaluations more scientific and objective (Gong *et al.* 2022). By employing Likert scales combined with cluster analysis, this study distilled key affective terms for bamboo pen holder design. Sequential quadratic programming was used to optimize the form, validating the KE–DT framework’s applicability in sustainable product design.

Finally, QFD was employed to systematically translate emotional factors into actionable design parameters. This approach was proposed by Mizuno and Akao (1978). It is centered on the ‘voice of customer,’ and arranges such technical input in an organized way. Its main tool, the ‘quality house,’ sets up a two-way relationship table involving customer needs and product design characteristics. This converts vague user choices into precise engineering statistics, guaranteeing design outputs closely align with user expectations. Tri Ummarta *et al.* (2024) employed Quality Function Deployment (QFD) within coffee packaging design. By comprehending consumers’ multidimensional emotional needs, the cited research achieved visual and functional optimization of packaging design. Fu *et al.* (2024) utilized HF-QFD to construct a hesitation-fuzzy matrix, enabling precise mapping from customer requirements (CRs) to engineering characteristics (ECs). This enhances the emotional value and user satisfaction of rosewood furniture. Wang *et al.* (2024) employed QFD to integrate affective factors with product identification characteristics, combining Sketching Generation (SG) and Midjourney for sketch generation. This ultimately achieved alignment between emotional needs and product form in the design of women’s electric lightweight motorcycles.

In summary, the affective engineering methodology chain, which is comprised of SD, followed by FA, then Likert scale, and lastly QFD, has shown great adaptability and scientific validity for many types of designs, producing especially significant results in terms of aesthetic design of product, design of product structure, and alignment of user emotion with the product. But these kinds of methods have not been systematically used on traditional furniture types such as the Ming Dynasty’s ‘Warped Table’, which are full of deep cultural symbolism and complex structural logic. This deficiency manifests itself in three key aspects: Firstly, there is currently no systematic model capable of achieving precise mapping between users’ emotional imagery and critical form details of the ‘Warped Table’. The above-mentioned methodological sequence was used in this work to form the traditional formal language-redesign system-user emotive cognition-modern engineering logic. It can be regarded as the theoretical basis and possible ways of contemporary interpretation of the ‘Warped Table’ to encourage interdisciplinary and comprehensive improvement in contemporary traditional furniture design.

EXPERIMENTAL

Research Framework

This study takes the Ming-style ‘Warped Table’ as a representative research subject, establishing a systematic redesign process that integrates affective ergonomics theory with multiple quantitative analysis tools. The overall research methodology follows the logical sequence: ‘SD→FA→Likert Weighting Method→QFD→Design Proposal Generation and Validation’. The goal is to achieve precise mapping of users’ affective needs onto the ‘Warped Table’ form, structure, and craftsmanship design parameters. The research technical pathway is illustrated in Fig. 1.

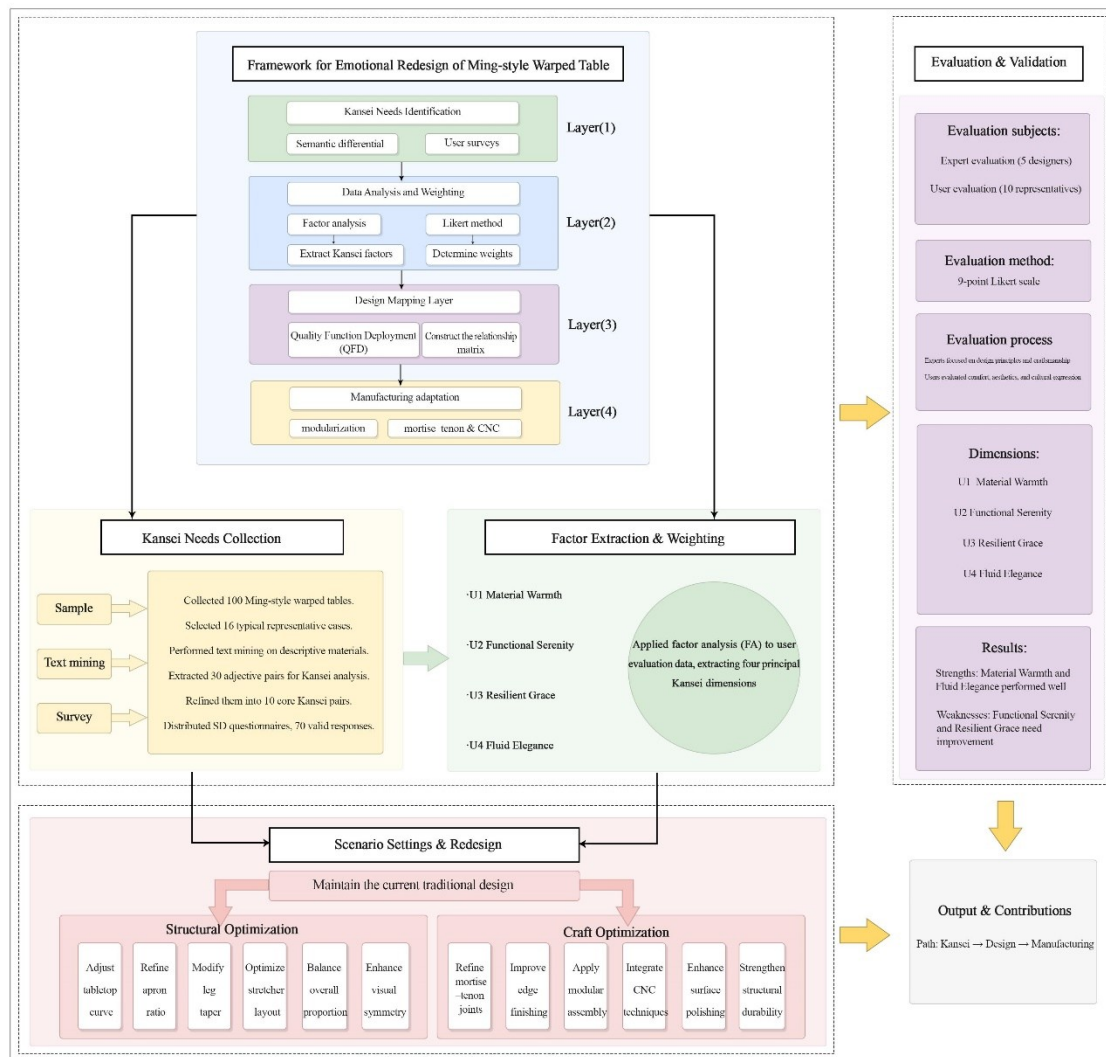


Fig. 1. Design Framework

Specific steps are as follows:

(1) Carry out a review of the literature, interview experts, and conduct user surveys, collecting text-based sensory description related to the raised-front desk. Employ text analysis methods to extract key sensations' vocabulary and set up an initial sample repository for sensory imagines.

(2) Employ a nine-level semantic differential (SD) scale to quantitatively collect users' emotional evaluation data regarding form characteristics.

(3) Conduct reliability and validity tests on the collected data. Use factor analysis (FA) to identify core affective factors such as rustic charm, stability, and refinement. Simultaneously, the table will be structurally decomposed into component units: such as table-top, yatou, chengzi, and leg.

(4) Utilize the Likert weighted method to determine the importance of weightings of each sensory factor and employ a Quality Function Deployment (QFD) system to establish mappings between sensory factors and design elements, thereby translating emotional requirements into specific engineering parameters.

(5) Based on the analysis, generate multiple design proposals. These will be validated and optimized through user evaluation experiments, ultimately yielding 'Warped Table' design that embodies Ming-style form language while satisfying contemporary users' emotional needs.

Data Collection

A search was conducted for relevant literature and documents about Ming style 'warped table' on search engines including Baidu and Google, as well as professional books such as *Research on Ming-style Furniture*, *Illustrated Handbook of Chinese Classical Furniture*, and visual materials published by organizations like the Palace Museum. After removing the duplicated images due to color interference, Photoshop was used for blurring the backgrounds and creating clear high-resolution images for later morphological feature analysis and perception evaluation. Ultimately 100 Ming-Style 'Warped Table' samples were selected, as can be seen from Fig. 2.

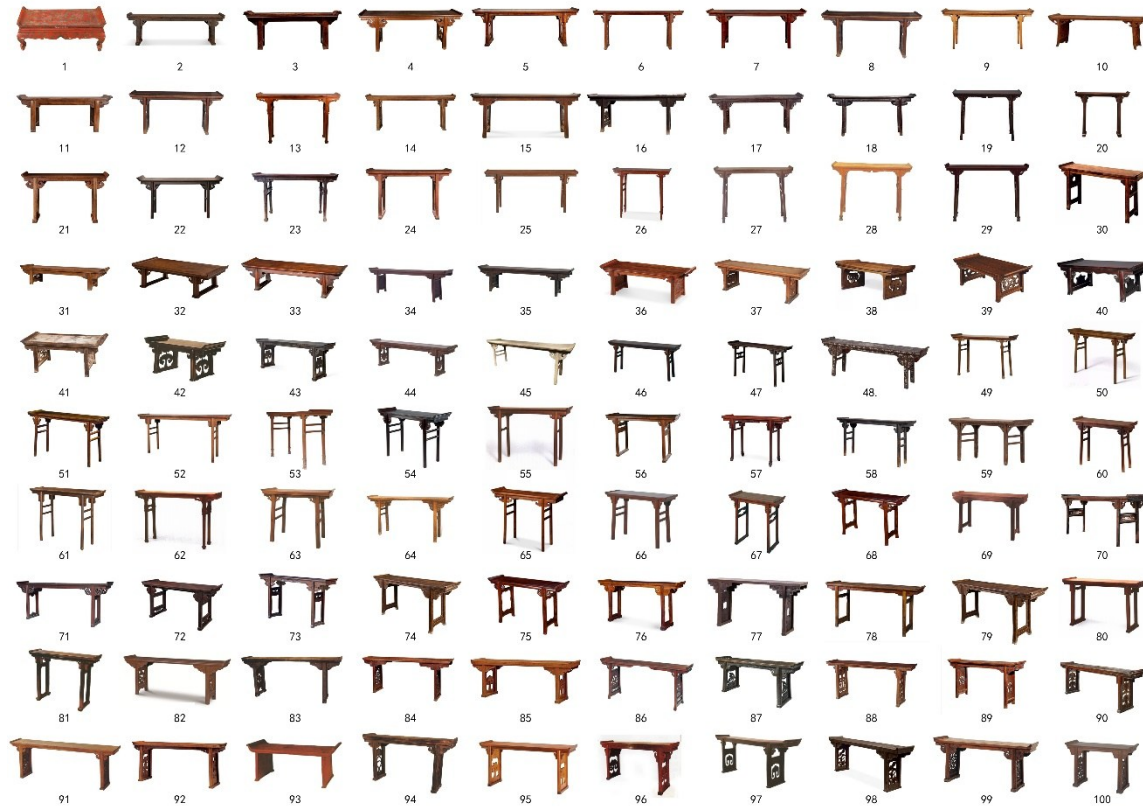


Fig. 2. Sample diagram of Ming-Style 'Warped Table'

To guarantee the representativeness of the sample and its academic nature, the researcher invited five university classic Chinese furniture design and craftsmanship professors, three senior furniture designers, and two furniture sales practitioners to thoroughly review the initial 100 Ming 'Warped Table' samples. Selection criteria included that the samples should possess the characteristics of Ming furniture, which are simplicity, refinement, and elegance. The structures should present good preservation, structural integrity, clear period, and craft. Additionally, components such as table-top should exhibit different forms and obvious variations to reflect morphological differences. Ultimately, 16 representative samples (Fig. 3) were selected as the main objects of research for this paper.



Fig. 3. Sample Diagram of Screened the 'Warped Table'

The research aimed at creating an affective vocabulary database about the Ming-style 'Warped Table,' which will record the semantic evaluation of users in order to be references for the making process: In order to accomplish this goal, the research process was done in 3 phases: Firstly, selecting Ming-style 'Warped Table' as the keyword, around 240,000 characters of text information were collected in many ways such as online resources, printed works, and industry promotion material. Afterwards, an ROST text analysis system was employed for semantic mining, resulting in 30 tentative affective term pairs. Then 15 furnishing design experts were asked to judge how relevant these term pairs were to the Ming dynasty 'Warped Table.' Conceptual integration was carried out on phrase sets with high semantic overlap and deleting the invalid data nodes that exceeded the predefined dispersion value. Ultimately, these top ten core pairs of affective terms were considered to be the main representations of the affectionate feature of the Ming-style 'Warped Table,' as shown in Table 1.

Table 1. Perceptual Vocabulary

No.	Perceptual Vocabulary	No.	Perceptual Vocabulary
1	Rustic - Ornate	6	Soft edged - Hard edged
2	Understated - Opulent	7	Sleek - Sturdy
3	Durable - Delicate	8	Serene - Vibrant
4	Warm - Cool	9	Utilitarian - Decorative
5	Fluid - Angular	10	Stable - Dynamic

Semantic Differential (SD)

The participants in the survey were a mixture of undergraduate and graduate students, faculty, and furniture designers. The questionnaire was distributed *via* an online platform with an explanation of the goals of the study, the introduction to the scoring mechanism, and explanation on how to fill out the questionnaire were given. Participants had to assess the provided adjectives based on a sample of the ‘Warped Table’—a Ming-style piece. In the study, an affective quantitative measurement was made using the Semantic Differential Scale.

There were 9 levels in this scale going from -4 to 4, where 0 signified being neutral. Positive and negative values indicated the degree to which participants were inclined towards a particular affective term. The first part of the questionnaire contained ten fundamental pairs of antonyms (see Table 2). Each pair was given a score on a nine-point scale. This was done to determine what people thought and felt about different morphological features. A total of 96 questionnaires were distributed, of which 70 effective questionnaires were returned. Statistical analysis was done using the average scores on each of the affective terms (Table 3).

Table 2. Questionnaire Settings

	Perceptual Vocabulary	-4 -3 -2 -1 0 1 2 3 4	Perceptual Vocabulary
	Rustic	-4 -3 -2 -1 0 1 2 3 4	Ornate
	Understated	-4 -3 -2 -1 0 1 2 3 4	Opulent
	Durable	-4 -3 -2 -1 0 1 2 3 4	Delicate
	Warm	-4 -3 -2 -1 0 1 2 3 4	Cool
	Fluid	-4 -3 -2 -1 0 1 2 3 4	Angular
	Soft edged	-4 -3 -2 -1 0 1 2 3 4	Hard edged
	Sleek	-4 -3 -2 -1 0 1 2 3 4	Sturdy
	Serene	-4 -3 -2 -1 0 1 2 3 4	Vibrant
	Practical	-4 -3 -2 -1 0 1 2 3 4	Decorative
	Stable	-4 -3 -2 -1 0 1 2 3 4	Dynamic

Table 3. The Average Value of Perceptual Vocabulary in Samples

	Rustic - Ornate	Understated - Opulent	Durable - Delicate	Warm - Cool	Fluid - An- gular	Soft edged - Hard edged	Sleek - Sturdy	Serene - Vibrant	Utilitarian - Decorative	Stable - Dynamic
A1	-2.20	-1.47	-1.76	-2.17	-1.76	1.29	-1.84	-2.11	-2.00	-1.67
A2	-1.96	-1.81	-2.20	-1.89	-2.20	1.51	-1.61	-2.19	-2.17	-2.21
A3	-2.03	-1.43	-1.54	-1.97	-1.54	1.97	-1.61	-1.97	-1.71	-1.39
A4	-1.81	-1.90	-1.77	-2.13	-1.77	1.71	-2.10	-1.64	-1.51	-1.33
A5	-1.41	-1.70	-1.99	-2.00	-1.99	2.03	-2.47	-1.49	-2.07	-1.83
A6	-1.49	-1.53	-1.87	-1.80	-1.87	1.81	-2.06	-2.06	-1.84	-1.54
A7	-1.49	-1.60	-1.29	-2.06	-1.29	1.29	-1.97	-2.06	-1.97	-2.23
A8	-1.97	-1.70	-2.36	-2.20	-2.36	1.79	-2.00	-1.76	-1.66	-1.27
A9	-1.71	-1.69	-2.40	-1.59	-2.40	2.40	-2.10	-1.67	-1.86	-2.04
A10	-2.19	-1.96	-2.04	-2.00	-2.04	2.33	-1.91	-1.86	-1.59	-1.66
A11	-1.56	-1.14	-1.84	-2.04	-1.84	1.54	-2.14	-1.67	-1.81	-1.77
A12	-1.91	-1.99	-1.77	-1.59	-1.77	1.59	-1.73	-1.44	-1.81	-1.61
A13	-1.80	-1.77	-1.56	-1.84	-1.56	1.91	-2.09	-2.24	-1.94	-1.91
A14	-1.84	-2.00	-2.01	-1.94	-2.01	1.99	-2.20	-1.79	-1.94	-1.60
A15	-1.84	-1.61	-1.67	-1.86	-1.67	1.69	-1.89	-1.44	-1.87	-1.89
A16	-1.81	-2.44	-2.07	-2.16	-2.07	1.30	-1.99	-1.47	-1.96	-1.41

Factor Analysis (FA)

Subsequently, the 70 sets of valid questionnaire responses obtained were used to carry out an appropriate test. The results showed a Kaiser-Meyer-Olkin (KMO) sampling adequacy value of 0.906, which indicated that there were good inter-variable correlations and suitable for factor analysis. Bartlett's Sphericity test gave a Chi-Square value of 291.224 with 45 degrees of freedom and a p-value < 0.001 . This showed strong correlations among the data, and the prerequisite for factor analysis was met. All these assessments on reliability and validity indicate that the reliability of the questionnaire's statistical foundation was solid. Thus, a good basis was formed for performing the analysis (Table 4).

Table 4. KMO And Bartlett's Test of Sphericity

KMO and Bartlett's Test of Sphericity		
KMO Sample Suitability Quantity		0.906
Bartlett's test of sphericity	Chi-square approximations	699.353
	Degrees of freedom	45
	Significance	< 0.001

In principal component analysis, the maximum variance orthogonal rotation method was employed to extract factors from the scale data, thereby obtaining the common factor variance values for each observed variable. Variance commonality, as a key statistical indicator within the factor loading matrix, reflects the extent to which common factors explain the variance of observed variables. It is generally accepted that when the commonality approaches 1, the extracted latent factor adequately explains the variability of the original variables, with an explanatory rate exceeding 85%, indicating a factor structure with strong explanatory power (Rahman *et al.* 2021). As can be seen from Table 5, the commonality values for all variables were between 0.814 and 0.955. The extracted factors showed a high variance over the observed variables. This means that it's reasonable to say that the factor model structure is accurate. This validates the validity and statistical reliability of the factor analysis results in this paper.

Table 5. Common Factor Variance

Perceptual Vocabulary	Initial	With-draw	Perceptual Vocabulary	Initial	With-draw
Rustic - Ornate	1.000	0.903	Soft edged - Hard edged	1.000	0.903
Understated - Opulent	1.000	0.955	Sleek - Sturdy	1.000	0.913
Durable - Delicate	1.000	0.878	Serene - Vibrant	1.000	0.814
Warm - Cool	1.000	0.899	Utilitarian - Decorative	1.000	0.865
Fluid - Angular	1.000	0.898	Stable - Dynamic	1.000	0.904

To determine the number of principal components to extract, a combined approach was followed using both the table of total variance explained and the scree plot. According to the data in Table 6, four principal components had eigenvalues greater than 1, satisfying Kaiser's criterion (Kaiser 1958). It first was confirmed that 4 principal components were extracted. The scree plot (Fig. 3) indicates that there were different parts of the data with distinct phases in the curvature.

Table 6. Explanation of Total Variance

Ingredient	Initial Eigenvalue			Extract the Sum of Squares			Rotational Load Square Sum		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.336	73.356	73.356	7.336	73.356	73.356	2.667	26.669	26.669
2	0.735	7.346	80.703	0.735	7.346	80.703	2.266	22.662	49.331
3	0.468	4.675	85.378	0.468	4.675	85.378	2.045	20.451	69.782
4	0.393	3.925	89.303	0.393	3.925	89.303	1.952	19.522	89.303
5	0.277	2.767	92.071						
6	0.237	2.367	94.437						
7	0.179	1.791	96.228						
8	0.163	1.631	97.859						
9	0.130	1.301	99.160						
10	0.084	0.804	100.000						

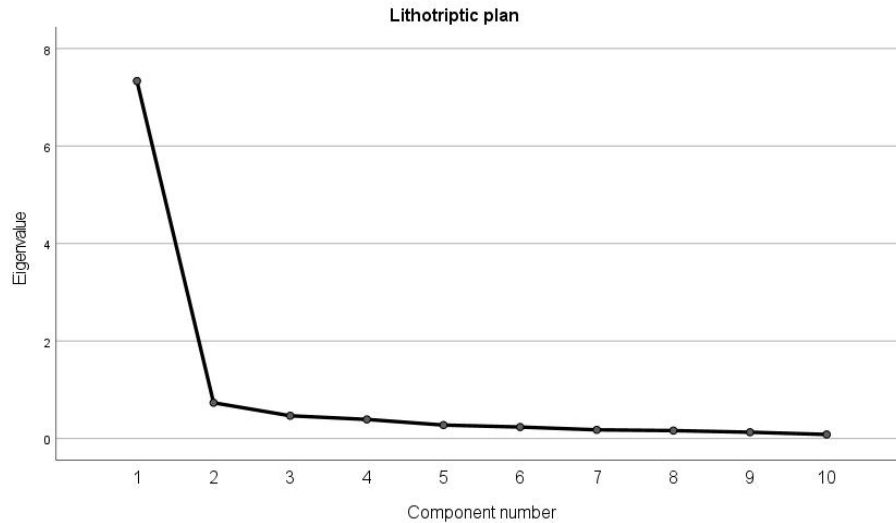


Fig. 4. Gravel diagram

The values for the 1st, 2nd, 3rd, and 4th phases were much greater than all others, as can be seen by the curve levelling off at around the 4th component, where there was an inflection point. Based on the Scree plot principle (Cattell 1966), the fourth eigenvalue point in the plot indicates the threshold where the explanatory power started to decrease. After which, the explanatory strength of following principal components started to converge, so further components only offered minor contributions to the total variance. In conclusion, according to the statistical measurement metrics and graph analysis, components 1, 2, 3 and 4 were the main factors for the study.

To present the sensory cognitive dimensions embodied by the four principal factors more intuitively, categorization and interpretation were conducted based on the rotated component matrix (see Table 7), arranging sensory vocabulary by factor loadings from highest to lowest.

Table 7. Rotated Composition Matrix Table

Perceptual Vocabulary	Principal Component			
	1	2	3	4
Rustic - Ornate	0.759			
Understated - Opulent				0.863
Durable - Delicate			0.710	
Warm - Cool	0.842			
Fluid - Angular				0.698
Soft edged - Hard edged	0.785			
Sleek - Sturdy			0.764	
Serene - Vibrant		0.590		
Utilitarian - Decorative		0.752		
Stable - Dynamic		0.740		

Results indicates that Principal Component Factor 1 was centered on materiality and tactile dimensions, encompassing terms such as: ‘Rustic – Ornate’, ‘Warm – Cool’, ‘Soft edged – Hard edged’, reflecting users’ perceptions of furniture texture, thermal sensation, and edge tactile characteristics. Factor 2 represented the ambience and functionality dimension, primarily encompassing: ‘Serene – Vibrant’, ‘Utilitarian – Decorative’, and ‘Stable – Dynamic’, revealing users’ sensory judgements regarding the atmosphere created by furniture and the balance between its practicality and decorative qualities. Factor 3 pointed to the structural and form dimension, encompassing terms such as: ‘Durable – Delicate’ and ‘Sleek – Sturdy’, emphasizing the visual and structural robustness and refinement of furniture. Factor 4 concerned the style and line dimension, with terms including: ‘Understated – Opulent’ and ‘Fluid – Angular’, reflecting users’ subjective perceptions of furniture style characteristics and the fluidity of its lines. All extracted factor loadings exceeded 0.550, indicating strong statistical correlations between each sensory term and its assigned factor, demonstrating the factor structure possesses sound explanatory validity.

Design Requirements Acquisition

Building upon the aforementioned factor analysis, the research team further screened and consolidated pairs of emotive terms based on user ratings, ultimately identifying ten representative vocabulary items (Shin *et al.* 2020). These were: ‘rustic’, ‘understated’, ‘durable’, ‘warm’, ‘fluid’, ‘soft edged’, ‘sleek’, ‘serene’, ‘utilitarian’, and ‘stable’. On this basis, the research team, by integrating factor attribution with semantic connotations and referring to the FA results, categorized the ten groups of perceptual terms into four core perceptual dimensions: U_1 (*Material Warmth*), which includes ‘rustic,’ ‘warm,’ and ‘soft edged,’ emphasizing material tactility and a gentle, warm quality; U_2 (*Functional Serenity*), encompassing ‘serene,’ ‘durable,’ and ‘stable,’ highlighting functionality and a sense of calm order; U_3 (*Resilient Grace*), composed of ‘sleek’ and ‘utilitarian,’ reflecting structural resilience combined with elegant proportions; and U_4 (*Fluid Elegance*), including ‘understated’ and ‘fluid,’ which express stylistic simplicity and the fluidity of lines. These dimensions not only establish a user perception framework for the Ming-style warped table but also provide semantic support for its future design language.

Subsequently, the percentage variance of the rotary load sum of squares was employed as the basis for factor importance. The contribution rates of the first four perceptual factors were normalized to ensure their combined weights sum to 1 (Li *et al.* 2025). Accordingly, the weights for the four core perceptual dimensions were: $U_1=0.299$, $U_2=0.254$, $U_3=0.229$, and $U_4=0.219$. To further quantify the relative importance of each perception factor in user evaluations, this study invited 10 experts in furniture design and 5 Ming-style furniture collectors to rate the four perception factors using the 9-point scale method shown in Table 8, yielding the user demand importance scores (Table 9).

Table 8. 1-9 Point Scale Method

Scale	Connotation
1	The former is as important as the latter
3	The former is slightly more important than the latter
5	The former is clearly more important than the latter
7	The former is significantly more important than the latter
9	The former is considerably more important than the latter
2, 4, 6, 8	The median of two adjacent factor judgments
The inverse of the above value	The inverse comparison of the two factors is the reciprocal of the original comparison value

Table 9. User Requirement Importance for the Four Perceptual Dimensions

Symbol	Customer Requirement	Requirement Weight U_i	Requirement Importance (Score)
U_1	Material Warmth	0.299	9.0
U_2	Functional Serenity	0.254	7.6
U_3	Resilient Grace	0.229	6.9
U_4	Fluid Elegance	0.219	6.6

Quality Function Deployment (QFD)

Building upon the identification of users' sensory requirements and their respective importance, this study employed Quality Function Deployment (QFD) to construct a Quality House linking sensory requirements to engineering characteristics. This facilitates the operational translation from abstract concepts to quantifiable parameters. First, based on 16 representative Ming-style raised-front desks from the sample repository, the furniture was subjected to component-based analysis with standardized terminology (Zhang and Song 2016), primarily dividing it into five sections: table-top (T1–T8), yaitiao (Y1–Y6), yatou (YA1–YA13), chengzi and panels (C1–C11), and legs (L1–L5) (see Fig. 5). Subsequently, a panel of ten furniture designers was convened to evaluate the relationship matrix using a symbolic scoring method: ○ = 1 point, □ = 3 points, ▲ = 5 points, with blank entries scoring 0 points. The absolute and relative weights for each engineering characteristic were calculated using the following formula:

$$W_j = \sum_{i=1}^q W_i P_{ij} \quad (1)$$

$$W_k = \frac{W_j}{\sum_{j=1}^q W_j} \quad (2)$$

In Eqs. 1 and 2, W_j denotes the absolute weight value in the Quality House; W_i represents the importance of user perceptual requirements; P_{ij} indicates the relationship strength correlation value between the i -th user requirement and the j -th engineering characteristic; W_k signifies the relative weight value in the Quality House.

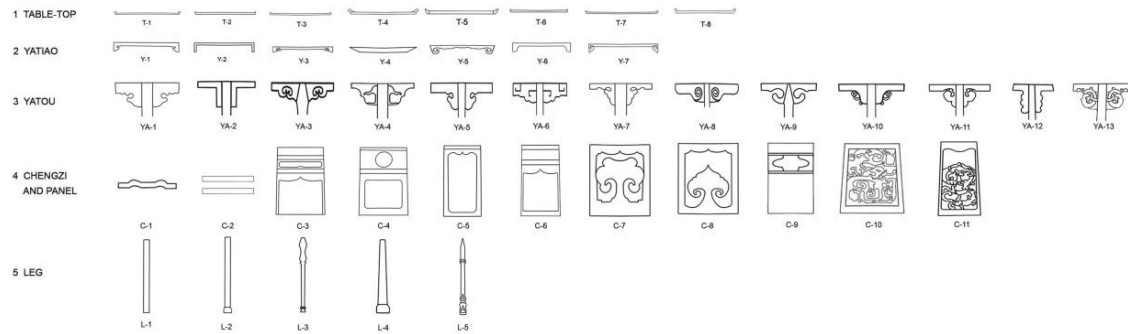


Fig. 5. Morphological analysis of Ming-style 'warped table'

Table 10. Correlation Degree of Quality House

Design Requirements	Demand Factors	U ₁	U ₂	U ₃	U ₄	Absolute weight	Relative weight (%)	Rank
	Importance	9	7.6	6.9	6.6			
1 TABLE-TOP	T-1	▲	▲	▲	▲	150.50	7.94	1
	T-2	○		□	○	36.30	1.91	13
	T-3	▲	▲	▲	□	137.30	7.24	2
	T-4		□	○	○	36.30	1.91	14
	T-5				□	19.80	1.04	26
	T-6	○	○			16.60	0.88	28
	T-7	▲	□	▲	▲	135.30	7.14	4
	T-8	□	▲	□	□	105.50	5.56	9
2 YATIAO	Y-1	○		○	○	22.50	1.19	23
	Y-2	○		□	□	49.50	2.61	12
	Y-3	○				9.00	0.47	35
	Y-4		○	○	□	34.30	1.81	15
	Y-5					0.00	0.00	42
	Y-6	▲	□	□	□	108.30	5.71	8
	Y-7	▲	□	□	▲	121.50	6.41	7
3 YATOU	YA-1				○	6.60	0.35	39
	YA-2		○	○		14.50	0.76	34
	YA-3	○	○			16.60	0.88	28
	YA-4	○				9.00	0.47	35
	YA-5	□	▲	□	○	92.30	4.87	10
	YA-6	○	○	○	○	30.10	1.59	16
	YA-7		○			7.60	0.40	37
	YA-8	○		○	○	22.50	1.19	23
	YA-9	○	○	○		23.50	1.24	20
	YA-10					0.00	0.00	42
	YA-11	□				27.00	1.42	19
	YA-12		○	○	○	21.10	1.11	25
	YA-13	○		○		15.90	0.84	32
4 CHENGZI AND PANEL	C-1	▲	□	▲	□	122.10	6.44	6
	C-2			○		6.90	0.36	38
	C-3				○	6.60	0.35	39
	C-4				○	6.60	0.35	39
	C-5	▲	▲	□	□	123.50	6.51	5
	C-6				□	19.80	1.04	26
	C-7	□	○		□	54.40	2.87	11
	C-8	○	○			16.60	0.88	28

	C-9		□			22.80	1.20	22
	C-10		○		□	27.40	1.45	17
	C-11	○	○		○	23.20	1.22	21
5 LEG	L-1	○	○			16.60	0.88	28
	L-2	▲	▲	□	▲	136.70	7.21	3
	L-3					0.00	0.00	42
	L-4		○		□	27.40	1.45	17
	L-5	○		○		15.90	0.84	32

The weight data obtained from the Quality House was tabulated (Table 10). It is evident that the relative weight of table-top T-1 was 7.94%, ranking first, primarily due to its strong correlations with U_1 and U_4 , indicating that the curvature and surface finish of the table-top directly influence users' perceptions of warmth and fluidity of lines. The relative weight of the T-3 was 7.24%, ranking second. It exhibited strong correlations with U_2 and U_3 , reflecting the crucial role in maintaining structural stability and refined proportions. The relative weight of leg L-2 stood at 7.21%, ranking third. Its lines, thickness, and tapered features significantly influenced the sensory perceptions of 'steadfast tranquility' and 'resilient dignity', embodying a unity of stability and elegance. T-7 (7.14%) and C-5 (6.92%) ranked fourth and fifth respectively. Though secondary components, they still played a supplementary role in the dimensions of 'leisurely charm' and 'unadorned refinement'. Overall, the table-top and leg components exhibited the highest coverage across the four major perceptual dimensions, constituting the key factors influencing users' emotional experience.

DESIGN PRACTICE AND DISCUSSION

Design Practice

Based on the QFD analysis results, this study identified the table-top (T-1, 7.94%), and legs (L-2, 7.21%)—the components with the highest relative weightings—as the primary focus for optimization. These three elements ranked highest in relative weighting, corresponding respectively to material warmth, structural stability, and refined proportions. As they exerted the most significant influence on the user's overall perception, they became the core components for redesign. The final solution is shown in Fig. 6.



Fig. 6. Design renderings of Ming-style 'warped table'

The solution builds upon the Ming-style 'Warped Table' traditional aesthetic of simplicity, refinement, and elegance, while implementing detail optimizations guided by sensory imagery for these key components. Firstly, the table-top (T-1) features moderately enhanced curvature and rounded edges to amplify the perceptual effects of U_1 (*Material Warmth*) and U_2 (*Fluid Elegance*). This design preserves the upright proportions characteristic of Ming furniture while imparting a softer, more fluid visual impression. Secondly, the yatiao (Y-7) was refined in proportion and thickness to achieve structural integrity while presenting a slender, elegant profile, reinforcing the sensory values of U_3 (*Resilient Grace*) and U_4 (*Functional Serenity*). Moreover, the leg design (L-2) employs a tapered form strategy, balancing structural integrity with visual lightness. This approach fulfils functional expectations for support while enhancing the overall elegance of the lines. Finally, auxiliary components such as the chengzi (C-5) and yatiao (YA-5) echo perceptual dimensions like U_1 and U_2 through their decorative details and curved treatments, further reinforcing the cultural imagery and visual harmony of the overall design.

Design Evaluation

To verify the effectiveness of the redesigned scheme, five furniture designers and ten user representatives were invited to evaluate the Ming-style 'Warped Table'. The evaluation was based on the four core perceptual dimensions extracted through prior factor analysis, which together form a multi-layered framework of user experience: U_1 (*Material Warmth*) reflects the warmth, rusticity, and affinity conveyed by the furniture, primarily associated with the tactile qualities of natural wood and its gentle connotations; U_2 (*Functional Serenity*) emphasizes the psychological sense of stability and practicality during use, highlighting the integration of functionality and tranquility; U_3 (*Resilient Grace*) concerns the balance between solidity and elegance achieved on both structural and visual levels, embodying the aesthetic tension between robustness and delicacy; and U_4 (*Fluid Elegance*) describes the fluidity of the overall form and the elegance of its lines, reflecting a lively, implicit, and rhythmic visual experience.

The test was conducted in two teams, the expert group, made up of 5 experienced professionals in both traditional furniture and modern design, looked at design standards

and novelty; the user group, comprised of 10 people of different ages, genders, and degrees of familiarity with traditional furniture, supplied feedback based on practical use and feeling. Participants rated the performance of the redesigned table on the four perceptual dimensions using a nine-point Likert scale, 1 = ‘completely dissatisfied’ & 9= ‘completely satisfied’. Calculating the average of each indicator comprehensively reflects the affective matching effect and overall satisfaction of the redesign scheme. Result is given in table 11.

Table 11. Design Evaluation Scoring

	U ₁	U ₂	U ₃	U ₄
Average User Score	4.6	5.9	5.5	5.6
Average Designer Score	5.8	4.4	4.8	5.3

The questionnaire results show that the redesigned Ming-style ‘Warped Table’ received high evaluations in terms of emotional expression and aesthetic appeal, particularly in *U₁* (*Material Warmth*) and *U₄* (*Fluid Elegance*), where both experts and users expressed consistently positive feedback. Specifically, in *U₁*, the average user score was 4.6 and the designer score was 5.8, indicating that the design effectively conveyed the warmth and affinity of traditional wooden furniture. The performance of *U₄* was similarly strong, demonstrating the design’s aesthetic ability to shape fluid lines and elegant forms. However, the evaluation also revealed room for improvement in *U₂* (*Functional Serenity*): while users rated it at 5.9, designers gave a lower score of 4.4. This discrepancy suggests that, although the design retained overall simplicity, it did not fully meet professional expectations regarding intuitive operation and practical usability. For *U₃* (*Resilient Grace*), user and designer scores were 5.5 and 4.8, respectively, reflecting a moderate-to-low level. Although the design successfully inherited the structural stability of mortise-and-tenon joints, the intended aesthetic tension between ‘solidity’ and ‘elegance’ was not fully achieved, marking this as a key area for further optimization.

In other words, the new design of the ‘Warped Table’ can still maintain the culture image of the traditional furniture and satisfy the perception and function needs of modern people. It is the evaluation process verifying the applicability and effectiveness of the Kansei Engineering approach in traditional furniture design and providing proof of emotion-driven design. Future research will continue to improve the scheme according to users’ feedback, trying to integrate the aesthetic principle of ‘simpler, purer, and more elegant,’ which is suitable for contemporary perceptual cognition, and promote the rejuvenation of Ming-style furniture in a modern context.

DISCUSSION

Based on Kansei Engineering (KE), this study has a set of systematic design methodology based on a chain of methods. Links in this chain included the semantic differential (SD), method for factor analysis (FA), the weighting method of the Likert scale, and methods for QFD. This approach was not only able to realize the quantitative extraction and dimensional reduction of users’ emotional imagery, but it also has established a logic map linking ‘user needs’ to ‘design elements’ using QFD, which provides scientific

backing and procedural guidelines for the modern redesigning of traditional furniture. The contributions of the research mainly include three aspects:

(1) Effectiveness and innovativeness of the methodology chain. This research is the first to systematically apply the SD–FA–Likert–QFD method chain to the Kansei design of the Ming-style ‘warped table’, effectively filling the theoretical gap in the ‘emotion – design’ mapping mechanism within traditional furniture research. Compared with conventional experience-based approaches, this method demonstrates greater systematization and logical rigor in data collection, factor extraction, and design parameter translation, particularly when addressing traditional furniture with profound cultural semantics. Furthermore, it provides a quantifiable and verifiable operational pathway for the ‘living inheritance’ of cultural heritage.

(2) Cultural adaptability and user responsiveness in design practice. Based on QFD weight analysis, the table-top, and legs were identified as the core components with the strongest emotional influence. During redesign, targeted optimization of these components significantly enhanced user emotional resonance and cultural identification. The optimized results not only extended the aesthetic features of Ming furniture—simplicity, refinement, and elegance—but also integrated modern functional requirements and manufacturing logic, thus achieving effective alignment between traditional forms and contemporary aesthetics.

(3) Manufacturing potential and structural translation of modular design. The ‘warped table’ structure was deconstructed into standardized modules (*e.g.*, table-top, yataio, legs), with weight priorities established within the QFD framework. This strategy provides a clear structural foundation for modern CNC-based manufacturing, while also opening new pathways for the contemporary expression and translation of mortise-and-tenon craftsmanship. Modular design not only improves processing efficiency and assembly flexibility but also offers practical feasibility for the personalized customization and industrial development of traditional furniture.

Despite establishing a preliminary ‘emotion–design–manufacture’ translation mechanism, this study still has limitations. First, the participants were primarily Chinese users, and differences in Kansei cognition across cultural contexts were not examined. Future studies should expand the sample scale and incorporate cross-cultural comparisons to enhance the generalizability and adaptability of the model. Second, questionnaires served as the main data source, which may be subject to individual biases. Future research could integrate artificial intelligence, physiological sensing, and big data approaches to improve the objectivity and precision of Kansei evaluation. Lastly, the redesign scheme was presented in the form of renderings, without validation through real interaction scenarios. Future work should employ prototyping and user testing to further verify design effectiveness, ensuring feasibility and user acceptance in practical applications.

CONCLUSIONS

Taking Ming-style ‘warped table’ as the research subject, by means of Kansei-Engineering methodology this study constructed an integrative design methodology chain for the warped table based on Kansei-Engineering theory, which incorporates semantic differential (SD), factor analysis (FA), the Likert weighting method, and quality function deployment (QFD). A systematic redesign framework was given to convert users’ feelings into actual design information. Firstly, SD was used to grasp the users’ perception of

traditional furniture. Then FA was applied to obtain four central perceptual variables—Material Warmth, Functional Serenity, Resilient Grace, and Fluid Elegance. These dimensions were related to corresponding structural parts by QFD, and it was determined that table-top, apron, and table legs were the parts worth optimizing. It was found that this method chain was able to pick up and translate the user's emotional needs towards Ming furniture. The proposed redesign not only retained the traditional stylistic language of simplicity, refinement, and elegant but also brings the material warmth, structure stability, line fluidity to achieve a new kind of organic integration between culture images and contemporary aesthetic psychology.

Future work will further expand the framework from these three directions: 1) more cross-cultural sampling; 2) integration of AI and physio metrics; 3) validation by physical prototype and testing. Such endeavors can improve the scientific nature of Kansei information. Design strategies' practicality is also improved, which further promotes the renovation and revival of traditional furniture in the modern world.

FUNDING

This work was supported by the Hunan Provincial Innovation Foundation for Post graduate (Grant No. CX20251680). The project is entitled "Red Cultural Creative Product Design for Qiu Jin's Former Residence Based on Qualia Theory."

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Article submitted: July 18, 2025; Peer review completed: August 7, 2025; Revised version received and accepted: September 7, 2025; Published: October 6, 2025.
DOI: 10.15376/biores.20.4.10082-10105