R&D Strategy Study of Customized Furniture with Film-Laminated Wood-Based Panels Based on an Analytic Hierarchy Process/Quality Function Deployment Integration Approach

Yushu Chen and Wenwen Sun *

Various methods exist for surface decoration of wood-based panels, with decorative plastic film emerging as a primary choice due to its environmental friendliness, design versatility, and ease of processing. To leverage the benefits of film-laminated wood-based panels, this study explored a research and development (R&D) strategy for customized kitchen cabinets made from these panels by the integration of the Quality Function Deployment (QFD) and the Analytic Hierarchy Process (AHP) approaches. AHP was employed to construct a hierarchical model of user requirements. Utilizing QFD, user requirements were translated into technical characteristics, and their degree of importance were determined, which facilitated a precise understanding of the technical priority. Study findings indicated that user requirements for film-laminated wood-based panels prioritized practicality, safety, appearance, and durability. The AHP-QFD model employed mathematical methods to establish a connection between the user and technical levels, so as to excavate the focus and direction of the process flow from the preparation of the material to the design and manufacture of the product, and to provide a reference for the future application of similar environmentally friendly materials.

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*Contact information: College of Furnishings and Industrial Design, Nanjing Forestry University, Nanjing, China 210037; *Corresponding author: 1149271862@qq.com*

INTRODUCTION

Contemporary customized interior furniture primarily utilizes veneered wood-based panels. These veneers provide both aesthetic enhancements and functional features, including resistance to moisture, stains, and chemicals. Melamine-coated boards, known for their cost-effectiveness and straightforward production, dominate the domestic and international markets. Other decorative materials, such as wood veneer, plastic film, leather, and fabric, contribute to the market landscape. Notably, plastic film is a favored choice for decorating wood-based panels, due to its readily available raw materials, vibrant coloring attributes, malleability, and efficient production. This trend partly reduces the customized furniture market's dependence on wood-based resources. Market research identifies polyvinyl chloride plastic film (PVC film), polyethylene terephthalate plastic film (PET film), and polypropylene plastic film (PP film) as the primary raw materials for interior decorative films on wood-based panels. Possessing excellent ductility, light resistance, stability, chemical resistance, high temperature resistance, notable mechanical strength, efficient processing, and impressive molding capability, PVC film commands the largest market segment among plastic decorative films (Peng and Zhang 2020).

In response to China's initiative to achieve carbon peak and carbon neutrality objectives within a new developmental framework, the wood-based panels industry has embraced the research, development, and production of environmentally friendly materials. Bolstering the share of low formaldehyde and formaldehyde-free wood-based panels, refining the species composition, and advancing the market-focused green technology framework have emerged as pivotal directives in the progression of wood-based panel development (Zhou *et al.* 2022). Concerning environmental attributes, the principal chemical constituent of PET film is polyethylene terephthalate, which exhibits non-toxicity and minimal odor (Hu *et al.* 2020). Additionally, complete combustion of PP solely produces carbon dioxide and water, rendering the recycling process for PP straightforward and secure. Consequently, PET film and PP film have garnered recognition within the customized home furnishing sector due to their remarkable environmental benefits (Chang *et al.* 2023). These materials are poised to define the future trajectory of surface decoration materials for wood-based panels.

The critical process that influences the visual outcome of film-laminated wood-based panels is the lamination process. The three types of film-laminated processes are thermoforming, wrapping, and flat-pressing. The main difference between these three is the number of surfaces that can be processed at one time. As shown in the picture below (Fig. 1), there are six processable surfaces in total.

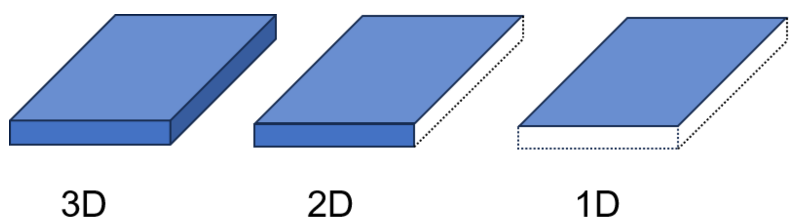

Fig. 1. Number of planes processed at one time

The thermoforming process simultaneously covers three visible surfaces, and thus it is referred to as the 3D process. The wrapping process can cover two of the three visible surfaces simultaneously, so it is known as the 2D process. The flat lamination process can only cover one surface at a time, and therefore it is called the 1D process. PVC, PP, and PET films can be applied in all three lamination processes. Refer to Table 1 for a detailed description and comparison of these processes.

The adoption of such eco-friendly materials within China’s customized furniture industry remains less prevalent in contrast to Japan, South Korea, and Europe. Plastic film, especially PP film, in China is still nascent in its development (Chang *et al.* 2022). To meet the requirements of target users for film-laminated wood-based panels within customized furniture, this study centered on customized kitchen cabinets (Fig. 2) crafted from such panels and adopted the integration of AHP and QFD to consider strategies for the future development of the similar product. This paper’s innovation lay in shifting the research focus from products to materials, conducting research on R&D strategies based on material characteristics and processes. By deconstructing the R&D technical aspects of customized furniture, it not only offered optimization suggestions for the design process but also enhanced the overall product quality at the material processing level.

Table 1. Three Types of Film-laminated Processes

Process Name	Thermoforming	Wrapping	Flat Lamination
Applicable Substrate	Medium/High Density Fiberboard	Fiberboard, Particleboard, Wood-plastic board, PVC Foam Board, etc. in Straight Lines	Fiberboard, Particleboard, Wood-plastic Board, PVC Foam Board, etc. in Straight Lines
Gluing Method and Object	Spraying on Substrate Surface	Scrape or Roller Coating on The Back of The Film	Roller Coating on Substrate Surface
Equipment	Vacuum Thermoforming Machine*	Wrapping Machine**	Roll Lamination Machine***
Process	Substrate Milling - Cleaning - Adhesive Application - Drying - Thermoforming - Trimming	Substrate Cleaning - Film Coating - Preheating - Guide Wheel Laminating - Lying	Substrate Cleaning - Preheating - Gluing - Roll Pressing - Lying
Characteristics	No Need to Seal The Edge, Realize Three-dimensional Modeling, Low Material Utilization Rate	Suitable for Long Format, Long Pre-adjustment Time	Easy Operation and High Shipping Rate

* Film can be processed on the machine through the application of heat, pressure, and vacuum, in combination with a polyurethane dispersion (PUD) adhesive to form a bond with the surface of the substrate. The heating method is divided into silica gel heating plate for heating or air conduction heating.
** Forming rollers are employed to mimic the manual lamination process. These rollers are systematically affixed along the contour of the substrate's surface, so that the film is fixed on the substrate.
*** The conveyor propels the substrate forward, while the pressure roller adjusts to the optimal height, conducting even roller pressing on both the substrate and the film.

Fig. 2. The cabinets with the texture of the decorative film

EXPERIMENTAL

Hierarchical Analysis Method (AHP)

This study established a user requirements model for cabinets and assessed the priority of each requirement using AHP. AHP, a subjective evaluation method introduced by the American operations researcher Saaty in the early 1970s, was employed for this purpose (Fu *et al.* 2023). With the incorporation of expert opinions, AHP organizes various decision-making elements into interconnected and ordered levels. This approach facilitates comparisons between elements at the same level, resulting in a comparison matrix that gauges the relative significance of individual-level elements. Subsequently, the comprehensive importance of each element within the overall system can be determined.

In this study, the focal point was enhancing user satisfaction as the overarching requirement. Employing AHP, a qualitative and quantitative analysis was performed to systematize the initial, unwieldy information and establish a hierarchical structure for the requirements. A comparison matrix was developed for same-level requirements, followed by a consistency test. The study evaluated and ranked the comprehensive importance of each requirement, contributing to the amplification of the intuitiveness and clarity of user requirements.

Quality Function Development (QFD)

QFD played a pivotal role in the product development process by facilitating the translation of user requirements into well-defined technical characteristics. QFD, developed by Japanese scholars Yoji Akao and Shigeru Mizuno in the 1960s, is a coordinated and systematic design tool to enhance consumer satisfaction by improving product quality (Wang *et al.* 2021). Given the increasing emphasis on user experience within the consumer market (Lyu *et al.* 2022), the value of QFD lies in its capacity to bridge the gap between user expectations and technical specifications. The goal is to shift the product development process from a reactive stance to a proactive approach with customer-driven insights. Through its systematic approach, QFD streamlines the overall development cycle, leading to time savings and heightened efficiency (Ginting *et al.* 2020).

House of Quality (HOQ), a central component of QFD, serves as the foundational tool. HOQ, presented as a house-shaped diagram, visually illustrates the interconnections among elements influencing product quality. Figure 3 shows a classic HOQ structure.

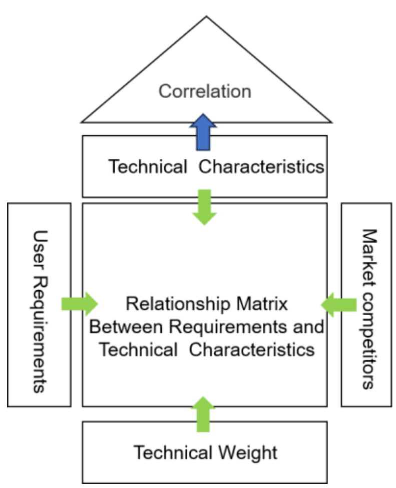

Fig. 3. Classic HOQ structure

The primary configuration comprises five segments (Chan and Wu 2002). The "left wall" embodies user requirements along with their respective importance levels, while the "right wall" involves market competitor analysis. The "ceiling" encompasses the product's technical attributes, and the "roof" delineates the positive and negative correlations between these elements. The "room" signifies the correlation matrix between user requirements and technical characteristics. The "Basement" underscores the importance of each technical attribute, computed from the correlation matrix. Part of the structure of the house can be taken according to the object or purpose of the study. Quality House assists teams in identifying essential technical features to meet user needs and offers decision support for product development.

The technical characteristics were designed from the perspective of the production process for cabinets made from film-laminated wood-based panels. The outcomes of the cabinet requirements hierarchy established *via* AHP were integrated into the "left wall" of the HOQ diagram to construct a correlation matrix with the technical characteristics. This process culminated in the identification of technological priorities, improving the success rate of new product development for customized furniture.

Research Framework

The integration of AHP and QFD theory can address the subjective bias inherent in the traditional QFD model concerning user requirements. This integration transforms qualitative issues into quantitative challenges, thus enhancing the scientific rigor of research outcomes. Rusli *et al*. (2020) applied the integrated AHP-QFD approach to evaluate Gemba Kaizen outcomes; the production needs dictated the implantation of Lean strategies. This evaluation determined the optimal amalgamation and prioritization of lean elements for implementing the production system, thus enhancing process improvement and standardization. Varolgunes *et al*. (2021) employed AHP-QFD within building design processes. The study revealed that the most important user requirements for thermal hotel buildings, in order of importance, are "health", "service", "comfort", and "functionality". This application emphasized customer satisfaction and facilitated the identification of design criteria. Existing studies demonstrate the effectiveness of AHP-QFD in achieving decision-making optimization and concretizing design processes. This methodology offers valuable insights for the design and development of analogous products. The framework of AHP-QFD method in this study is displayed in Fig. 4.

In this study, three main aspects were addressed. First, a hierarchical user requirement model was established for cabinets. AHP was utilized to construct a comparison matrix between the requirement elements, and to calculate the comprehensive hierarchical weights for each requirement. Next, the user requirements were translated to technical characteristics. HOQ, a core tool of QFD, allowed for the formation of a correlation matrix between user requirements and technical characteristics. The technical priority was finally calculated and ranked to meet user requirements. Finally, strategies for future development are discussed. The data were synthesized with the industry status to discuss development strategy and trend of customized cabinets made from film-laminated wood-based panels.

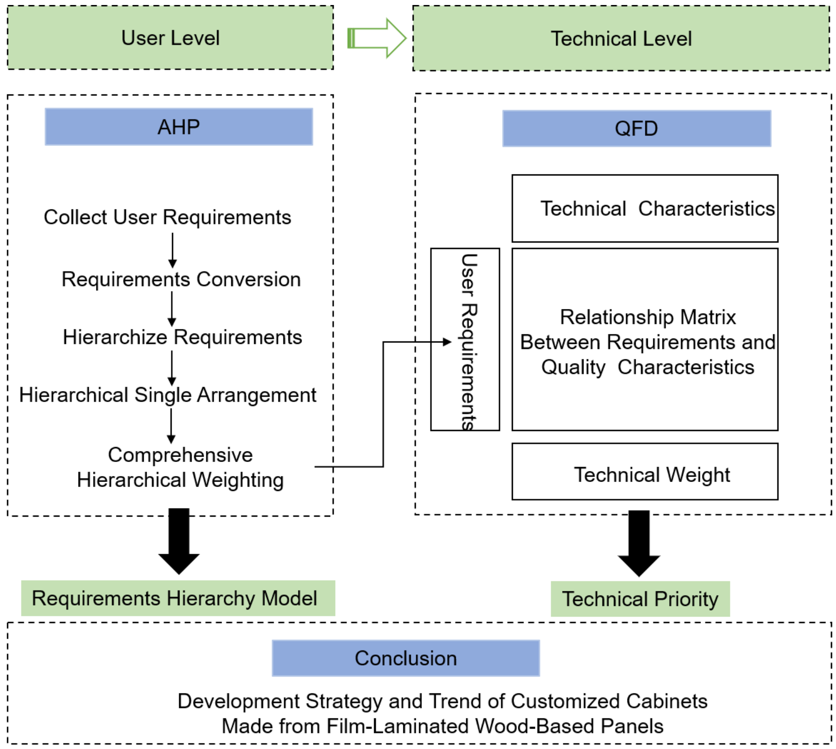

Fig. 4. The framework of AHP-QFD method

RESULTS AND DISCUSSION

Requirements Hierarchy Model

Product requirements encompass usage and service aspects. The former involves factors including appearance, function, and structure, while the latter entails aspects such as product acquisition, delivery, and after-sales service. This paper primarily concentrated on the former aspect. The creation of the requirements hierarchy model involved four steps:

Step 1: Collect Online and Offline User Requirements. Online information collecting primarily involved reviewing consumer feedback on kitchen cabinet products from e-commerce platforms. Background big data was analyzed to capture consumer search terms and browsing preferences. As of July 1, 2023, a search for customized cabinets on the Tmall and Taobao websites yielded 2564 valid comments from approximately 54 links. Through the utilization of word cloud analysis, keywords with higher frequencies were identified, with aesthetics, logistics, quality, and anti-fouling being ranked highest in importance. The frequency of these keywords reflects the significance of consumer preferences. Concurrently, eight individuals who have experience with laminated artificial boards or customized cabinets were interviewed. The participants, four men and four women, were between the ages of 25 to 35. By examining their product usage experiences and gathering feedback on potential improvements, the primary aspects of consumer demand for such products can be comprehended.

Step 2: Convert Requirements. Given the extensive spectrum of user requirements encompassing aspects like price, design, functionality, accessories, and other dimensions, the raw information obtained from users often contained unrefined terminology, convoluted requirement elements, and a dearth of precise definitions. Consequently, this raw data could not be directly employed in subsequent data processing. Transforming user requirements involves scrutinizing the original data, extracting requirement elements, and refining requirement expressions (Li and Wang 2023). For instance, functions related to moisture resistance and mold prevention could be consolidated, as their purpose is to prevent water retention that might lead to product quality issues.

Step 3: Hierarchical Organization of User Requirements. Following preliminary categorization of the amassed information, a total of 34 requirements were identified. Through consultations with a professor in the field of furniture design theory and two R&D experts from a plastic film company, a comprehensive assessment was conducted, streamlining 21 user requirements (Li *et al.* 2022). For example, service, logistics, after-sales and other things that are not a requirement of the process of use were censored, because it is not possible to intervene from the product R&D level. Ultimately, the interrelationships among requirements were elucidated, giving rise to a hierarchy of requirements as illustrated in Table 2. The first-level requirement category encompassed four dimensions: appearance, practicality, durability, and safety requirements.

Table 2. Hierarchy of User Requirements

Number	First-level Requirement Element	Number	Second-level Requirement Element
X1	Appearance	X11	Realistic Texture
		X12	Harmonious and Classic Colors
		X13	Three-dimensional Design
		X14	High-quality Texture
X2	Practicality	X21	Stable and Solid
		X22	Reasonable Partition and Size
		X23	No Rattles
		X24	Easy to clean
		X25	High Precision Assembly of Components
X3	Durability	X31	Durable Hardware
		X32	Not Easy to Pigmentation
		X33	Anti-scratch
		X34	Moisture and Mold Resistant
		X35	No Color Fading or Yellowing
		X36	Film Does not Delaminate
X4	Safety	X41	Harmless to Human Body
		X42	No Odor
		X43	Environmentally Friendly
		X44	Anti-bacteria
		X45	Fireproof and High Temperature Resistant
		X46	Rounded Corners Without Sharp Edges

Step 4: Hierarchical Single Arrangement. On July 14, 2023, a focus group consisting of 12 employees (7 women and 5 men) aged 25 to 35 was assembled at a plastic film sheet company. The panelists possessed requirements for purchasing custom cabinets and had the corresponding purchasing capacity, but they were not design professionals. They were tasked with evaluating the significance levels of various requirement elements in order to construct a two-by-two comparison matrix (Li *et al.* 2021). This study adopted the 1-5 point scale method, with 5 points for factor A being very important relative to factor B, 3 points for factor A being relatively important relative to factor B, and 1 point for factor A being of the same importance relative to factor B at this point. The weights were

computed, and consistency evaluation was conducted. the principal eigenvalue of the comparison matrix (λ_{max}) was determined, with the normalized eigenvector corresponding to this eigenvalue denoted as W. The consistency index (CI) of the comparison matrix was calculated using Eq. 1, and the consistency ratio (CR) is derived using Eq. 2, as follows,

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

$$CR = \frac{CI}{RI} \quad (2)$$

where λ_{max} is the maximum root of identity and RI is stochastic consistency indicator and n is the number of indicators. A CR value below 0.1 indicates successful passage of the consistency assessment. In cases where this criterion is not met, the comparison matrix necessitates reconstruction.

The comparison matrix of the first-level requirements elements was computed, yielding Table 3. A CR value of 0.013 (< 0.1) was determined, confirming the consistency of the assessment. The priority order of the first-level requirement elements is as follows: safety, practicality, appearance, and durability. Then the comparison matrix of the second-level requirements elements was calculated. All results successfully met the consistency criteria, leading to the formulation of Tables 4 through 7.

Step 5: Comprehensive Hierarchical Weighting. The weights of the first-level elements were multiplied by the corresponding second-level element weights to yield the ultimate weight value (W_i) for each second-level requirement element. The resultant rankings are depicted in Fig. 5.

Table 3. Comparison Matrix of First-level Requirements Elements

	X1	X2	X3	X4	W	λ_{max}	CI	RI	CR
X1	1	1/2	3	1/3	0.1722	4.0340	0.0110	0.89	0.0130
X2	2	1	5	1	0.3595				
X3	1/3	0.2	1	0.2	0.0693				
X4	3	1	5	1	0.3990				

Table 4. Comparison Matrix of Appearance Layer

	X11	X12	X13	X14	W_1	λ_{max}	CI	RI	CR
X11	1	1/2	2	1/3	0.1609	4.0340	0.0110	0.89	0.0130
X12	2	1	3	1	0.3320				
X13	1/2	1/3	1	0.2	0.0911				
X14	3	1	5	1	0.4159				

Table 5. Comparison Matrix of Practicality Layer

	X21	X22	X23	X24	X25	W_2	λ_{max}	CI	RI	CR
X21	1	3	4	2	1	0.3376	5.2830	0.0710	1.12	0.0630
X22	1/3	1	1	2	1	0.1783				
X23	1/4	1	1	1/2	1/3	0.0959				
X24	1/2	1/2	2	1	1	0.1611				
X25	1	1	3	1	1	0.2271				

Table 6. Comparison Matrix of Durability Layer

	X31	X32	X33	X34	X35	X36	W_3	λ_{max}	CI	RI	CR
X31	1	3	5	1	4	3	0.3230	6.1260	0.0250	1.26	0.0200
X32	1/3	1	1	1/4	1	1/3	0.0755				
X33	0.2	1	1	1/3	1	1/3	0.0724				
X34	1	4	3	1	3	2	0.2753				
X35	1/4	1	1	1/3	1	1/3	0.0751				
X36	1/3	3	3	1/2	3	1	0.1787				

Table 7. Comparison Matrix of Safety Layer

	X41	X42	X43	X44	X45	X46	W_4	λ_{max}	CI	RI	CR
X41	1	2	1	3	2	4	0.2750	6.2850	0.0570	1.26	0.0450
X42	1/2	1	1/2	2	1/2	3	0.1399				
X43	1	2	1	3	1	3	0.2312				
X44	1/3	1/2	1/3	1	1/3	1/3	0.0652				
X45	1/2	2	1	3	1	2	0.1954				
X46	1/4	1/3	1/3	3	1/2	1	0.0935				

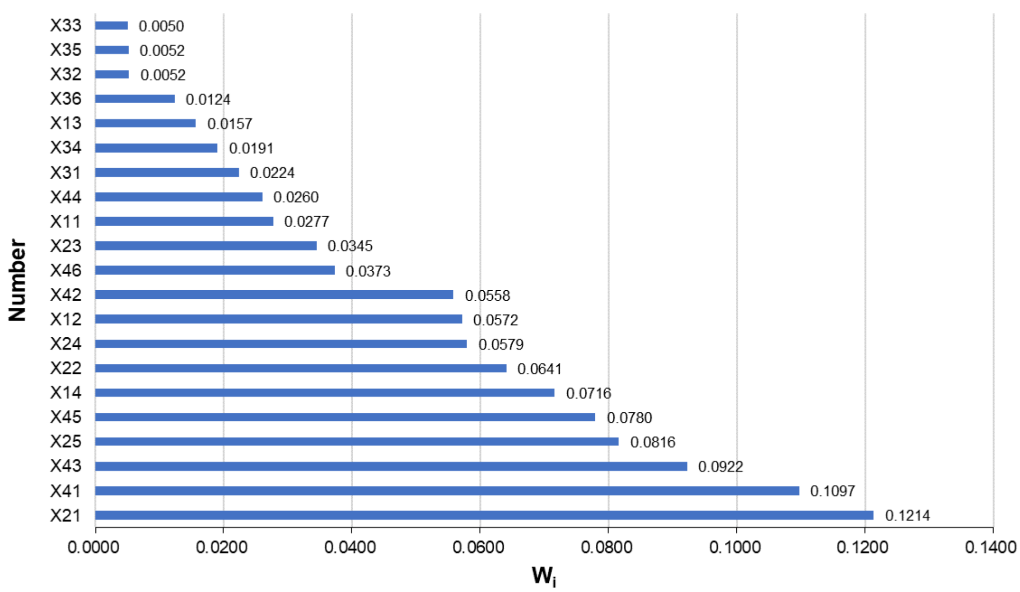

Fig. 5. The comprehensive importance degree of user requirements

As shown in Fig. 5, the user requirements for cabinets made from film-laminated wood-based panels, ranked in the top ten were as follows: stable and solid > harmless to human body > environmentally friendly > high precision assembly of components> fireproof and high temperature resistant > high-quality texture > reasonable partition and size > easy to clean > harmonious and classic colors > no odor. Clearly, the central concern of consumers’ top-priority demands for customized kitchen furniture lies in the fundamental function of cabinets. Given the challenges posed by factors like high temperatures and challenging cleaning conditions within the kitchen environment, the associated specialized functions have evolved into pivotal determinants impacting cabinet quality. Special emphasis should be placed on the heightened eco-awareness among consumers, with a growing focus on the implications of furniture for both human health and environmental balance. The ecological performance of products will emerge as a pivotal factor influencing purchasing decisions.

Technical Characteristics

Translating user requirements into technical characteristics for furniture products is essential, as the content from users does not directly serve as the design language for research and development. The design elements aligned with user requirements are not linear; one requirement can correspond to multiple design elements, and one design element can fulfill multiple requirements simultaneously. Thus, the design elements corresponding to each requirement were isolated to ensure they are precise, quantifiable, and comprehensive. In the subsequent step, the KJ method is employed to integrate and categorize these design elements, resulting in a technical characteristics classification table. As presented in Table 8, the technical characteristics are divided into five dimensions: customized design, physical and chemical properties of the film, decorative properties of the film, lamination process, and substrate properties.

Table 8. Classification of Technical Characteristics

Number	Classification	Number	Technical characteristic Element
Y1	Customized Design	Y11	Environmental Performance of Raw Materials
		Y12	Ergonomic Size Design
		Y13	Drilling Accuracy
		Y14	Panel Fixing Structure
		Y15	Hardware Strength
Y2	Film Physical and Chemical Properties	Y21	Oxidation Resistance
		Y22	Hydrophobicity
		Y23	Surface Hardness
		Y24	Chemical Resistance
		Y25	High Temperature Resistance
		Y26	Anti-bacterial Rate
		Y27	Raw Material Purity
Y3	Film Decorative Properties	Y31	Color design
		Y32	Printing Process
		Y33	Embossing Process
		Y34	Surface Tactile Design
Y4	Lamination process	Y41	Adhesive Strength
		Y42	Heating Temperature
		Y43	Three-dimensional Molding Fit
		Y44	Edge Banding
Y5	Substrate properties	Y51	Mechanical Properties
		Y52	Processing Performance
		Y53	Curing Process of Wood-based Panels
		Y54	Waterproofing

Building HOQ

The user requirements were entered into the left wall of the HOQ, and the technical elements were entered into the ceiling. The room part in the middle is the correlation matrix between the two (Fig. 4). The ●, ◎, ○ symbols are used to indicate strong correlation, correlation, and weak correlation, representing correlation coefficients of 5, 3, and 1 respectively, and the blank part indicates that the correlation coefficient is 0. This work incorporated an expert discussion methodology to score the correlation with a design professor and two design R&D experts on July 23, 2023, thus ensuring the professionalism and market value of the correlation matrix. The absolute weights and relative weights of the technological requirements are calculated according to Eq. 3 and 4, as follows,

$$W_j = \sum_{i=1}^{q} W_i P_{ij} \tag{3}$$

$$W_k = \frac{W_j}{\sum_{i=1}^{q} W_j} \tag{4}$$

where W_j is absolute weights of technical characteristics, and W_i is requirement weights, and P_{ij} is correlation coefficients, and q is total number of user requirements, and W_k is Relative weights of quality features, and m is total number of quality features.

	W_i	Y11	Y12	Y13	Y14	Y15	Y21	Y22	Y23	Y24	Y25	Y26	Y27	Y31	Y32	Y33	Y34	Y41	Y42	Y43	Y44	Y51	Y52	Y53	Y54
X11	0.0277						○						◎		●	◎	○		◎	◎	◎				
X12	0.0572						●			○			○	●	◎		○		○						
X13	0.0157		○																	●	◎	○	◎	○	
X14	0.0716			◎			●						○	●	◎	◎	●	◎	◎	●	○	○	◎		
X21	0.1214			◎	●	●																●	◎	◎	
X22	0.0641		●																			○			
X23	0.0345		◎	○	○	◎																	◎		
X24	0.0579						◎	●	○	◎	○		○	○		○	○				○	●			○
X25	0.0816		○	●		●			○									○			○	◎	●	○	
X31	0.0224		◎	◎	◎	●																◎	◎		
X32	0.0052						○	○		●			◎	○			○								
X33	0.0050		○						●													◎			
X34	0.0191							●		○		○												○	●
X35	0.0052						●	○		◎	○		◎		◎				◎				○		
X36	0.0124							○			◎		◎					●			◎				○
X41	0.1097	●										◎	◎											●	
X42	0.0558	◎									○		◎											◎	
X43	0.0922	●										○	◎											●	
X44	0.0260							○				●	◎								○				○
X45	0.0780										●														
X46	0.0373		○		○													○			●		○		
W_i(*100)		118	63	109	75	123	88	43	16	29	55	57	119	71	54	36	51	40	37	52	59	137	125	166	19
W_k(%)		6.76	3.63	6.26	4.29	7.07	5.04	2.49	0.95	1.68	3.14	3.28	6.84	4.06	3.11	2.04	2.91	2.27	2.13	2.99	3.40	7.90	7.17	9.53	1.10

Fig. 6. The correlation matrix

The procedure is to arrange the technical characteristics based on the weights (Wj), as shown in Fig. 6. The disparities in data are then depicted in a bar chart, giving rise to Fig. 7.

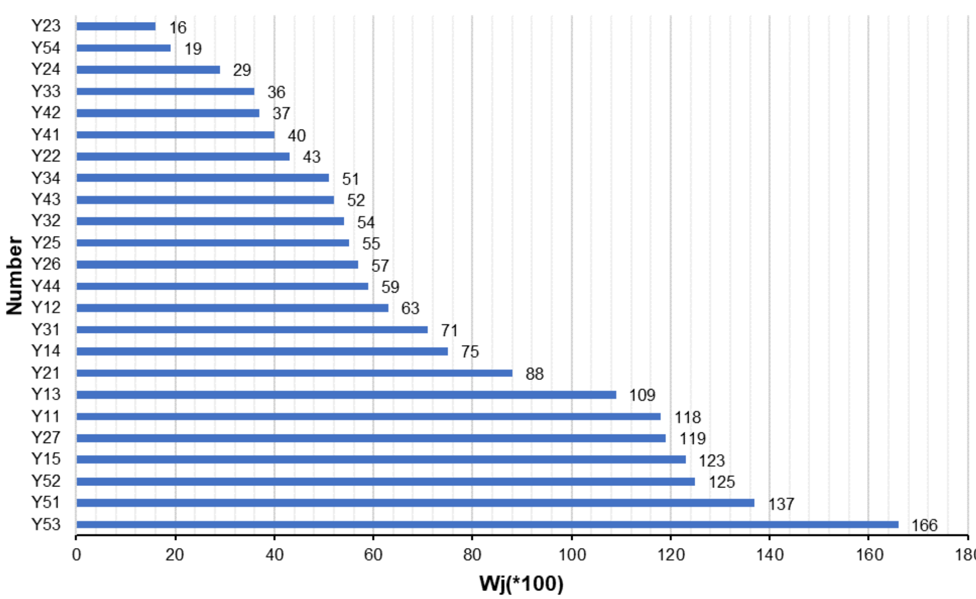

Fig. 7. The importance degree of technical requirements

This graph clearly reveals the technical focal points for cabinets constructed from film-laminated panels, including the strength of hardware, environmental performance of raw materials and drilling accuracy in customized design, the curing process, mechanical properties and processing performance of wood-made panels in the performance of the substrate, the purity of the raw materials and antioxidant resistance in the physical and chemical properties of the film, the color design and printing process in the decorative properties of the film, and the edge banding and three-dimensional modeling fit of the laminated film process.

When considering both Figs. 5 and 7, it becomes evident that the fundamental performance of cabinet manufacturing materials takes precedence, irrespective of user demands or technical characteristics. This leads to the prediction that customized cabinets with film-laminated wood-based panels will enhance consumer satisfaction by prioritizing high quality development. In the face of intense market competition, a diverse array of products, and varying levels of quality in customized furniture industry, the product quality is pivotal in dictating brand positioning and sustainable growth (Lu *et al.* 2022). Figure 7 highlights a particular concern for the physical and chemical properties of the film. A high-quality plastic film comprises a face film, a backing film, and it undergoes back-coating treatment, which could improve adhesive strength to substrate. The use of high-purity raw materials also contributes to the aesthetic performance of the cabinets. In the research on decorative films for wood-based panels, enterprises emerge as the driving force for technological innovation, propelling high-quality development in the industry. In this era of emerging technologies, it becomes imperative to enhance the film's resistance to stains to meet the specific environmental demands of kitchen settings. Japan pioneered the use of Electron Beam Curing Technologies, applying EB resin to the outermost layer of PP film and subjecting it to EB electron beam irradiation. This process aims to bolster the PP film's resistance to staining, scratching, and overall durability. The bar chart distinctly illustrates that the precision of workmanship in the final construction of custom cabinets emerges as the pivotal factor in determining quality. For enterprises in the customized furniture sector, it is imperative to advocate for industrial automation. This approach enhances product processing precision and manufacturing efficiency, ultimately contributing to an expanded market share of medium and high-end products. For the governing bodies overseeing the furniture industry, it is essential to develop and refine industry quality standards, guiding the wood-based panel industry towards high-quality development.

Plastic film has the potential to replace wood materials, mitigating the resource crisis. However, user research reveals that consumers place significant emphasis on the environmental performance of "plastic" products. Given the risk of high temperatures in kitchen spaces, it is imperative to intensify efforts in researching and applying environmentally friendly materials. PP decorative film, characterized as a green material, employs a surface water-based coating process, resulting in a more authentic texture on the veneer of wood-based panels. The latest research indicates that low-temperature ionic modification can enhance the adhesion of water-based paint film on the surface of PP decorative sheets, thereby expanding the application of PP decorative sheets on wood products (Peng and Zhang 2020). Manufacturing enterprises should proactively shoulder social responsibility and advocate for sustainable development. The research and development of customized cabinet products should encompass the entire life cycle, including raw material procurement, production, transportation, maintenance, and recycling, with a keen focus on their impact on human health and the environment (Woo and Zhu 2023).

Figure 5 reveals that users of cabinet panels articulate a diverse range of functional requirements. In Fig. 7, the decoration quality places color design and three-dimensional modeling in high priority. The expansion of customized furniture development will inevitably result in product diversification. However, the uniformity in product appearance and performance may diminish the brand's competitive edge. From a decorative design perspective, it is imperative to incorporate distinctive visual, tactile, and other sensory attributes to offer a tailored sensory experience. For instance, in the panel decorative design, applying paint with varying gloss levels can achieve a high-gloss texture akin to baking varnish, or a matte texture with a gloss degree below 3.0. Moreover, in terms of tactile sensation, providing a smooth, fingerprint-resistant surface that mimics the delicacy of skin is essential. In the realm of technology, enterprises should augment investments in independent research and development, as well as in upgrading processing equipment and refining process parameters. For example, Germany has pioneered synchronized printing, aligning texture with embossing effects to achieve a realistic play of light and shadow, resembling wood grain. These R&D endeavors are pivotal in ensuring that products attain maximum design impact and heightened texture quality (Zhu 2016). Regarding product performance, precision in defining product usage scenarios is of paramount importance. This approach facilitates the development of specialized functional products tailored to meet specific user requirements. For instance, the incorporation of nano-silver ions can confer antibacterial and antiviral functions. Alternatively, implementing surface anti-ultraviolet treatment can endow products with outdoor architectural decoration capabilities.

CONCLUSIONS

To distinguish itself from the traditional designer-centric design approach, the Analytic Hierarchy Process with Quality Fusion Development (AHP-QFD) integrated method makes it possible to conduct strategy research with a market-oriented perspective. It commences from the consumer side, leveraging user requirements as the driving force for design (Yang and Xiong 2021). In this study, a hierarchical requirements model was developed for film-laminated wood-based panel cabinets by AHP, encompassing 4 first elements and their corresponding 21 second-level elements. The results showed that consumers were concerned about the requirements of cabinets in the order of practicality, safety, appearance, and durability. QFD then translated the requirements into 24 technical characteristics and calculated the technical priorities, which clarified the focus of the product development. Utilizing the AHP-QFD integration approach, it is conjectured that the utilization of film-laminated panels in the customized furniture sector is progressing towards a trajectory characterized by high quality, environmental sustainability, and personalization. This process illuminated the key points of product research and development. the central facets of product evolution, facilitating strategies for enhancement and advancement.

The evaluation outcomes derived from AHP-QFD rely on the pairwise comparison technique. The quality house chart enables the depiction of a multi-dimensional comparative scenario. Its advantage lies in its adaptability to product attributes and the ability to hierarchically categorize them based on the specific features of the R&D target. This enables the assessment of product quality at the design phase, subsequently facilitating a smooth development process. The comparative analytical capability of AHP-QFD fulfills the roles of quality control and user satisfaction assessment during the R&D phase.

One of the primary challenges in product development lies in the realization of numerous technical elements after their identification. The ultimate result derived from data acquired through AHP-QFD is a prioritized ranking of the R&D object's quality characteristics on a technical level. The determination of weights for these technical characteristics is founded on user expectations of the product, supplemented by expert opinions. This guarantees that the conclusions are both market-oriented and scientifically sound. This primarily addresses the decision-making challenges faced by R&D teams in search of focal points during the product R&D process. It can serve as a decision support system for optimizing existing products or planning new product lines.

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