A Multi-Criteria Decision-Making Framework for Tibetan Furniture Design Driven by the Needs of Users: Integration and Evaluation *via* TFAHP-QFD-VIKOR

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Tibetan furniture faces the dual challenge of maintaining the authenticity of cultural heritage while meeting the functional needs of modern living. The Tibetan-style seating bed is used in religious rituals and for daily purposes. A hybrid model integrating the Triangular Fuzzy Analytic Hierarchy Process (TFAHP), Quality Function Deployment (QFD), and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) was constructed, aiming to resolve the conflict between cultural heritage revival and modern functional requirements in Tibetan furniture design. Through the grounded theory, 16 design elements were identified. TFAHP was employed for quantitative analysis, and the results showed that the cultural dimension of Tibetan furniture has a higher weight than the functional, apparent, and technological dimensions. Cultural recognition and Buddhist culture are the core driving forces behind this design. After mapping user needs *via* QFD, technical features such as modular design and integrated seating/storage designs were identified. Finally, VIKOR was used to conduct multi-objective optimization on three design schemes, and the optimal one is selected. The hybrid model proposed in this study provides a scientific framework for balancing cultural authenticity and user experience and offers a replicable design paradigm for the modern transformation of ethnic cultural heritage.

DOI: 10.15376/biores.20.4.8566-8590

Keywords: Tibetan furniture; Cultural heritage revitalization; TFAHP-QFD-VIKOR; Design model; Multi-Criteria decision making

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INTRODUCTION

Tibetan aesthetics, as a tangible carrier of Tibetan culture, deeply integrates multiple elements such as religious rituals, plateau ecology (Wang and Cao 2022), and social ethics. Tibetan furniture, which originated in Tibetan areas and is crafted by Tibetan artisans to meet local people's living needs and aesthetic habits (Lv and Lv 2018), bears the dual mission of preserving cultural heritage and adapting to modern life. This creates a core contradiction: how to maintain the authenticity of cultural symbols such as Buddhist motifs, traditional craftsmanship, and ethnic color systems while satisfying the functional demands of contemporary living, such as space efficiency and usability. The Tibetan-style seating bed (TSSB) typifies this contradiction. It is integral to religious rituals, offering a sacred space for meditation and scripture recitation with forms and decorations tied to

Buddhist culture. It also functions as a daily necessity for Tibetan families, used for sitting, lying, and storing items. This dual role makes it a microcosm of the conflict between preserving cultural heritage and adapting to modern functions in Tibetan furniture. For instance, the traditional TSSB has a large, heavy structure suitable for spacious traditional Tibetan residences, but it is incompatible with modern urban apartments. Its rigid design, though conforming to religious ritual norms, lacks the flexibility needed for daily life. Exploring TSSB design optimization thus addresses not only a specific furniture type but also provides a breakthrough to resolve the universal contradiction in Tibetan furniture design. Existing research on Tibetan furniture has covered multiple dimensions but has limitations in systematicity and practicality, which can be analyzed in three progressive layers.

In terms of cultural connotation interpretation, studies mainly have focused on symbolic translation and aesthetic feature extraction. Zhao (2019) analyzed the thematic types and patterns of Tibetan architectural murals, proposing the possibility of transforming them into street furniture design elements. Chen *et al.* (2025) interpreted the cultural external layers (form, color, craftsmanship) and internal layers (symbolic meaning, religious beliefs) of Qianci symbols through semantic analysis, extracting core elements suitable for modern furniture design.

While these studies reveal the expression logic of cultural symbols in Tibetan furniture, they remain at the qualitative description level, relying on participatory observation or text analysis (Alhazmi and Kaufmann 2022). They fail to fully integrate artisans' practical experience, making it difficult to translate cultural logic into operable design guidelines. In the quantification and structuralization of needs, some scholars have attempted to combine qualitative research with the Analytic Hierarchy Process (AHP) to enhance scientific rigor. Chen *et al.* (2024) collected sales data from local rattan enterprises through group interviews and used AHP to construct a demand priority matrix, identifying "sofa" as the design direction. Zheng *et al.* (2024) summarized user demand factors in children's hospital environmental design through field research and interview analysis. Then AHP was applied to calculate the weight indicators of these needs. Although these methods have structured needs and quantified weights, they are limited to the demand extraction stage, lacking an effective path to transform user needs into product functions, resulting in a disconnect between "needs" and "functions."

Finally, in method integration and practical application, the academic community has further combined AHP with Quality Function Deployment (QFD) to build a "demand-function" transformation model. Xu *et al.* (2024) determined demand weights using AHP and mapped them to technical parameters *via* QFD, proposing an innovative design scheme for Spartina alterniflora control equipment. Karasan *et al.* (2022) applied the AHP-QFD method in automotive seat design to accurately convert user experience demands into hardware functions. However, these studies often use traditional AHP to handle indicator weights, whose precise numerical judgments conflict with the fuzziness inherent in cultural heritage design, such as the evaluation of non-objective factors such as "cultural identity" and "religious symbolic meaning" (Chou and Chang 2008). This leads to deviations between weight calculations and actual design scenarios. Additionally, existing models lack multi-objective optimization mechanisms, failing to effectively reconcile conflicts between cultural inheritance and functional innovation, which limits their application in designing products like Tibetan furniture that have both cultural and practical attributes. In Tibetan furniture design, non-objective factors are prevalent and include cultural identity, the adaptability of religious symbolic meanings, and the inheritance value of traditional craftsmanship. These factors are difficult to quantify with precise numerical values due to their reliance on subjective perceptions and cultural contexts.

The triangular fuzzy AHP addresses these challenges by introducing triangular fuzzy numbers to characterize the fuzziness of human judgment. For instance, when evaluating "cultural identity," instead of requiring experts to give a definite weight, it allows for a fuzzy interval judgment, which better reflects the ambiguity and subjectivity in human evaluations. This approach can resolve several complex multi-criteria decision-making problems in the fuzzy analytical hierarchical process (Upadhyay *et al.* 2021). Furthermore, the study introduces the VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method, which effectively handles conflicts and contradictions between multiple indicators in the evaluation process.

An approach based on constructing a compromise solution close to the ideal solution avoids decisions dominated by a single indicator. In addition, while considering overall benefit maximization, it takes into account the importance of minor indicators, with the final ranking results balancing objectivity and decision-maker preferences (Yu *et al.* 2025). Wu *et al.* (2022) introduced an evaluation framework based on the improved FAHP-CRITIC and VIKOR methods in the final assessment, proposing a decision-making system for cement supplier evaluation in concrete production plants. This strategy is scientifically reliable and aids managers in decision-making.

To address these limitations, this study innovatively constructed an integrated framework combining the Triangular Fuzzy Analytic Hierarchy Process (TFAHP), Quality Function Deployment (QFD), and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR). TFAHP was used to quantify Tibetans' modern furniture needs by introducing triangular fuzzy numbers, handling decision-making uncertainties, and overcoming the fuzziness of traditional weight allocation. Combined with QFD, user needs were systematically transformed into actionable technical parameters such as structural innovation and process optimization, achieving structural coupling between the cultural symbol system and the functional technical system. Finally, VIKOR was used to screen the optimal solution from multiple design schemes by constructing compromise solutions close to the ideal scenario, avoiding decisions dominated by a single indicator and balancing the maximization of overall benefits with the importance of minor indicators. Taking the Tibetan-style seating bed as a case study, this framework considered user experience, ecological craftsmanship, sustainability, and social ethical adaptability, providing comprehensive decision support for Tibetan furniture design and offering a replicable paradigm for the modern transformation of ethnic cultural heritage.

EXPERIMENTAL

Method

In this study, a progressive research framework was constructed based on "theoretical modeling - demand analysis - scheme design - evaluation and optimization", with the overall context as shown in Fig. 1. By adopting the grounded theory research method at the beginning, it was initiated from the multiple elements of religious rituals, plateau ecology, and social ethics in Tibetan aesthetics. This work considered limitations of existing studies in symbolic translation and functional adaptation. On this basis, an innovative path involving a TFAHP-QFD-VIKOR hybrid model is proposed.

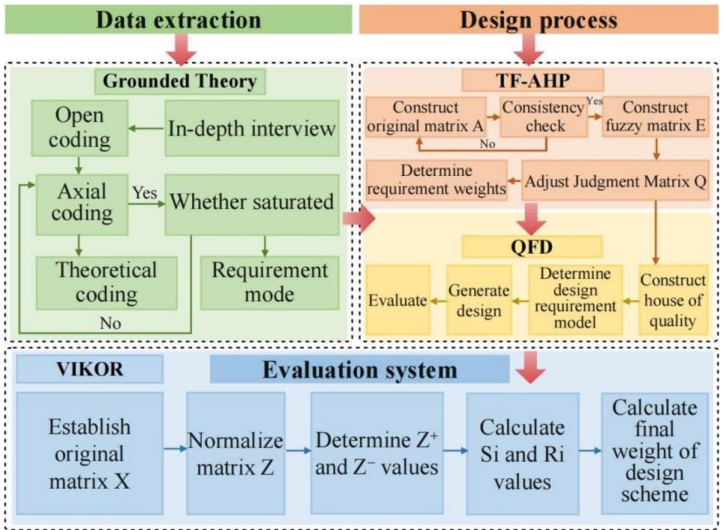

Fig. 1. Technology roadmap

Grounded Theory

Grounded Theory (GT) is a qualitative research method introduced into the field of sociology in the 1960s by sociologists Barney Glaser and Anselm Strauss (Wang *et al.* 2024). The core concept of GT is to inductively analyze semi-structured interview materials and gradually refine them into a systematic theory. This process allows for the abstraction of core concepts that reflect the essence of the phenomenon (Zhao *et al.* 2024). Miao *et al.* (2024) used interviews and grounded theory to observe and summarize the behavioral needs of 3 to 6-year-old children and preschool teachers, in order to optimize the zoning of kindergarten toys. Wang *et al.* (2025) summarized the elements of Zen aesthetics in furniture design through grounded theory. The application of grounded theory has been involved in various design fields, including mechanical design (Saadi and Yang 2023), nursing ward design (Burke and Veliz-Reyes 2023), and furniture design (Zhou *et al.* 2023).

Triangular Fuzzy Analytic Hierarchy Process (TFAHP)

TFAHP, as an improved version of the Analytic Hierarchy Process (AHP), introduces Triangular Fuzzy Numbers (TFNs), transforming the decision-maker's fuzzy judgments and subjective preferences into mathematical language, effectively addressing the issue in traditional AHP, for which precise numerical values cannot reflect the fuzziness in complex decision-making scenarios (Spanidis *et al.* 2021). This approach has been widely applied in multi-criteria decision-making scenarios, such as geological disaster assessment (Sun *et al.* 2024), product optimization weight analysis in complex environments (Ikedue *et al.* 2024), and economic decision-making under uncertain market conditions (Rui *et al.* 2021). The Triangular Fuzzy AHP improved by Sui and We (2000) is applied in this study, where TFAHP is used to analyze the weight of Tibetan furniture design elements, quantifying the fuzzy cultural preferences and design needs. The result is a more scientific and practical priority ranking for design decisions. Before delving into the detailed analysis, it is necessary to first clarify the concept of Triangular Fuzzy Numbers.

A triangular fuzzy number $\widetilde{M}$ can be represented by a triplet (l, m, u), where its membership function $\mu_{\widetilde{M}}(x)$can be expressed as (Eq.1) (Chang 1996):

$$\mu_{\widetilde{M}} = \begin{cases} \frac{x-l}{m-l}, x \in [l, m] \\ \frac{x-u}{m-u}, x \in [m, u] \\ 0, x \in (-\infty, l) \cup (u, +\infty) \end{cases} \tag{1}$$

For triangular fuzzy numbers, there are three specific values: the lower limit l, the middle value m, and the upper limit u, where the relationship $l \leq m \leq u$ holds. In this context, x represents the variable within the range of the fuzzy number, and $\mu_{\widetilde{M}}(x)$ is the membership function of the triangular fuzzy number, which indicates the degree to which x belongs to the fuzzy number concept, where the value of $\mu_{\widetilde{M}}(x)$ is a number within the interval [0, 1]. This quantity reflects how close x is to the triangular fuzzy number. The lower limit l and upper limit u can be determined based on the fuzziness degree, and $u-l$ indicates the degree of fuzziness: the smaller the value of $u-l$, the clearer the fuzzy judgment; when $u-l=0$, the judgment is non-fuzzy, and the values of $l=m=u$ are the same as those in conventional fuzzy logic.

Triangular Fuzzy Judgment Matrix

A triangular fuzzy number $\widetilde{M}$ can be expressed in the form of (l,m,u). First, it is necessary to define the judgment matrix and determine the indicator weights through expert group discussions during the research process. When applying the triangular fuzzy number (l,m,u), experts evaluate the importance of two major indicators and perform judgments based on the results. The median value m can be determined by referring to the 1 to 9 scale method (Table 1).

Table 1. The Meaning of the Median Values 1 to 9 for Triangular Fuzzy Numbers

Number	Meaning
1	It means that the two indicators are equally important
3	Indicates that the first indicator is slightly more important than the second indicator
5	Indicates that the first indicator is significantly more important than the second indicator
7	Indicates that the first indicator is much more important than the second indicator
9	Indicates that the first indicator is extremely more important than the second indicator
2, 4, 6, 8	Represents the intermediate values between the judgments above

The Geometric Mean Matrix Calculates the Weights

After establishing a hierarchical structure, the following steps are taken to calculate criterion weights (Xu *et al*. 2012; Li *et al.* 2022).

Step 1: Construct a triangular fuzzy judgment matrix A $(a_{ij})_{n\times n}$, where $a_{ij}=(l_{ij},m_{ij},u_{ij})$. Here, a_{ij} is a closed interval with m_{ij} as the middle value, and the triangular fuzzy values are shown in Table 2 (Singh *et al.* 2018).

Multiple experts were invited to construct the triangular fuzzy judgment matrix and perform geometric average calculations (Eq. 2) for the triangular fuzzy numbers at each corresponding position in the matrix.

$$\left(\bar{l}_{ij}, \overline{m}_{ij}, \bar{u}_{ij}\right) = \left(\sqrt[n]{l_{ij}^1 l_{ij}^2 \cdots l_{ij}^n}, \sqrt[n]{m_{ij}^1 m_{ij}^2 \cdots m_{ij}^n}, \sqrt[n]{u_{ij}^1 u_{ij}^2 \cdots u_{ij}^n}\right) \tag{2}$$

Table 2. Determination of Triangular Fuzzy Numbers' Bounds

Confidence Level	$u-l$	Numerical Characteristics	Meaning of Score
High	1	(max(m-1/2,1), m, min(m+1/2,9))	Experts' scoring is not fuzzy
Low	2	(max(m-1,1), m, min(m+1,9))	Experts' scoring is relatively fuzzy
Medium	3	(max(m-3/2,1), m, min(m+3/2,9))	Experts' scoring is highly fuzzy

Step 2: Consistency testing was performed on the middle value matrix M (Xue *et al.* 2023; Nadeem *et al.* 2025). The maximum eigenvalue λ_{max} of the middle value matrix M was calculated, and λ_{max} was substituted into Eq. 3. The CR value was calculated with Eq. 4, where CI is the consistency index, and RI is the average random consistency index. If CR<0.1, then the consistency test is considered passed.

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{3}$$

$$CR = \frac{CI}{RI} \tag{4}$$

Step 3: First, quantify the degree of uncertainty in the expert judgments by using the fuzzy interval width uij−lij, then construct the non-diagonal elements of E, thereby constructing the fuzzy judgment factor matrix (Eq. 5).

$$E = (e_{ij})_{n\times n} = \begin{bmatrix} 1 & 1-\frac{u_{12}-l_{12}}{2m_{12}} & \cdots & 1-\frac{u_{1n}-l_{1n}}{2m_{1n}} \\ 1-\frac{u_{21}-l_{21}}{2m_{21}} & 1 & \cdots & 1-\frac{u_{2n}-l_{2n}}{2m_{2n}} \\ \vdots & \vdots & \vdots & \vdots \\ 1-\frac{u_{n1}-l_{n1}}{2m_{n1}} & 1-\frac{u_{n2}-l_{n2}}{2m_{n2}} & \cdots & 1 \end{bmatrix} \tag{5}$$

Where $e_{ij} = \frac{u_{ij}-l_{ij}}{2m_{ij}}$ is the standard deviation, representing the degree of fuzziness in the expert's judgment. When this value is large, it indicates that the fuzziness of the evaluation is higher, and at the same time, the confidence of the evaluation is greater; conversely, if the standard deviation is low, it reflects that the fuzziness of the evaluation is smaller, but the confidence may be relatively weaker.

Step 4: Adjust the judgment matrix (n×n), and obtain the adjusted judgment matrix Q through the correlation between M and E (Eq. 6). Adjust the judgment matrix Q by converting it column by column into a judgment matrix with ones on the diagonal.

$$Q = M \times E \tag{6}$$

Step 5: Use the geometric mean method to calculate the weights of each indicator. For the judgment matrix that has been constructed, first, calculate the n-th root of all elements in each row (Eq. 7). Then, normalize all row roots to obtain the final weight of the i-th indicator (Eq. 8).

$$\overline{w_i} = \left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}, i = 1,2,3\ldots,n \tag{7}$$

$$w_i = \frac{\overline{w_i}}{\sum_{i=1}^{n} \overline{w_i}}, i = 1,2,3\ldots,n \tag{8}$$

Quality Function Deployment (QFD)

Quality Function Deployment (QFD) was developed in Japan in the late 1960s (Geng and Xu 2018). It purpose is to help in the designing of products that meet customer requirements and to improve manufacturing processes (Cristiano *et al.* 2001; Akao and Mazur 2003; Ince *et al.* 2025). As a user-demand-driven structured design method, QFD uses a multi-level mapping matrix of demand - function - technology to transform vague user expectations into actionable technical parameters. In interdisciplinary applications, QFD has demonstrated strong demand analysis capabilities: in the automotive industry (Liu *et al.* 2024), it provided a theoretical foundation and practical framework for age-friendly design; in the medical device field (Zhu *et al.* 2022), QFD can precisely capture the dual needs of healthcare workers and patients, optimizing equipment-human interaction logic; in the research on revitalizing traditional crafts (Li *et al.* 2023), QFD establishes a correlation matrix between cultural symbols and modern functions, enabling the innovative translation of traditional elements. In the present work, QFD was applied to the demand analysis of Tibetan furniture design, represented in the form of an intuitive matrix framework, incorporating user needs into the product design Quality House framework (De Ana *et al.* 2013).

The House of Quality (HOQ) is the core of QFD (Das and Mukherjee 2008; Xu and Chen 2025), with its left wall recording user needs and corresponding weights to reflect the importance of different demands. The ceiling lists design elements, quality characteristics, and functional features as key technical points for achieving product functions. The room section constructs a relationship matrix between left-wall user needs and ceiling design elements, visually presenting their correlation degree. The floor shows the weighted results of ceiling elements to indicate their significance, while the roof serves as a correlation matrix to analyze inter-relationships among design elements.

QFD ranks the importance levels and supplements it with expert ratings. The core demand results are ranked according to the analysis of demand weight. Experts are invited to score the correlation and provide judgment data for QFD construction. The correlation strength scores are mainly marked based on six levels: values are assigned using the numbers 0, 1, 2, 3, 4, and 5, and the final weight value is calculated based on the collected data. The calculation method for combined weight values is shown as Eq. 9). Here, TIR_j represents the absolute weight value of the j-th product characteristic, CIR_i represents the weight of the i-th user demand, and R_{ij} represents the correlation relationship value between the i-th user demand and the j-th product characteristic.

$$TIR_j = \sum_{i=1}^{n} CIR_i R_{ij}, (i = 1,2,\ldots\ldots n) \tag{9}$$

Multi-Criteria Optimization and Compromise Solution (VIKOR)

VIKOR is a multi-criteria decision-making method based on compromise thinking. It provides an optimal compromise solution for complex decision problems by quantifying the distance between alternatives and the positive and negative ideal solutions, taking into account both group benefits and individual regrets. Compared to traditional methods such as TOPSIS, the VIKOR method avoids the extreme evaluation of “non-optimal means elimination.” VIKOR introduces the group benefit index (S) and individual regret index

(R), retaining the TOPSIS distance measurement logic while further quantifying the "degree of compromise" of each alternative, especially suitable for situations such as Tibetan furniture design, which involves multi-dimensional conflicting demands. In the field of rail transit (Demir *et al.* 2023), VIKOR, combined with fuzzy set theory, addresses the uncertainty of indicators, and helps in prioritizing railway line alternative schemes; it has also provided compromise solutions for decision-making and design in energy (Abdul *et al.* 2022), medical (Albahri *et al.* 2022), and driving (Mehrparvar *et al.* 2024) sectors. In this study, VIKOR was applied to the comprehensive evaluation of Tibetan furniture design schemes. The basic steps of the VIKOR method are as follows:

Step 1: Assume that in the evaluation system, there are n evaluation objects and m evaluation indicators, which can form a matrix X (Eq. 10).

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{1m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \tag{10}$$

When performing the standardization operation on matrix X, the column vector normalization method is applied. For any element X_{ij} in matrix X, it is divided by the square root of the sum of the squares of all elements in the j-th column (Eq. 11).

$$Z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \tag{11}$$

Step 2: Determine the positive ideal solution and the negative ideal solution. The positive ideal solution consists of the maximum values of each column (Eq. 12), while the negative ideal solution consists of the minimum values of each column (Eq. 13).

$$Z^+ = \left(Z_1^+, Z_2^+, \ldots, Z_n^+\right) = \left(\max\{z_{11}, z_{21}, \ldots z_{n1}\}\right), \left(\max\{z_{12}, z_{22}, \ldots z_{n2}\}\right), \ldots, \left(\max\{z_{1m}, z_{2m}, \ldots z_{nm}\}\right) \tag{12}$$

$$Z^- = \left(Z_1^-, Z_2^-, \ldots, Z_n^-\right) = \left(\max\{z_{11}, z_{21}, \ldots z_{n1}\}\right), \left(\max\{z_{12}, z_{22}, \ldots z_{n2}\}\right), \left(\max\{z_{1n}, z_{2n}, \ldots z_{nm}\}\right) \tag{13}$$

Step 3: The group effect value Si is calculated by the weighted difference between the alternative and the optimal solution for each criterion (Eq. 14). The smaller the value, the higher the overall satisfaction of the alternative across all criteria, reflecting the "group satisfaction" dimension. The individual regret value R_i is taken as the maximum value of the ratio of the difference between the alternative and the optimal solution for each criterion (Eq. 15). The smaller the value, the smaller the regret of the alternative in the most sensitive criterion, ensuring the "individual no regret" dimension.

$$S_i = \sum_{j=1}^{m} \frac{\omega_j\left(z_j^+ - z_{ij}\right)}{\left(z_j^+ - z_j^-\right)} \tag{14}$$

$$R_i = \max_i \frac{\omega_j\left(z_j^+ - z_{ij}\right)}{z_j^+ - z_j^-} \tag{15}$$

Step 4: Calculate the final comprehensive evaluation value (Eq. 16).

$$Q_i = \frac{v(S_i - S^-)}{S^+ - S^-} + \frac{(1-v)(R_i - R^-)}{R^+ - R^-} \quad (16)$$

In the context of Tibetan furniture design, the determination of ν is tailored to specific application scenarios as well as cultural and functional priorities. Therefore, the previous definitions of ν (Yang *et al.* 2025; Gavanas *et al.* 2024) can be regarded as appropriate. In these relationships, ν represents the decision coefficient. When $\nu>0.5$, it indicates that the decision maker tends to choose the alternative that is more favorable in terms of S; when $\nu=0.5$, it means the decision maker is neutral and does not favor either S or R, reflecting a compromise approach; when $\nu<0.5$, it indicates that the decision maker tends to choose the alternative that is more favorable in terms of R.

RESULTS AND DISCUSSION

Data Collection

Previous studies have shown that a sample size of 10 to 30 participants is typically sufficient to achieve representativeness and data depth (Kamaruzzaman *et al.* 2018). Selecting a small sample of experts can ensure data richness while avoiding the unnecessary complexity that may arise from larger sample sizes (Wang *et al.* 2025) Therefore, this study employs purposive sampling to select 15 respondents, covering three key user groups: the cultural heritage and craftsmanship group (6 people), the modern use scenario group (6 people), and the theoretical calibration group (3 people). Immersive interviews (lasting 30 to 45 min each) were conducted to gather users' perceptions of the functions and cultural meanings of the seating bed (Fig. 2).

Fig. 2. On-site research images

The cultural heritage and craftsmanship group included traditional woodworkers (3 people) and painters (3 people), as they are familiar with material characteristics and craft metaphors. The modern use scenario group includes Tibetan family users (3 people) and cultural tourism consumers (3 people), with the former reflecting everyday usage pain points and the latter capturing modern aesthetic trends. The theoretical calibration group includes Tibetan studies experts (1 person) and industrial design scholars (2 people), with the former calibrating the accuracy of cultural decoding and the latter ensuring the logical consistency of the transformation from user needs to design elements. The interview texts of the 15 respondents were analyzed sentence by sentence. The process can be divided into three steps: open coding, axial coding, and theoretical coding. Open coding ultimately extracted 19 initial categories, as shown in Table 3. Axial coding involved organizing the raw data into relevant categories and determining the main categories based on logical relationships. This process refined the data into four major categories: function, culture, appearance, and craftsmanship, as shown in Table 4

Table 3. Open Coding Process

Original data representative sentence	Initial concept
Tibetan settlements are mostly located at higher altitudes. The materials used are primarily solid wood sawn timber and solid wood boards, with a painted finish.	A1: Base material is solid wood sawn timber A2: Base material is solid wood boards A3: Painted finish
Walnut wood, pine, Linzhi spruce, and Himalayan red cedar are commonly used softwoods, with occasional use of composite materials.	A4: Primarily softwood materials are used A5: Composite materials used as auxiliary
Modern Tibetan furniture places more emphasis on functionality.	A6: Increased priority on functionality
Tibetan furniture often uses carving techniques and painted patterns, which represent our ethnic characteristics.	A7: Carving/painting as cultural symbols
Previously, hand-carving required 30 steps and took over 200 hours, but now machines are used.	A8: Machine carving improves efficiency
The craftsmanship and shape are quite refined, with a preference for deep colors such as red, yellow, blue, and green.	A9: Refined craftsmanship A10: Bold color choices
The creation of the "TSSB" is related to the Tibetan people's religious beliefs in Buddhism. The large seating surface is conducive to sitting cross-legged. It is usually placed in the main room or scripture hall, in rectangular or square shapes, often with straight legs and segmented backs.	A11: "TSSB" shape originates from religion A12: Segmented square shape
The TSSB serves as both a sofa and a bed in daily use.	A13: Dual-purpose seating and bed
Changing from sitting to lying down requires moving the cushions, which is time-consuming; disassembly requires two people, making it difficult to move.	A14: Bulky, with complicated usage transitions
The storage compartments are too small, only able to hold a few scriptures.	A15: Insufficient storage capacity
The seat is too hard, causing back pain for the elderly when sitting for long periods; during winter, it is cold to sit on, and people desire heating functionality.	A16: Seat hardness is not suitable A17: Winter insulation demand
Traditional seating beds are quite large, but I prefer a smaller and more delicate design.	A18: Preference for a smaller, more delicate design
The new Tibetan-style seating beds on the market "do not look Tibetan."	A19: Insufficient cultural identity

Table 4. Axial Coding Process

Category	Subcategory	Concept Category
Technology	Solid Wood	A1, A4
	Composite Material	A2, A5
	Paint Finish	A3
	Machine Carving	A8
Appearance	Exquisite and Gorgeous	A9
	Rich in Color	A10
	Elegant in form	A12
	Compact and aesthetically pleasing	A18
Culture	Symbol Carving	A7
	Religious Painting	A7
	Buddhist Culture	A10, A11
	Cultural Recognition	A19
Function	Multifunctionality	A6, A13, A17
	Portability	A14
	Space Storage Rate	A15
	Seat Comfort	A16

By integrating and compressing the concept categories encoded in the first two stages, core categories were formed, with user needs as the central focus, to complete the theoretical coding. The interview data from the remaining 3 respondents were subjected to saturation testing around the theory of user needs, ensuring the effectiveness and reliability of the research model. The theoretical saturation of the model was confirmed when no new concepts or categories emerged. All the categories were logically connected to create the theoretical analysis model of user needs (Fig. 3).

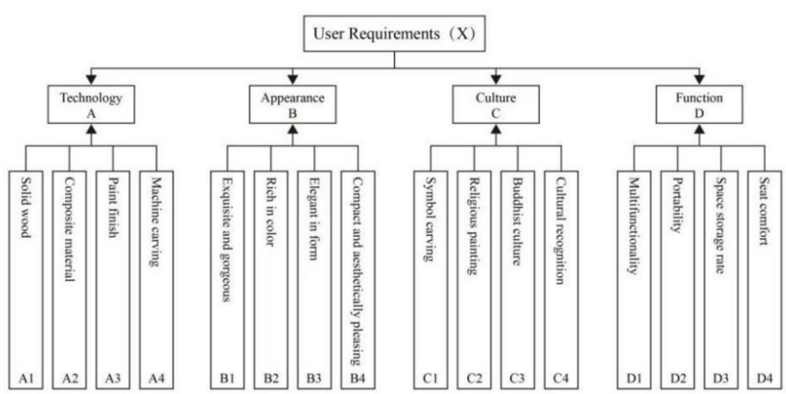

Fig. 3. User Requirement Analysis Model

Hierarchical Structure Construction (Importance Scoring)

The study invited 10 cross-disciplinary experts (including 5 Tibetan craftsmanship inheritors, 3 furniture designers, and 2 design professors) to use the triangular fuzzy number scaling method to conduct pairwise importance assessments of each level of indicators, constructing a fuzzy judgment matrix (Eqs. 17 to 21). By extracting the values from the matrix, a clear matrix M was constructed, and consistency testing was performed. The results showed that the random consistency ratio CR<0.1, indicating that the judgment matrix met the consistency requirements.

$$X = \begin{bmatrix} (1.000,1.000,1.000) & (0.438,0.613,0.857) & (0.149,0.165,0.186) & (0.202,0.242,0.309) \\ (1.167,1.631,2.286) & (1.000,1.000,1.000) & (0.208,0.304,0.547) & (0.346,0.474,0.851) \\ (5.382,6.069,6.709) & (1.827,3.292,4.815) & (1.000,1.000,1.000) & (1.397,1.864,2.712) \\ (3.235,4.129,4.946) & (1.259,2.107,3.099) & (0.395,0.536,0.767) & (1.000,1.000,1.000) \end{bmatrix} \quad (17)$$

$$A = \begin{bmatrix} (1.000,1.000,1.000) & (0.708,0.812,1.661) & (1.431,2.431,3.644) & (0.829,0.912,2.036) \\ (1.000,1.231,2.346) & (1.000,1.000,1.000) & (0.491,0.758,1.492) & (0.779,0.933,2.120) \\ (0.294,0.411,0.749) & (0.805,1.320,2.446) & (1.000,1.000,1.000) & (1.000,1.096,2.454) \\ (0.282,0.404,0.733) & (0.896,1.072,2.440) & (0.829,0.912,2.036) & (1.000,1.000,1.000) \end{bmatrix} \quad (18)$$

$$B = \begin{bmatrix} (1.000,1.000,1.000) & (0.912,0.933,1.465) & (3.392,4.579,5.741) & (4.217,5.479,6.640) \\ (1.041,1.072,1.672) & (1.000,1.000,1.000) & (2.427,3.603,4.806) & (2.987,4.146,5.349) \\ (0.174,0.218,0.295) & (0.208,0.278,0.412) & (1.000,1.000,1.000) & (1.854,2.847,3.870) \\ (0.151,0.183,0.237) & (0.187,0.241,0.335) & (0.258,0.351,0.539) & (1.000,1.000,1.000) \end{bmatrix} \quad (19)$$

$$C = \begin{bmatrix} (1.000,1.000,1.000) & (0.246,0.283,0.356) & (0.209,0.252,0.329) & (0.179,0.211,0.256) \\ (2.921,3.529,4.230) & (1.000,1.000,1.000) & (1.000,1.000,1.771) & (0.226,0.301,0.451) \\ (3.040,3.970,4.784) & (1.000,1.000,1.771) & (1.000,1.000,1.000) & (0.551,0.860,1.642) \\ (3.909,4.749,5.577) & (2.216,3.321,4.425) & (0.731,1.162,2.181) & (1.000,1.000,1.000) \end{bmatrix} \quad (20)$$

$$D = \begin{bmatrix} (1.000,1.000,1.000) & (1.876,2.930,3.961) & (1.931,3.088,4.228) & (0.311,0.404,0.579) \\ (0.252,0.341,0.533) & (1.000,1.000,1.000) & (1.026,1.966,3.094) & (0.295,0.430,0.732) \\ (0.237,0.324,0.518) & (0.323,0.508,0.975) & (1.000,1.000,1.000) & (0.288,0.443,0.835) \\ (1.728,2.475,3.210) & (1.365,2.325,3.394) & (1.196,2.259,3.466) & (1.000,1.000,1.000) \end{bmatrix} \quad (21)$$

The fuzzy judgment factor matrix E was calculated according to Eq. 5 (Eqs. 22 to 26).

$$E_X = \begin{bmatrix} 1 & 0.658 & 0.889 & 0.78 \\ 0.657 & 1 & 0.442 & 0.467 \\ 0.891 & 0.546 & 1 & 0.647 \\ 0.793 & 0.563 & 0.654 & 1 \end{bmatrix} \quad (22)$$

$$E_A = \begin{bmatrix} 1 & 0.413 & 0.545 & 0.561 \\ 0.454 & 1 & 0.34 & 0.281 \\ 0.447 & 0.378 & 1 & 0.336 \\ 0.443 & 0.28 & 0.339 & 1 \end{bmatrix} \quad (23)$$

$$E_B = \begin{bmatrix} 1 & 0.704 & 0.743 & 0.779 \\ 0.706 & 1 & 0.67 & 0.715 \\ 0.724 & 0.633 & 1 & 0.646 \\ 0.763 & 0.694 & 0.6 & 1 \end{bmatrix} \quad (24)$$

$$E_C = \begin{bmatrix} 1 & 0.806 & 0.762 & 0.819 \\ 0.815 & 1 & 0.614 & 0.626 \\ 0.78 & 0.614 & 1 & 0.366 \\ 0.824 & 0.667 & 0.376 & 1 \end{bmatrix} \quad (25)$$

$$E_D = \begin{bmatrix} 1 & 0.644 & 0.628 & 0.669 \\ 0.589 & 1 & 0.474 & 0.491 \\ 0.565 & 0.359 & 1 & 0.382 \\ 0.701 & 0.564 & 0.498 & 1 \end{bmatrix} \quad (26)$$

The adjusted judgment matrix Q was calculated using Eq. 6. After adjustment, diagonal normalization was performed on matrix Q to obtain the matrix Q'(Eqs. 27 to 31).

$$Q'_X = \begin{bmatrix} 1 & 0.598 & 0.164 & 0.255 \\ 1.685 & 1 & 0.276 & 0.434 \\ 6.085 & 3.544 & 1 & 1.582 \\ 3.895 & 2.267 & 0.639 & 1 \end{bmatrix} \quad (27)$$

$$Q'_A = \begin{bmatrix} 1 & 1.38 & 2.001 & 2.225 \\ 0.686 & 1 & 1.02 & 1.177 \\ 0.547 & 1.057 & 1 & 1.109 \\ 0.49 & 0.906 & 0.898 & 1 \end{bmatrix} \quad (28)$$

$$Q'_B = \begin{bmatrix} 1 & 1.206 & 3.021 & 6.411 \\ 0.825 & 1 & 2.472 & 5.205 \\ 0.362 & 0.44 & 1 & 2.505 \\ 0.15 & 0.186 & 0.408 & 1 \end{bmatrix} \quad (29)$$

$$Q'_C = \begin{bmatrix} 1 & 0.297 & 0.255 & 0.176 \\ 3.355 & 1 & 0.89 & 0.566 \\ 3.918 & 1.156 & 1 & 0.69 \\ 5.737 & 1.831 & 1.45 & 1 \end{bmatrix} \quad (30)$$

$$Q'_D = \begin{bmatrix} 1 & 2.265 & 3.188 & 0.792 \\ 0.493 & 1 & 1.723 & 0.408 \\ 0.315 & 0.611 & 1 & 0.277 \\ 1.225 & 2.442 & 3.252 & 1 \end{bmatrix} \quad (31)$$

Finally, the weights of each indicator at all levels were calculated using the geometric mean method, resulting in the indicator weight in Table 5. The results of the fuzzy triangular hierarchical analysis method show that user needs in the criteria layer of Tibetan furniture design followed the trend C>D>B>A. The cultural dimension C had the highest weight (0.481), forming the core driver of user needs, followed by the functional dimension D (0.307), the appearance dimension B (0.133), and the craftsmanship dimension A (0.079).

Table 5. Weights and Comprehensive Rankings of Design Elements

Criterion Layer	Weight	Sub-criterion Layer	Weight	Comprehensive Weight	Comprehensive Ranking
A	0.079	A1	0.373	0.029	11
		A2	0.226	0.018	13
		A3	0.212	0.017	14
		A4	0.189	0.015	15
B	0.133	B1	0.429	0.057	6
		B2	0.352	0.047	8
		B3	0.155	0.021	12
		B4	0.064	0.008	16
C	0.481	C1	0.071	0.034	9
		C2	0.238	0.114	4
		C3	0.278	0.134	2
		C4	0.413	0.199	1
D	0.307	D1	0.339	0.104	5
		D2	0.168	0.052	7
		D3	0.105	0.032	10
		D4	0.387	0.119	3

In the sub-criteria layer, the comprehensive weight ranking was as follows: C4 > C3 > D4 > C2 > D1 > B1 > D2 > B2 > C1 > A1 > B3 > A2 > A3 > A4 > B4. The comprehensive weight ranking of Cultural Recognition (0.199) ranked first, reflecting the core user need for the unique cultural transmission of Tibetan furniture. Buddhist Culture (0.134), Seat Comfort (0.119), and Religious Painting (0.114) reflect the prioritization of cultural core values and functional practicality. Exquisite and Gorgeous (0.057), Multifunctionality (0.104), and other needs focusing on cultural visual expression and scene adaptability are ranked in the middle. Meanwhile, fundamental support needs such as Solid Wood (0.029) and Symbol Carving (0.034) have a lower priority.

User Needs Conversion to Technical Characteristics Based on QFD

After quantifying the weights of design elements, QFD theory was applied to establish a mapping link between user needs and technical characteristics. Seven furniture designers (3 specializing in Tibetan cultural heritage with ≥5 years of experience and 4 in modern furniture engineering with ≥3 years of experience in parametric/modular design, all holding design-related academic qualifications and having some knowledge of Tibetan-style furniture design) extracted design elements based on user needs, resulting in three major categories of design features further divided into 16 design elements, which were then incorporated into the House of Quality.

After identifying the technical requirements to meet customer needs, the research team, based on 7 existing experts, further invited 3 additional experts, including a professor of design, a furniture designer, and a postgraduate student majoring in furniture design, all with more than 3 years of professional experience or academic research experience in the field. The research team provided the participants with a detailed introduction to the background, purpose, and core objectives of this study to help them fully understand the significance and value of the research. Subsequently, the research purpose was specifically elaborated, and the participants were clearly instructed to use designated symbols to characterize the coordination or conflict relationships between different quality characteristics. To scientifically determine the "roof" part of the House of Quality, which represents the relationships between quality characteristics, the project team systematically referred to the approach of organizing focus group interviews adopted by previous studies (Li *et al.* 2023; Kürüm *et al.* 2021).

Through synthesizing opinions from multiple parties, the team ultimately completed the definition of relationships between quality characteristics. The procedure was to sort the product design elements and collect data, then calculate the comprehensive weight value according to Eq. 9 (Fig. 4). In the HOQ, the mapping relationship between user needs and design requirements exhibited significant hierarchical characteristics (Fig. 5). The ranking shows that Tibetan-style Totems (3.014), Tibetan-style Colors (2.482), and Traditional Patterns (2.293) were at the top due to their strong association with core needs such as cultural recognition and Buddhist culture, making them the core carriers of cultural gene expression. Functional Design for Meditation Scenarios (2.179), Sitting Posture Support System (1.867), and Integrated Design for Sitting, Reclining, and Storage (1.645) are functional elements that, through their deep coupling with needs such as seating comfort and multifunctionality, achieve a balance between cultural scenarios and modern user experiences. Natural Mineral Coating (0.519) and Plateau Solid Wood with Lightweight Material Combination (0.583), as material and craftsmanship elements, had lower weights and serve as implicit support for cultural symbol presentation and functional need satisfaction.

More Strongly correlated	Strongly correlated	Correlated	Moderately correlated	Weakly correlated	Uncorrelated
■	★	◆	▲	●	
5	4	3	2	1	0

User Requirements \ Technological Needs		Material Techniques					Cultural Ornamentation				Functional Experience						
	Weight of Demand	Solid Wood + Lightweight Materials	Natural Mineral Coating	Eco-Friendly Anti-fouling Coating	Digital Engraving	Openwork Geometric Frame	Tibetan-style Colors	Three-dimensional Relief Patterns	Traditional Patterns	Tibetan-style Totems	Modular Design	Functional Design for Meditation Scenarios	Integrated Design for Sitting, Reclining, and Storage	Design with Universal Wheels for Mobility	Efficient Utilization of Vertical Space	Sitting Posture Support System	Intelligent Temperature-controlled Cushion
A1	0.029	■						●					●	▲			
A2	0.018	■											●	▲			▲
A3	0.017		■	■			◆			▲							
A4	0.015		●	●	■	■		★	●	▲							
B1	0.057		●	●			■	▲	★	★							
B2	0.047					▲	▲	◆	★	■		◆					
B3	0.021	●			●	●		◆		▲	●	●	◆		●	●	
B4	0.008						▲	★	★	■		■					
C1	0.034				★	★		■	★	■		▲					
C2	0.114		▲	▲			■	●	▲	■		■					
C3	0.134		●				■	●	■	■		■					
C4	0.199				◆	▲	★		★	■							
D1	0.104										■	◆	■	◆	◆	●	◆
D2	0.052	★									◆		■	■	◆	▲	◆
D3	0.032										■		■	●	◆	▲	▲
D4	0.119	●									■	◆	■		★	■	■
Relative Weight(%)		0.583	0.519	0.385	0.829	0.724	2.482	0.857	2.293	3.014	1.452	2.179	1.645	0.698	1.061	1.867	1.163
Rank		14	15	16	11	12	2	10	3	1	7	4	6	13	9	5	8

Fig. 4. House of Quality Model

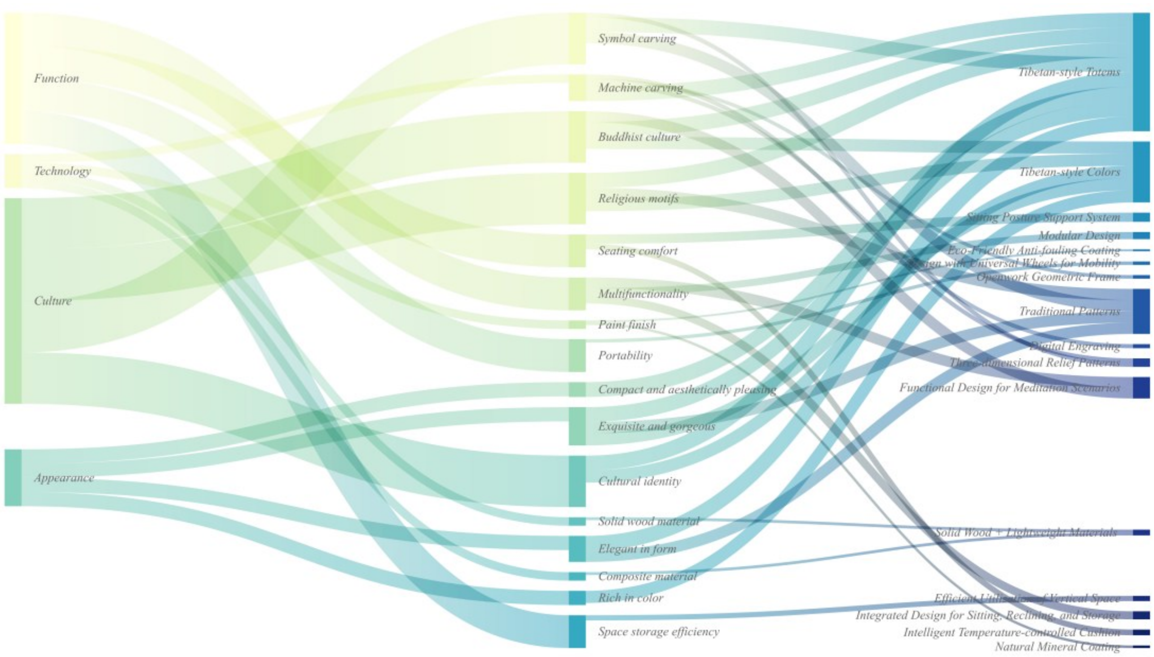

Fig. 5. Mapping diagram of user requirements and design requirements

Description of Modeling and Rendering Techniques for Design Schemes

This study divides design elements into three categories based on their weights: Material Techniques, Cultural Ornamentation, and Functional Experience. By adjusting the combinations of design elements and technical implementation paths, three differentiated design schemes are created (Fig. 6). The three design schemes were modeled and rendered using professional tools and standardized processes: 3D modeling with Rhinoceros 7.0 for parametric design ensured precise control over cultural elements such as Tibetan-style totem proportions, while functional structures were built based on Tibetan adults' anthropometric data. Rendering *via* Keyshot 11 used high-resolution local Tibetan wood materials to simulate smoking and tea dyeing effects, with mineral pigment colors calibrated against traditional Tibetan painting colorimeter data and lighting matching plateau natural light and butter lamp scenarios.

Fig. 6. Three alternative diagrams

In the analysis results, the cultural symbol system of Tibetan furniture has strong historical depth and ethnic specificity. Therefore, traditional patterns and religious symbols, such as the Dharma wheel, lotus, and victory banner, can be incorporated into the design process. It is recommended to use traditional hand-carving techniques to carve traditional Tibetan symbols with tools. Furthermore, through symbol-layer translation technology, an organic integration of symbols and modern furniture forms can be achieved while retaining cultural recognition. Functionally, an integrated design for sitting, reclining, and storage is constructed. Through ergonomic analysis, the furniture form is reconstructed, expanding the traditional single seating into a multifunctional composite that includes sitting, storage, and reclining. The storage area uses a pull-out design, which can effectively improve space utilization. While elements such as eco-friendly anti-pollution coatings and universal wheel handling design enhance the user experience, their cultural attributes and functional innovation are weaker, and the technical implementation difficulty is relatively low. The design goal for these elements is to meet basic functional needs at the lowest cost. Therefore, standardized industrial solutions are adopted. For the high humidity and dusty environment characteristics of Tibetan areas, composite coatings can be selected to achieve anti-pollution and easy cleaning functions, and scale production can be achieved through roller coating techniques. Thus, three differentiated design schemes were completed.

From the perspectives of Material Techniques, Cultural Ornamentation, and Functional Experience, the three design schemes can be described in detail. In terms of Material Techniques, Scheme 1 uses walnut and elm as base materials, presenting Tibetan-style textures with a smoked and tea-dyed aging process, complemented by environmentally friendly coatings for protection. Schemes 2 and 3 use dried solid wood to construct the frame, strictly controlling the moisture content to ensure structural stability. The traditional mortise and tenon craftsmanship is used for precise joining, inheriting the essence of Tibetan furniture-making techniques. All three schemes are primarily made of solid wood, with modern craftsmanship ensuring durability. Scheme 3 additionally incorporates modern design thinking, highlighting the natural texture and smooth touch of the materials. In terms of Cultural Ornamentation, all three schemes center on Tibetan cultural symbols as the core decorative elements. Scheme 1 carves the Eight Treasures pattern, using a warm wood color with golden carvings and multicolored fabrics to create a national atmosphere through visual contrast. Scheme 2 combines auspicious patterns with a warm yellow color tone, complemented by traditional Tibetan embroidered and printed patterns and hollow wood artistry. Scheme 3, on the other hand, incorporates carvings and paintings of religious motifs like the lotus, using traditional Tibetan color aesthetics such as red, blue, and pink, paired with ethnic pattern fabrics to enhance cultural recognition and sacred significance. In terms of Functional Experience, all three schemes follow ergonomic principles, optimizing seat height and backrest angle to alleviate fatigue from prolonged sitting. Schemes 1 and 2 feature drawers, open storage areas, and other storage spaces to meet daily storage needs. Scheme 2 additionally includes small cushion storage, enhancing convenience. All three schemes, through reasonable size and structural design, accommodate various scenes such as sitting and lying, providing a comfortable and practical experience for family interactions and personal rest, thus promoting the inheritance and innovation of Tibetan furniture.

Design Scheme Evaluation Based on VIKOR

This study evaluates three proposed Tibetan-style seating bed designs. To enhance the comprehensiveness and credibility of the assessment, two representative commercial products (option 4 and option 5) are incorporated for comparative analysis (Fig. 7). Option 4 is sourced from the best-selling Tibetan-style seating bed on Taobao, a leading e-commerce platform in China. With a high sales volume of over 100 units monthly (data retrieved from Taobao’s public sales statistics as of July 26, 2025), it is a mass-produced model from a well-known domestic brand. It features simplified traditional motifs, which are likely a strategy to appeal to a broader consumer base, and has a primary focus on basic functionality. Option 5 is a handcrafted product widely available in local Tibetan markets. The authors selected it due to its prevalence among residents and its strong emphasis on traditional craftsmanship, such as the use of traditional mortise-tenon joints and hand-carved religious symbols.

Fig. 7. Commercial Tibetan-style seating bed options

A total of 40 evaluators were recruited *via* a mixed-methods approach, comprising 25 Tibetan residents and 15 Tibetan cultural specialists (including academic researchers and cultural heritage practitioners). Demographic characteristics were as follows: age distribution was 20 to 30 years (n=12, mean±SD: 25.6±3.2 years), 31 to 50 years (n=18, mean±SD: 40.2±5.8 years), and ≥51 years (n=10, mean±SD: 56.8±4.5 years); gender distribution included 22 males and 18 females; occupational breakdown consisted of 10 farmers/herdsmen, and 15 urban office workers among the Tibetan residents, and 9 university researchers and 6 cultural heritage protection workers among the specialists. All five schemes were scored by evaluators using a 7-point scale across 16 user-demand design elements. Final scores were derived from mean values, forming the original matrix with positive indicators. Judgment matrix X was normalized to matrix Z *via* Equation 11 (Eq. 32). This comparison enables both intra- and inter-group analysis, validating the superiority of the QFD-guided approach in integrating cultural inheritance and functional innovation.

$$Z=\begin{cases} 0.526 & 0.493 & 0.506 & 0.540 & 0.494 & 0.463 & 0.506 & 0.497 & 0.476 & 0.463 & 0.504 & 0.504 & 0.488 & 0.504 & 0.502 & 0.466 \\ 0.386 & 0.466 & 0.415 & 0.400 & 0.414 & 0.378 & 0.391 & 0.371 & 0.368 & 0.401 & 0.344 & 0.414 & 0.398 & 0.390 & 0.390 & 0.383 \\ 0.511 & 0.478 & 0.444 & 0.502 & 0.484 & 0.513 & 0.506 & 0.519 & 0.546 & 0.491 & 0.494 & 0.474 & 0.504 & 0.467 & 0.494 & 0.526 \\ 0.411 & 0.439 & 0.467 & 0.408 & 0.461 & 0.468 & 0.443 & 0.413 & 0.458 & 0.456 & 0.443 & 0.449 & 0.434 & 0.474 & 0.461 & 0.464 \\ 0.381 & 0.344 & 0.396 & 0.361 & 0.372 & 0.400 & 0.374 & 0.419 & 0.360 & 0.420 & 0.433 & 0.386 & 0.401 & 0.388 & 0.372 & 0.380 \end{cases} \quad (32)$$

Using Eqs. 14 through 17, the group utility value S_i, individual regret value R_i, and compromise value Q_i, the three design schemes were calculated in sequence. The values for the three types of indicators were then ranked in ascending order. The results are summarized in Table 6.

Table 6. Calculation Results for Each Scheme

Scheme	S	R	Q	Rank
1	0.131	0.048	0.019	2
2	0.900	0.152	0.845	4
3	0.100	0.051	0.008	1
4	0.440	0.093	0.361	3
5	0.889	0.199	0.993	5

All alternative schemes were sorted in ascending order based on their Q_i, H_i, and R_i values, respectively. Schemes a and b were the top two alternative schemes in the ranking by Q_i values. Scheme A was the optimal scheme when the following two conditions are satisfied:

1: $Q_2 - Q_1 \geq \frac{1}{n-1}$, where n is the number of alternative schemes;

2: A_1 also ranks first in the sorting of S_i and R_i.

When only Condition 1 is not satisfied, the schemes can be substituted one by one into Condition 1 for verification according to the ranking of values. Suppose the value of the t-th scheme satisfies Condition 1, then all schemes from the first to the t-th are ideal compromise schemes. When only Condition 2 is not satisfied, both schemes a and b are ideal compromise schemes (Arıkan and Cesur 2024).

Scheme 3 (Fig.8) deeply integrates the essence of Tibetan culture with modern functional needs. In terms of material techniques, it uses solid wood as the main framework, combining modern drying treatment with traditional mortise and tenon craftsmanship to balance stability and cultural authenticity. In terms of cultural decoration, it incorporates carvings and paintings of religious auspicious patterns such as the lotus, paired with a traditional Tibetan color scheme of red, blue, and pink, along with ethnic pattern fabrics to create a highly recognizable visual symbol system. In terms of functional experience, it follows ergonomic principles to optimize the sitting and reclining structure, while the well-designed storage spaces meet daily storage needs. This scheme achieves an organic unity of cultural heritage, aesthetic value, and practical functionality, aligning with the VIKOR method's pursuit of balancing group benefits and individual regrets, making it the preferred solution for the modernization of Tibetan furniture design.

Fig. 8. Optimal design solution

Discussion

This study quantitatively found through TFAHP that the cultural dimension in Tibetan furniture design had a weight of 0.481, which was significantly higher than the functional (0.307), aesthetic (0.133), and craftsmanship (0.079) dimensions, confirming that the cultural carrier attribute is its core feature (Shutao *et al.* 2020). This result resonates with Zhu *et al.* (2024), who proposed that "traditional furniture, as a material cultural heritage, has practical value, artistic value, and collectability," revealing that the Tibetan community prioritizes cultural authenticity over functional practicality. Within the cultural dimension, cultural recognition (0.199) and Buddhist culture (0.134) have the highest weights, indicating that the semantic preservation of religious symbols is the core design demand. The gradient of weights for religious paintings (0.114) and symbolic carvings (0.034) further confirms the hierarchical translation logic of Tibetan furniture as "faith symbols - cultural identifiers - craftsmanship expression" (Markel 2010).

The weight of seating comfort (0.119) and multifunctionality (0.104) highlights the functional transformation of Tibetan furniture from a "religious ritual tool" to a "modern living carrier," which aligns with the theory proposed by Rui and Firzan (2025), stating that "the combination of aesthetics and emotion in interior design can enhance user experience." However, the low weight of portability (0.052) and space storage rate (0.032) suggests that users are willing to compromise on some functional convenience for cultural authenticity, reflecting the constraint of cultural priorities on functional innovation. In the technical dimension, solid wood material has the highest weight (0.029), corroborating Podrekar Loredan *et al.* (2024), who noted that "wooden interiors have a positive impact on physical and mental states." The low weight of machine carving (0.015) implies that technological innovation should serve cultural inheritance rather than replace traditional craftsmanship.

The low weights of rectangular shape (0.021) and geometric patterns (0.008) reveal a conflict between traditional geometric shapes and the layout of modern living spaces, indicating that symbol innovation must strike a balance between cultural purity and modern aesthetics (Fu *et al.* 2024). The strong association between Tibetan colors and traditional patterns (Wang 2020) confirms that the visual expression of religious symbols is the key carrier of cultural recognition, while functional designs such as intelligent temperature-controlled cushions and integrated seating/storage help compensate for the traditional functional shortcomings under the priority of culture. The VIKOR-optimal Scheme 3 confirms the balanced path of "cultural symbol integrity - functional innovation - craftsmanship feasibility," resonating with the design methodology proposed by Wang *et al.* (2025).

CONCLUSIONS

1. This study, based on the perspective of cultural heritage revitalization, constructed a FAHP-QFD-VIKOR hybrid model to systematically address the contradiction between cultural symbol translation and modern functional adaptation in Tibetan furniture design. Through the Triangular Fuzzy Analytic Hierarchy Process (TFAHP), it was quantitatively found that the cultural dimension, with a weight of 0.481, is the core driving force of the design. Within this dimension, cultural recognition (0.199) and Buddhist culture (0.134) form the dual core of user demands, validating the design logic of Tibetan furniture, which prioritizes "cultural authenticity." Quality Function Deployment (QFD) converts abstract demands into 16 technical characteristics, such as Tibetan totems (3.014) and traditional patterns (2.293), achieving a structured mapping of "demand - function - technology." The Multi-Criteria Compromise Solution (VIKOR) method finally selected Scheme 3, which, through lotus carvings, integrated seating and storage, and the fusion of solid wood with modern craftsmanship, achieves the optimal balance of cultural symbol integrity, functional innovation, and craftsmanship feasibility (S=0.100, R=0.051)
2. The innovation of this study's methodology lies in: (1) introducing triangular fuzzy numbers into the weight analysis of Tibetan furniture design for the first time, addressing the fuzziness in cultural assessment; (2) using the QFD matrix to achieve the systematic transformation of Tibetan user demands into technical parameters, overcoming the limitations of traditional symbolic collage design; (3) utilizing the VIKOR method to quantify the compromise solution of "culture – function" conflicts, providing a scientific paradigm for multi-objective decision-making. Practically, the design scheme guided by this model retains cultural genes such as Tibetan totems and color systems while meeting modern living needs, transitioning seamlessly between the religious hall and home environments.
3. The limitations of this study primarily include two aspects. First, it failed to adequately capture the implicit needs in the diverse life scenarios of Tibetans, such as functional adaptability in agricultural or urban living environments, which may restrict the practicality of the designed schemes in specific contexts. Second, the study did not incorporate a full lifecycle cost analysis, limiting the comprehensive evaluation of the economic and environmental sustainability of the design solutions.
4. To address these limitations, future research directions are proposed as follows: First, combining user journey maps and scenario simulation technologies to conduct in-depth investigations into the demand weights across different lifestyles (*e.g.*, agricultural production, urban daily life) and refine the mapping relationship between implicit needs and technical features. Second, integrating Life Cycle Assessment

(LCA) methods to construct a "cultural-environmental-economic" three-dimensional decision framework, which will expand the model's application depth in the full lifecycle design of Tibetan furniture. These improvements will help enhance the study's integration into the broader research context of ethnic furniture design and promote more targeted and sustainable design practices.

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Article submitted: June 14, 2025; Peer review completed: July 25, 2025; Revised version received and accepted: July 29, 2025; Published: August 7, 2025.
DOI: 10.15376/biores.20.4.8566-8590