Design of Taishan Cultural and Creative Products Integrating Cultural IP with Wood-based Materials

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Aiming at the problems of strong subjectivity in Taishan wood-based cultural and creative design, low added value of bio-based materials, and superficial cultural translation, this paper proposes a systematic design framework coupling Grounded Theory with the Fuzzy Analytic Hierarchy Process (FAHP). A three-dimensional evaluation system covering culture, function, and emotion is constructed, based on which three Taishan wood-based cultural and creative products are developed. A multi-criteria evaluation framework is established using a Likert-type five-point scale for efficacy verification. The results indicate that this quantitative path mitigates wood anisotropy and accurately restores complex contours. It enhances the added value of wood-based materials while preserving high recognizability of authentic cultural imagery. This method facilitates the shift of cultural and creative development from empirical judgment to data-driven decision-making, and provides solid theoretical support and a universal research direction for the high-value sustainable development of mountain-type cultural heritage.

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INTRODUCTION

As a World Cultural and Natural Heritage site, Mount Tai, with its profound historical heritage and temperate forest ecosystem, has nurtured a unique cultural IP spectrum containing elements such as ancient architectural aesthetics and iconic cliff stone carvings. Typical northern coniferous and broad-leaved tree species here, including Mount Tai pine, *Platycladus orientalis*, Chinese catalpa, walnut wood and beech wood, have been the material carriers of regional traditional woodcraft and architectural frames. From the perspective of materials science, these forest resources feature unique microstructural arrangements of tracheids and vessels, excellent specific strength and natural grain textures. They are ideal substrate materials for high-precision processing technologies including solid wood integral molding, CNC bas-relief carving and glue-free mortise-and-tenon structures, laying a solid foundation for developing high value-added wood-based cultural products and realizing the modern transformation of biomass resources.

However, against the global context of high-value utilization of biomass resources, the development of Mount Tai wood-based products still faces dual bottlenecks in design and engineering. First, existing product R&D processes rely excessively on designers' perceptual experience and subjective aesthetics, lacking scientific theoretical guidance and quantitative evaluation systems. This results in the visual expression of Taishan cultural IP often being a superficial stacking of symbols, leading to severe product homogenization (Du 2025). Second, there is a significant risk of mismatch between the physical properties of materials and processing technologies. Due to the failure to conduct scientific design by in-depth combining the tracheid structure of different tree species, differences in wood density, and laws of dry shrinkage and wet expansion, finished products are prone to physical failures, such as microcracks and geometric deformation, induced by alternating environmental stresses during service. This not only weakens product stability but also severely restricts the modern transformation of Taishan cultural heritage into high-value-added, high-performance biomass products (Li 2025; Hu *et al.* 2020). Therefore, constructing a standardized method that can guarantee cultural authenticity, restrain physical defects of natural wood, and optimize multi-criteria allocation is an urgent scientific problem to be solved in the current field of biomass material application.

To resolve the mismatch between cultural semantics and engineering quantitative control mentioned above, multi-criteria hybrid decision-making models are gradually becoming introduced into the field of biomass materials to realize accurate mapping of interdisciplinary indicators. The Fuzzy Analytic Hierarchy Process (FAHP) analytically optimizes the classic Analytic Hierarchy Process (AHP) by introducing fuzzy set theory, which can effectively address cognitive fuzziness and subjective uncertainty in the extraction of multi-criteria indicators and decision-making processes. Nevertheless, a standardized evaluation system capable of deeply integrating specific regional cultural semantics with physical and mechanical properties of wood-based materials has not yet been established (Zhu *et al.* 2015). Traditional qualitative descriptions fail to provide precise mathematical weight allocation among conflicting criteria including historical authenticity of culture, structural stability of wood and market functional adaptability (Dhingra and Chattopadhyay 2021).

Therefore, it is important to construct a closed research path integrating qualitative induction and quantitative optimization: first, systematic three-level coding of qualitative text data is carried out through Grounded Theory to convert abstract user narratives into concrete and objective structured design indicators and realize theoretical construction based on underlying data; subsequently, the FAHP is adopted, and fuzzy consistent judgment matrices are used to scientifically eliminate experts' cognitive biases and determine the core priority of each design element. In the context of modern forestry engineering and design science, this hybrid research path featuring deep coupling of "qualitative-quantitative" approaches has been widely proven effective. For instance, Liu *et al*. (2020) quantified the process parameters and semantic priorities of laser cutting for micro-thin wood; Ho (2008) demonstrated the robustness of fuzzy logic in handling complex forestry decision-making systems; Gao *et al*. (2026) constructed an application framework of transparent wood functional spaces based on AIGC and AHP.

To consolidate the interdisciplinary logic of this research from a theoretical perspective, the deep coupling mechanisms among cultural translation, cultural and creative product design, and cultural heritage and wood product development are first clarified.

First, in the dimension of cultural translation, regional cultural heritage is often characterized by high unstructuredness, historical accumulation, and symbolic abstraction. Without a scientific translation mechanism, cultural product design is highly likely to fall into the dilemma of "superficial symbolic copying" (Li *et al*. 2024). Cultural translation in the sense of design science is essentially a semantic mapping process that converts historical semantics, collective memories and regional spectrums into contemporary creation language.

Second, within the conceptual framework of cultural and creative product design, high-quality cultural and creative products serve not only as material carriers of culture, but also as core media linking audience emotional resonance and practical functional demands. Such an approach requires the design process to shift away from sole dominance by perceptual experience toward multi-dimensional coordination of "cultural demand – functional utility – emotional expectation" (Mohan *et al*. 2022).

Finally, regarding the integration of cultural heritage and wood product development, biomass wood nurtured by forest ecosystems (such as typical coniferous and broad-leaved tree species in the Mount Tai area) possesses natural biomass carbon sink attributes and excellent physical and mechanical characteristics. The unique tracheid arrangement, grain orientation and mild tactile sensation further provide an ideal material substrate for bearing profound mountain culture. However, there is currently a lack of systematic theoretical bridges to achieve seamless connection between intangible Mount Tai cultural IP and processing technologies of hard solid wood (such as glue-free mortise-and-tenon joints and CNC bas-relief carving) (Xu *et al*. 2025).

Although existing literature has respective strengths in qualitative extraction of cultural symbols and quantitative optimization of engineering parameters, there remains an obvious scientific gap between the two: there is a lack of a mathematical mapping mechanism that can translate unstructured regional cultural features into structured engineering parameters of wood-based materials. This study aims to fill this theoretical gap and construct a closed research path of "qualitative induction-quantitative mapping," so as to realize the transformation from empirical design to the paradigm of engineering science (Ma *et al*. 2026). This is precisely because there exists an obvious scientific gap between the "conceptual foundation of cultural translation" and the "integration of wood engineering properties" in existing research.

This study constructs a closed-loop framework of Feature Anchoring, Weight Deduction, Strategy Synthesis, and Design Validation. Integrating Grounded Theory with the FAHP algorithm, this framework realizes qualitative construction of design indicators and quantitative deduction of weights, further carrying out translation practice of Taishan wood-based cultural and creative products and expert efficacy verification under strategic guidance, providing a scientific path for the high-value utilization of biomass resources.

EXPERIMENTAL

This study constructs a closed research path composed of Feature Anchoring, Weight Deduction, Strategy Synthesis, and Design Validation. Through the deep coupling of qualitative analysis and quantitative decision-making, it achieves systematic integration of Taishan cultural IP and wood-based material properties (Fig. 1).

Feature Anchoring

Grounded Theory is used to conduct three-level coding on Taishan cultural genes and wood-based material perceptual characteristics, deconstructing original indicators for design evaluation.

Weight Deduction

The FAHP is introduced to construct a judgment matrix, transforming experts' subjective experience into scientific decision-making weights and establishing the core priority of cultural and creative development.

Strategy Synthesis

Design strategies are formulated based on weight guidance, translating abstract cultural semantics into tangible wooden product forms, realizing the integration of cultural authenticity and material craftsmanship.

Design Validation

A multi-criteria evaluation framework is established using a Likert-type five-point scale to conduct efficacy verification on the outcomes, ensuring that the schemes have both cultural inheritance value and scientific application of bio-based materials.

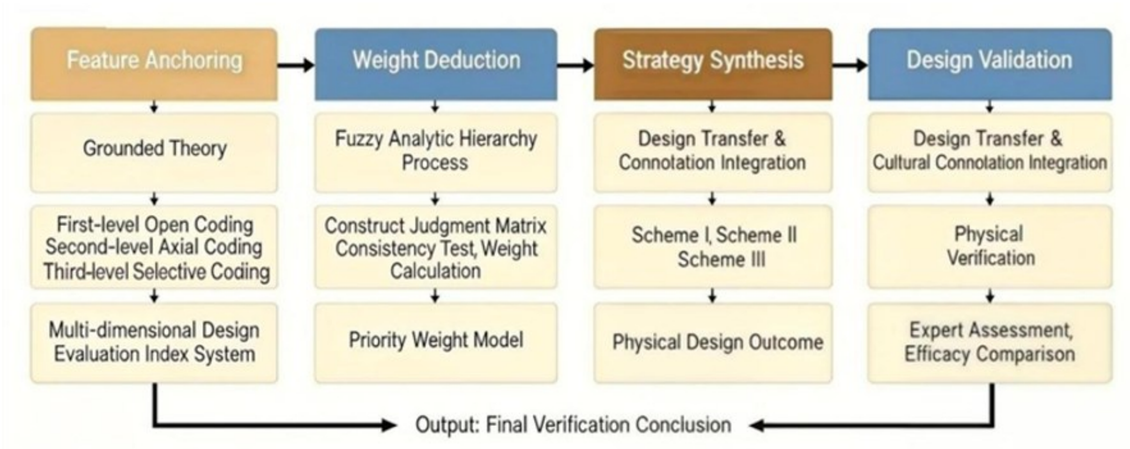

Fig. 1. Research framework flowchart

RESEARCH PROCESS

Data Collection and Corpus Construction

To deeply explore audience demands and cultural context of Mount Tai tourism cultural and creative products, this study follows the principle of multi-source mutual verification and constructs a comprehensive corpus covering digital archives, in-depth interviews, and online reviews.

The data sources mainly include: (1) Digital archive corpus: extracted from the Mount Tai Digital Archives and CNKI academic database, covering materials on Mount Tai historical buildings, stone carvings and traditional crafts; (2) Online review corpus: Python technology was adopted to crawl comments concerning "Mount Tai cultural and creative products" from JD.com and Xiaohongshu, with a time span from January 2023 to January 2025. A total of 860 original crawled comments were obtained. After manual cleaning to eliminate invalid, redundant, and advertising information, 468 valid narrative corpora were finally acquired to guarantee the authenticity and quality of research samples.

For the sampling of interview respondents, purposive sampling and snowball sampling strategies were adopted to select 15 senior experts engaged in Mount Tai cultural IP development, intangible cultural heritage wood art inheritance and forestry material engineering (including university design professors, senior industrial artists and material science researchers with an average working experience of over 6 years), as well as core audiences who have purchased Mount Tai cultural and creative products. Interviews were conducted following a semi-structured guideline covering three core dimensions: cultural pain points, material characteristics and interaction demands. Interviews were carried out via offline face-to-face communication or online video conferences, each lasting 45 to 60 minutes. The whole process was audio-recorded and transcribed to ensure the traceability of original corpora.

Qualitative Analysis Coding and Reliability Test

Data were collaboratively processed by an interdisciplinary coding team consisting of one biomass materials science PhD, one design science researcher and one digital humanities expert. First, during the initial coding test, two independent coders conducted blind review on randomly selected 20% corpus samples. The calculated inter-coder agreement percentage was significantly higher than the threshold of 85%, ensuring a high degree of consistent understanding of category definitions within the team.

Based on Grounded Theory, the research analyzed 468 corpora in three stages:

Open Coding: Sentence-by-sentence micro-analysis was performed to initially conceptualize the visual representation of Mount Tai cultural IP and the properties of wood-based materials, and 23 initial concepts were finally identified (Table 1).

Axial Coding: Logical clustering and tracing were adopted to explore the coupling relationship between cultural semantics and physical properties of materials, and 9 main categories were condensed (Table 2).

Selective Coding: Logical connections among categories were clarified to construct three core categories, namely cultural demand, functional demand and emotional demand (Table 3).

In addition, to guarantee scientificity, 87% of the samples (n=408) were imported into NVivo 12 for coding, and the remaining 13% (n=60) were used as an independent validation set for theoretical saturation test. The test verified that all semantic features were covered by existing categories without new concepts emerging.

Table 1. First-level Open Coding

Main Category	Initial Concepts	Representative Statements
Cultural Genes	Historical tracing, regional code	The most authentic and representative original elements in Taishan culture (*e.g.*, stone carvings, Fengshan sacrifice). Mining their spiritual core ensures products have accurate identity attributes and cultural belonging in cultural and creative translation.
Aesthetics	Exquisite shape, visual atmosphere	Cultural and creative products feature exquisite and delicate shapes, smooth carving lines, and a strong Taishan cultural atmosphere. The appearance should be elegant and durable, creating a unique visual atmosphere when displayed on desks.

Main Category	Initial Concepts	Representative Statements
Material Perception	Natural texture, tactile properties	Utilizing the natural texture and characteristics of wood-based materials to establish a deep emotional connection between humans, products, and the vitality of nature.
Emotional Interaction	Ritual sense, narrative, situational memory	The craftsmanship and Taishan spirit embedded in product details can trigger emotional resonance, making cultural and creative products a medium for telling Taishan stories and emotional communication.
Storability	Easy storage, portable storage, multi-scenario placement	Appropriate product size for easy storage and portability when traveling. Regular shape, portable storage, suitable for home, office, and travel use, adapting to multiple scenarios.
Educational Transmission	Cultural continuity, social education	Regarding cultural and creative products as learning carriers for understanding Taishan sacrifice, calligraphy, and other cultures, connecting historical memory with contemporary communication through product interaction.
Sensory Expectation	Solemnity, immersive experience, multi-dimensional perception	Integrating the warmth of materials with the solemn aura of Taishan, guiding users from visual attraction to cultural exploration through narrative shape design.
Durability	Sturdy wood material, wear-resistant, long-term preservation	Sturdy and stable wood-based materials, resistant to wear and bumping during daily handling. Solid wood materials and reliable craftsmanship enable long-term preservation, suitable for long-term collection and display.
Dynamic Communication	Cross-media communication, communication efficiency, social sharing	The ability of products as information carriers to interact and circulate in external environments. Enhancing audience sharing willingness through narrative design, realizing cross-dimensional value-added and extension of Taishan regional cultural IP.

Second-level Axial Coding

Second-level Axial Coding was used to establish logical connections between concepts. Through analyzing causal relationships, semantic contexts, and dimensional differences, it clusters and integrates initial concepts from open coding, constructing a main category structure that explains the laws of cultural IP transformation and wood-based material application in Taishan tourism cultural creativity. Combined with open coding results and constant comparison, 9 categories were formed around three logical chains: culture, function, and emotion (Table 2).

Table 2. Second-level Axial Coding

Main Category	Category Connotation	Reference Points	Proportion (%)	Cumulative Proportion (%)
Cultural Genes	Extract core Taishan genes and motifs, establish product cultural identity and belonging	92	12.99	25.28
Educational Transmission	Regard products as carriers for understanding Taishan sacrifice and calligraphy culture, realize knowledge translation	64	9.04	
Dynamic Communication	Strengthen information interaction and circulation, realize cross-dimensional communication and value-added of regional IP	23	3.25	
Storability	Portable and easy-to-store product specifications, multi-scenario placement, balancing travel portability and daily storage	145	20.48	38.56
Durability	Sturdy and wear-resistant wood-based materials, stable craftsmanship, long-term preservation, suitable for collection and long-term use	52	7.34	
Aesthetics	Create visual atmosphere through wood carving shapes and texture, meet user aesthetic needs for viewing and display	76	10.73	
Sensory Expectation	Combine warm wood-based materials with solemn aura, guide users from visual attraction to cultural exploration	74	10.45	36.16
Emotional Interaction	Craftsmanship and Taishan spirit trigger	68	9.60	

Main Category	Category Connotation	Reference Points	Proportion (%)	Cumulative Proportion (%)
	emotional resonance, make products communication media			
Material Perception	Utilize natural texture and characteristics, establish emotional connection with natural vitality	114	16.10	

Third-level Selective Coding

The Third-level Selective Coding stage focuses on clarifying path-dependent relationships among categories through in-depth logical analysis, thereby constructing a systematic theoretical model. To ensure research conclusion scientificity, this study further abstracted and refined the above 9 thematic categories, finally establishing three core categories: cultural demand, functional demand, and emotional demand. These three dimensions were intertwined, together forming the theoretical driving framework for Taishan tourism wood-based cultural and creative product design (Table 3).

Table 3. Third-level Selective Coding

Initial Concepts	**Main Category**	**Core Category**
Historical tracing, orthodox tone, regional code, symbol reconstruction, image translation, educational communication, knowledge translation, cross-media communication, narrative expression	Cultural Genes, Educational Transmission, Dynamic Communication	Cultural Demand
Tactile properties, natural texture, processing precision, structural delicacy, strict logic, seamless connection, physical stability, sustainability, visual adaptation	Storability, Durability, Aesthetics	Functional Demand
Solemnity, warm touch, multi-dimensional perception, immersive experience, ritual sense, narrative guidance, craftsmanship empathy, belonging, motivation stimulation	Sensory Expectation, Emotional Interaction, Material Perception	Emotional Demand

Theoretical Saturation Test

To ensure the sufficiency and robustness of theoretical construction, this study strictly followed the constant comparison principle of Grounded Theory to judge theoretical saturation. Instead of adopting quantitative training with reserved data for verification, the research team applied a progressive iterative analysis method. In the later stage of coding, researchers conducted continuous incremental comparison on subsequently collected corpus. The analysis results demonstrate that with the deepening of coding work, all semantic features presented in the corpus were fully covered by the existing 9 main categories and 3 core categories, and no new initial concepts or logical relations between categories emerged. Accordingly, this study judges that the coding framework has reached theoretical saturation; all core demand characteristics have been fully interpreted, and no additional samples need to be introduced for coding.

Weight Calculation of Fuzzy Hierarchy Model

To ensure weight allocation scientificity, this study invited 36 cross-disciplinary experts and senior users to form an evaluation group. The group consisted of two parts: an academic and industry expert group (n = 15), including Taishan culture researchers, senior industrial artists, and biomass material researchers, with an average working experience of over 6 years, ensuring evaluation authority in culture and materials; a design evaluation and in-depth user group (n = 21), composed of master and doctoral students in design and senior cultural and creative consumers, aiming to capture market aesthetic trends and functional demands. Integrating professional judgments from these 36 evaluators can effectively balance the theoretical depth and market application value of the evaluation model.

Based on experts' scoring results, weights of the criterion layer and index layer were calculated through the following steps:

Step 1: Construction of Fuzzy Judgment Matrix According to the hierarchical model, n elements at the same level were compared pairwise to clarify their relative importance. A 0.1 to 0.9 linguistic scale method was introduced (Table 4). In this system, 0.5 indicates equal weight between indicators, while 0.6 to 0.9 finely represent a logical increase from "slightly important" to "extremely important".

Table 4. 0.1 to 0.9 Scale and Definitions of Fuzzy Consistent Matrix

Scale	Definition	Explanation
0.5	Equally important	Factor a_i is equally important as factor a_j
0.6	Slightly important	Factor a_i is slightly more important than factor a_j
0.7	Clearly important	Factor a_i is clearly more important than factor a_j
0.8	Strongly important	Factor a_i is strongly more important than factor a_j
0.9	Extremely important	Factor a_i is extremely more important than factor a_j
0.1, 0.2, 0.3, 0.4	Reverse comparison	If r_{ij} is obtained by comparing a_i with a_j, then $r_{ji} = 1 - r_{ij}$

Step 2: *Construction of Fuzzy Consistent Judgment Matrix.* After determining the evaluation index system, n influencing factors (A1, A2, ..., An) under the same criterion layer are compared pairwise, and expert evaluation results are quantified using the aforementioned 0.1 to 0.9 scale method. This process aims to eliminate the arbitrariness of subjective judgments and scientifically reflect the relative importance of different factors in the Taishan wood-based cultural and creative evaluation system by constructing a fuzzy consistent judgment matrix A. The mathematical expression of judgment matrix A is shown in Eq. 1,

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \vdots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \tag{1}$$

where $0 \leqslant r_{ij} \leqslant 1$; $a_{ii} = 0.5$, $i = 1,2,3,\ldots,n$, $n \in N^*$;

$a_{ij} + a_{ji} = 1, j, i = 1,2,3,\ldots,n, n \in N^*$.

Step 3: *Fuzzy Consistency Test of the Matrix*. The purpose of this test is to ensure that the matrix solution results satisfy the two conditions of "equal cross sums" and "constant column differences", indicating that experts' scores are logically self-consistent and can safely enter the weight calculation stage:

$$a_{11} + a_{dd} = a_{1d} + a_{d1}, a_{11} - a_{d1} = a_{1d} - a_{dd} = b(b\text{=constant}) \tag{2}$$

$$a_{12} - a_{d2} = b, a_{13} - a_{d3} = b, \ldots, a_{1j} - a_{dj} = b(b\text{=constant}) \tag{3}$$

$(j = 2,3,\ldots,n, n \in N^*, j \neq D)$

Step 4: *Calculation of Criterion Layer Weights* ω_i and *Sub-criterion Layer Weights* ω_{ij} (where d is the column number of the fuzzy judgment matrix):

$$\omega_i = \frac{\sum_{d=1}^{n} a_{id} + \frac{n-1}{2}}{n(n-1)} \tag{4}$$

Following the aforementioned FAHP calculation process, weights of indicators at all levels in the Taishan tourism cultural and creative design evaluation system were solved, and fuzzy consistency tests completed. Specifically, a fuzzy judgment matrix was constructed around the overall target layer (G); corresponding fuzzy consistent matrices were constructed for the criterion layer and sub-criterion layer, respectively. Criterion layer weights (ω_i) and sub-criterion layer local weights (ω_{ij})) were calculated using Eq. 4, and further synthesized to obtain global weights ($\omega_{ij}^{\text{global}}$) of each indicator. The weight allocation results of indicators at all levels are summarized in Table 5.

Table 5. Fuzzy Judgment Matrix and Weights of Each Criterion Layer

Primary Indicator (Criterion Layer)	Criterion Layer Weight (ω_i)	Secondary Indicator (Sub-criterion Layer)	Local Weight (ω_{ij})	Global Weight ($\omega_{ij}^{\text{global}}$)	Global Weight Ranking
Cultural Demand (A1)	0.3929	Cultural Genes (A11)	0.5012	0.1969	1
		Educational Transmission (A12)	0.2974	0.1169	4
		Dynamic Communication (A13)	0.2014	0.0791	6
	0.3216	Storability (B21)	0.5616	0.1806	2

Primary Indicator (Criterion Layer)	Criterion Layer Weight (ω_i)	Secondary Indicator (Sub-criterion Layer)	Local Weight (ω_{ij})	Global Weight ($\omega_{ij}^{\text{global}}$)	Global Weight Ranking
Functional Demand (B2)		Durability (B22)	0.2551	0.0820	5
		Aesthetics (B23)	0.1833	0.0589	8
Emotional Demand (C3)	0.2855	Sensory Expectation (C31)	0.5482	0.1565	3
		Emotional Interaction (C32)	0.1893	0.0540	9
		Material Perception (C33)	0.2625	0.0749	7

Aggregation of Expert Scores and Judgment Matrix

To guarantee openness, transparency and verifiability of the quantitative deduction process, geometric mean aggregation was performed on the original scale scores of 36 evaluators, including 15 academic and industrial experts as well as 21 design assessors and in-depth users, to eliminate outliers and converge group decision consensus. On this basis, an actual fuzzy consistent judgment matrix of the target layer (G) corresponding to the first-level criteria layer indicators was constructed. The specific aggregated matrix data are shown in Table 6:

Table 6. Fuzzy Consistent Judgment Matrix

Target Layer (G)	Cultural Demand (A1)	Functional Demand (B2)	Emotional Demand (C3)	Local Weight (Wi)
Cultural Demand (A1)	0.5000	0.5714	0.6071	0.3929
Functional Demand (B2)	0.4286	0.5000	0.5357	0.3216
Emotional Demand (C3)	0.3929	0.4643	0.5000	0.2855

Results of Fuzzy Consistency Test

Logical self-consistency testing of the above matrix was conducted in accordance with Formula (5) and Formula (6). Taking elements in Table 6 as examples, all elements satisfied the following mathematical constraint:

$$r_{ij} + r_{ji} = 1(e.g., r_{12} + r_{21} = 1=0.5714+0.4286=1.0000) \tag{5}$$

Meanwhile, the matrix was verified to strictly meet the fuzzy consistency criteria of “equal cross sums” and “constant column differences”:

$$r_{12} - r_{32} = 0.5714 - 0.4643 = 0.1071 \quad (6)$$

$$r_{13} - r_{33} = 0.6071 - 0.5000 = 0.1071 \quad (7)$$

Calculation results demonstrated that the matrix elements satisfied the necessary and sufficient conditions for fuzzy consistency judgment, *i.e.*, elements of each row present a constant offset difference (b=0.1071) within the same column, which shows that this judgment matrix possesses high logical consistency and the obtained weight allocation is supported by rigorous mathematical derivation. Based on Formula (4), precise allocated weights of each criteria layer indicator were finally calculated through row sum normalization aggregation: W_{A1}=0.3929, W_{B2}=0.3216, W_{C3}=0.2855.

The raw data aggregation, pairwise comparison matrix forms, and consistency test procedures corresponding to the three local fuzzy judgment matrices of secondary indicators (sub-criteria layer) can be fully uploaded as electronic supplementary materials for review and reproducibility.

Analysis of Weight Results of Taishan Cultural and Creative Design Indicators

Through constructing a fuzzy consistent judgment matrix and quantitatively solving it using the 0.1 to 0.9 scale method, the calculation results showed that in the criterion layer, cultural demand (A1) dominated with a weight of 0.3929, while functional demand (B2) and emotional demand (C3) accounted for 0.3216 and 0.2855, respectively. This indicates that the core of evaluating Taishan tourism cultural and creative products lies in the in-depth translation of cultural connotations, while the practicality of material functions and the empathy of sensory experience are also important dimensions for building product competitiveness.

From the global weight distribution of secondary indicators, cultural genes (A11, 0.1969), storability (B21, 0.1806), and sensory expectation (C31, 0.1565) rank top three, forming the core direction of design. The high weight of cultural genes reflects audiences' high recognition of the authentic expression of Taishan IP; storability closely follows, revealing the market trend of cultural and creative products transforming from pure appreciation to life-oriented functionality; sensory expectation, as a trigger point for emotional interaction, directly drives audiences' purchase intention through initial visual and tactile evaluation.

In summary, the design of Taishan wood-based cultural and creative products should follow the logical framework of taking cultural genes as the core, storability as the carrier, and sensory experience as the guidance. In design practice, while strengthening the reconstruction of core Taishan visual elements, the durability and practical value of products should be improved through technical logic, and the warm material perception of wood (C33, 0.0749) should be utilized to stimulate emotional interaction, thereby achieving deep alignment between cultural value and market application value.

DESIGN PRACTICE

Scheme I

Scheme I: This scheme is a "Five Sacred Mountains Supreme" wood-based cultural and creative product. Taking Taishan culture as the core and solid wood as the material, it is a desktop cultural and creative product integrating study display and small item storage.

Strictly constructed based on the weight logic in Table 5, it realizes accurate translation from quantitative evaluation to qualitative design. Centered on cultural genes (A11, 0.1969) with the highest global weight, the design reproduces iconic IPs, such as the "Taishan Yue Song Zun" stone carving, Taishan pine, and sea of clouds through bas-relief craftsmanship, strengthening cultural authenticity and bearing the cultural communication value of educational transmission (A12, 0.1169). In response to the storability (B21, 0.1806) demand ranking second in global weight, the product innovatively adopts a side-opening hollow structure, transforming traditional study utensils into life-oriented artifacts that can store notes and jewelry, responding to audiences' practical demands through functional transformation. Carefully selected warm and delicate walnut or beech wood with rounded polishing, combined with concave-convex relief texture, meets audiences' experience demand for material perception (C33, 0.0749). Through closed-loop coverage of high-weight indicators, it achieves the unity of cultural value and daily practicality (Fig. 2).

Fig. 2. Wood-based cultural and creative product Scheme I

Scheme II

Scheme II: This scheme is a Taishan "Blessing Landscape" wood-based cultural and creative product. At the criterion layer level, the design prioritizes meeting the highest-weight cultural demand (0.3929). The box surface is carved with panoramic Taishan landscape, South Heavenly Gate, and blessing cloud patterns. Through visual presentation of the core global weight of cultural genes (A11, 0.1969), it deeply integrates the peace implication of "steadfast as Taishan"; storability (B21, 0.1806) is transformed into a mini square internal structure, which can hold incense, pills, jewelry, or commemorative small items, flexibly adapting to multi-scenario demands of tourists carrying when traveling and placing at home, enhancing product practical value; in the dimension of emotional resonance, the product endows wood with a warm hand feel through fine polishing, optimizing the key experience indicator of sensory expectation (C31, 0.1565) with smooth and elegant carving lines, serving as a high-quality cultural and creative product with service life and cultural memory bearing capacity for cultural and creative gifts (Fig. 3).

Fig. 3. Wood-based cultural and creative product Scheme II

Scheme III

Scheme III: This "Mount Tai Big Dipper" wood-based cultural and creative product realizes precise matching between cultural narratives and functional structures *via* in-depth analysis of indicator weights. The design extracts cultural genes (A11) including the Mount Tai Big Dipper and Dai Temple's Tiankuang Hall. Supported by its local weight of 0.5012, it converts core royal ritual and blessing culture into constellation patterns and stone carving silhouettes on the box cover to guarantee authentic expression of the cultural IP. To satisfy key functional demands, storability (B21, local weight 56.16%) is realized using a multi-layer partitioned drawer for classified storage of small cultural and creative accessories such as bracelets and seals. Emotionally, the design fulfills audiences' sensory expectation (C31, local weight 0.5482). Highly polished hardwood is adopted to deliver pleasant tactile sensations and solemn visual effects. Furthermore, traditional mortise-and-tenon techniques enhance structural durability (B22, 0.0820). Adapted for high-end cultural and creative gift scenarios, the product retains premium texture, which fully validates the rationality of weight-driven design (Fig. 4).

Fig. 4. Wood-based cultural and creative product Scheme III

PRODUCT EVALUATION

Evaluation Framework and Indicator System

In terms of scale design, this study adopted a 5-point Likert scale to reduce cognitive load in multi-dimensional evaluation and ensure data convergence. Meanwhile, this scale was adapted from classic scales validated by scholars including Park (2025) and Liu (2024), with localized revisions tailored to the attributes of Mount Tai wood-based cultural and creative products.

Table 7. Evaluation Scale and Reliability Test

Evaluation Dimension	Item No.	Measurement Item	Dimension Cronbach's α
Cultural Genes (D1)	D1-1	Accurately translates authentic cultural symbols and visual imagery of Mount Tai.	0.845
	D1-2	Retains the historical identity of Mount Tai's ancient buildings or natural landscapes on wood-based materials.	
Storability (D2)	D2-1	Modular or mortise-and-tenon structure facilitates convenient daily storage.	0.812
	D2-2	Volume and space occupancy adapt to diverse desktop display and storage scenarios.	
Sensory Expectation (D3)	D3-1	The combination of wood texture and shape creates a solemn yet gentle tactile experience.	0.856
	D3-2	Detailed processing effectively enhances the overall visual atmosphere.	
Educational Transmission (D4)	D4-1	Acts as an effective carrier to convey specific historical knowledge or sacrificial culture of Mount Tai.	0.821
	D4-2	Possesses strong narrativeness and guides audiences to explore the underlying cultural connotations.	
Durability (D5)	D5-1	Rational structural mechanics design prevents loosening or fracture caused by uneven stress.	0.864
	D5-2	Effectively resists abrasion from daily handling and physical deformation induced by temperature and humidity alternation.	

To verify the scientific validity of the integrated Grounded Theory–FAHP framework in the translation of Mount Tai wood-based cultural and creative elements, this study first screened key factors according to the global weight ranking of each indicator in Table 5. In line with the Pareto principle and multi-criteria decision-making optimization principles, marginal indicators ranked 6th to 9th in global weight with low overall contribution were eliminated to improve the focus of subsequent expert efficacy evaluation and reduce cognitive load during blind scoring. Only the top five core indicators by global weight were retained for follow-up assessment.

To guarantee the scientificity and reproducibility of expert blind evaluation data, a Likert-type five-point scale containing 10 specific measurement items (2 observed variables for each dimension) is developed based on the 5 core dimensions screened via FAHP above. Detailed scale items, dimensional structure and Cronbach's α coefficient of each dimension are presented in Table 7.

To verify the scientificity of the integrated path of Grounded Theory–FAHP in Taishan wood-based cultural and creative translation, this study constructed a multi-criteria expert evaluation framework based on a Likert-type five-point scale, covering five criterion dimensions: cultural genes (D1), storability (D2), sensory expectation (D3), educational transmission (D4), and durability (D5). Thirty-two experts composed of Taishan culture scholars, product designers, material engineers, and target users were invited for blind evaluation scoring ($n = 32$), ensuring the evaluation system balanced cultural authenticity, engineering feasibility, and market perception. After reliability testing, the overall Cronbach's α coefficient of the scale was 0.832, and the coefficients of all dimensions were greater than 0.8, indicating good internal consistency of the evaluation tool and high reliability and statistical inference value of the obtained data.

Statistical Results

Based on descriptive statistical results from experts (Table 8), the average scores of the three Taishan wood-based cultural and creative schemes in five core dimensions were all at a high level (mean range: 4.45 to 4.85), strongly indicating that the path of Feature Anchoring–Weight Deduction–Strategy Synthesis constructed in this study was able to stably output highly recognized design results in different product carriers (paperweight, portable box, compartment box). If the arithmetic mean of the five dimensions was used to measure overall performance, the overall scores of Scheme I, Scheme II, and Scheme III were all above 4.60, with Scheme III having a slightly higher comprehensive score (Fig. 5).

Table 8. Scheme Multi-dimensional Evaluation Scores

Dimension	Scheme I	Scheme II	Scheme III
D1 Cultural Genes	4.85	4.60	4.75
D2 Storability	4.55	4.70	4.80
D3 Sensory Expectation	4.50	4.65	4.85
D4 Educational Transmission	4.75	4.50	4.60
D5 Durability	4.45	4.80	4.70

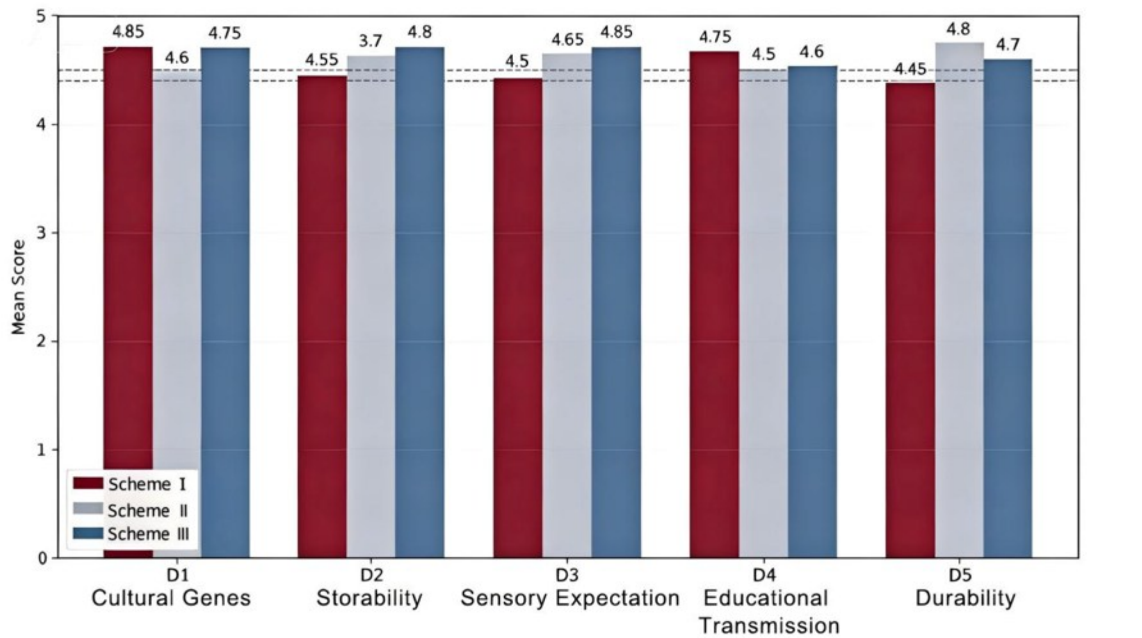

Fig. 5. Comparative analysis diagram

Specific dimensional performance differences showed that Scheme I excels in cultural genes (D1 = 4.85) and educational transmission (D4 = 4.75), fully reflecting its accurate translation of Taishan stone carving IP semantics; Scheme II peaks in durability (D5 = 4.80), verifying the stability of sturdy and wear-resistant wood-based materials in cultural creativity; Scheme III performs strongest in sensory expectation (D3 = 4.85) and storability (D2 = 4.80), demonstrating the significant advantages of multi-layer functional structures in enhancing audiences' emotional resonance and practical experience.

Evaluation Results and Significance Analysis

To statistically verify whether the efficacy differences of the three Mount Tai wood-based cultural and creative schemes across the five core dimensions are significant, standard deviation (SD) and non-parametric Friedman test were adopted for the original scoring data from 32 experts. Detailed statistical indicators of each scheme are shown in Table 9.

A two-tailed non-parametric Friedman test ($\alpha = 0.05$) was performed to examine score disparities among schemes on core indicators. The results revealed highly statistically significant inter-scheme efficacy differences ($p < 0.01$), even for dimensions with close mean values (*e.g.*, Scheme 1's score of 4.85 and Scheme 3's score of 4.41 for Cultural Genes). Subsequent pairwise Wilcoxon signed-rank tests indicated that Scheme 1 achieved significantly higher scores in Cultural Genes (D1) than Scheme 2 and Scheme 3 ($z = -3.12$, $p = 0.002$, $d = 0.78$); Scheme 2 dominated the Durability (D5) dimension; Scheme 3 exhibited statistically optimal performance in Storability (D2) and Sensory Expectation (D3). The above analysis proves that the comparative advantages and disadvantages of each scheme in core dimensions are supported by robust statistical inferences.

Cohen's d effect sizes were calculated to further quantify the magnitude of differences among the three schemes. The results demonstrated a large effect size ($d > 0.75$) of Scheme 1 over Scheme 2 and 3 for Cultural Genes, while Scheme 2 yielded $d > 0.65$ for Durability against the other two schemes, signifying its statistically substantial superiority in engineering and physical material properties. These inferential statistics confirm that the superior performance of certain schemes is not merely random fluctuation of sample means but originates from distinct data distributions.

Table 9. Summary of Multi-Criteria Evaluation Scores for Each Scheme

Evaluation Dimension	Scheme 1 (Mean±SD)	Scheme 2 (Mean±SD)	Scheme 3 (Mean±SD)	Test Statistic (χ^2)	Significance (p)	Effect Size (W)
Cultural Genes (D1)	4.85±0.36	4.22±0.54	4.41±0.50	16.42	<0.01	0.51 (Large)
Storability (D2)	3.91±0.64	4.15±0.58	4.80±0.41	18.15	<0.01	0.57 (Large)
Sensory Expectation (D3)	4.34±0.48	4.28±0.52	4.85±0.36	14.88	<0.01	0.46 (Medium)
Educational Transmission (D4)	4.47±0.51	4.03±0.69	4.25±0.57	8.54	<0.05	0.27 (Small)
Durability (D5)	4.12±0.61	4.80±0.41	4.06±0.67	19.33	<0.01	0.60 (Large)

Result Discussion and Applicability Assessment of Wood-Based Carriers

The synthesized results (Table 9) indicate that the proposed integrated framework effectively balances the artistic translation of Mount Tai culture and the engineering constraints of wood-based materials. The framework exhibits excellent stability in adapting to wood anisotropy, enabling rigid wooden structures to accurately reproduce design-derived complex contours and avoid morphological defects prevalent in soft materials.

This study provides a significant methodological improvement over existing cultural and creative design research, which typically depends on subjective designer experience and qualitative intuition and thus lacks reproducibility for industrial application. By integrating Grounded Theory and FAHP, the proposed quantitative mapping model maintains high recognizability of abstracted Mount Tai cultural imagery and provides traceable mathematical support for design decision-making.

Although validated with Mount Tai cultural elements and forestry residual materials, the integrated framework is not regionally restricted. It offers a generalized methodology for biomass design that transforms abstract intangible cultural narratives into quantifiable engineering parameters for wooden products. This study provides a feasible reference for the sustainable and high-value development of wood-based cultural and creative products based on mountain cultural heritage.

CONCLUSIONS

1. *Framework Efficacy:* The study successfully established and validated a “closed-path” design framework—comprising Feature Anchoring, Weight Deduction, Strategy Synthesis, and Design Validation—which transforms Taishan cultural creativity from fragmented element stacking into a structured, rigorous, and reusable semantic translation process.
2. *Quantitative Precision:* The integration of the fuzzy analytic hierarchy process (FAHP) successfully converted subjective design judgments into a quantifiable, evidence-based index system, prioritizing cultural genes, storability, and sensory expectations to ensure design strategies are both scientific and reproducible.
3. *Demonstrated Practical Application:* Expert evaluations confirmed the framework’s effectiveness, achieving a high overall mean score of approximately 4.65 (out of 5). The validated design schemes demonstrate a successful balance between cultural authenticity, material durability, and functional utility, proving the framework’s potential for large-scale, cross-category development.
4. The proposed Grounded Theory–FAHP framework was effectively validated based on three Mount Tai wood-based cultural and creative design schemes, while its general applicability remains bounded. Current results mainly focus on desktop and box-type products with limited scales and application scenarios. Scheme 1 emphasizes CNC integral molding for cultural gene interpretation, Scheme 2 focuses on anti-crack stress regulation for durable large-area wood panels, and Scheme 3 optimizes storability through modular mortise-and-tenon structures. These cases cover typical challenges in wood product processing. Future studies will incorporate large-scale wooden landscapes and digital interactive devices to further verify and improve the framework’s adaptability for broader and more complex application conditions.

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Use of Generative AI

ChatGPT-4 was used to assist in formatting the initial references. All references were manually checked and cross-referenced with the Web of Science database to ensure accuracy. No generative artificial intelligence tools were used in writing the main text, creating figures, or designing tables.

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