Evaluating the Material-Technique Adaptability of Bamboo Weaving for Fashion Accessories: A Delphi-AHP Approach

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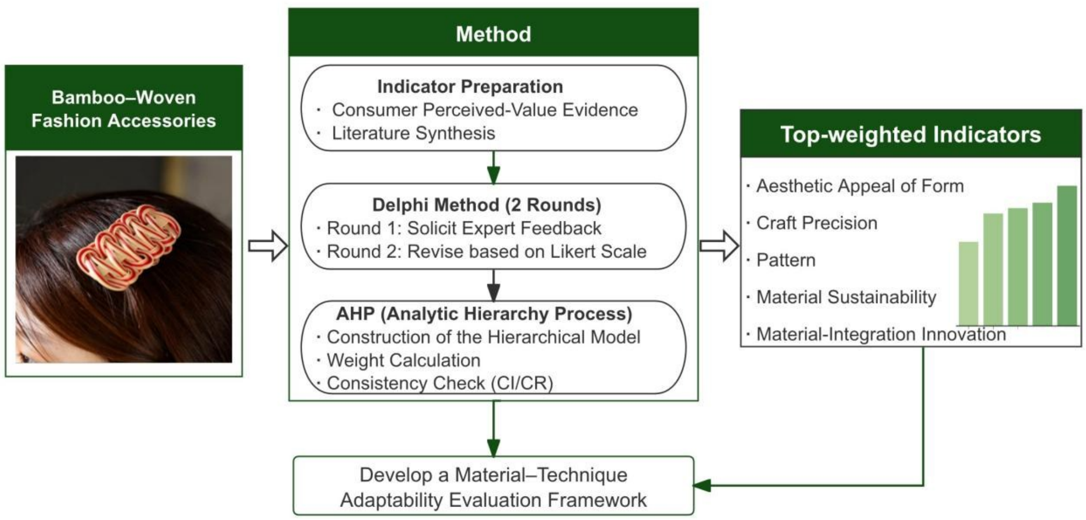
GRAPHICAL ABSTRACT



Evaluating the Material-Technique Adaptability of Bamboo Weaving for Fashion Accessories: A Delphi-AHP Approach

Xiaozheng Wei,[a,b] and Hwee Ling Siek,[a,*]

Bamboo weaving is a renewable, low-energy craft technique with growing potential for value-added applications in fashion accessories. Bamboo-related studies primarily have focused on material properties or cultural documentation. This study proposes a material-technique adaptability evaluation framework for bamboo-woven fashion accessories, using an integrated Delphi and Analytic Hierarchy Process (AHP) approach. Building upon established dimensions of consumer perceived value initially derived from a perception model constructed using e-commerce platform data, the study identified 17 design-evaluable indicators through two rounds of expert consultation. The results indicated that emotional and functional value dominated the evaluation structure with form aesthetics, crafts precision, pattern expression, material integration and innovation, and material sustainability receiving the highest weights. To verify the operational applicability of the proposed framework, a design practice was conducted based on the high-priority indicators, and a bamboo-woven shawl cape was developed as a prototype for small-scale user testing. The validation results further confirmed the framework's suitability for evaluating the adaptability of bamboo weaving in fashion accessory design. The proposed framework provides a systematic and operational tool for assessing the adaptability of bamboo weaving as a bio-based material-technique system, supporting the sustainable utilization and contemporary transformation of bamboo resources in fashion accessory design.

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Keywords: Bamboo fashion; Form aesthetics; Analytic hierarch process; Pattern expression; Bio-based materials

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INTRODUCTION

Fashion accessories are generally defined as decorative items that enhance one's outfit. Examples include jewelry, gloves, handbags, hats, belts, scarves, watches, sunglasses, pins, stockings, bow ties, leggings, and tights (Aboagyewaa-Ntiri 2024).

With the continued deepening of environmental responsibility considerations in the fashion industry, the focus of accessory design has shifted from purely visual embellishment to environmental friendliness of material selection and the low-impact nature of craft processes (Jayapriya *et al.* 2025). Consequently, material innovation and the sustainable transformation of artisanal techniques have become important directions for industry development (Chen 2022). Consumers increasingly value materials and products that demonstrate environmental responsibility, cultural authenticity, and craftsmanship quality, rather than mass-produced uniformity (Guha *et al.* 2025). This trend has encouraged the revival application of traditional plant-based materials and handcrafts techniques, such as bamboo weaving, rattan work, and natural fiber processing, in fashion-related product development (Islam *et al.* 2025). From a material and bioresource perspective, bamboo has attracted considerable attention due to its rapid renewability, low embodied energy, and favorable mechanical and physical characteristics (Dlamini *et al.* 2022). While extensive research has examined bamboo's structural performance, composite applications, and engineering properties, comparatively limited attention has been given to its transformation into small-scale, value-added consumer products, particularly fashion accessories that rely on material expression and craftsmanship rather than structural strength alone.

At the same time, the inherent physical properties of bamboo impose natural constraints on design practice. Due to its pronounced anisotropic fiber structure, featuring high longitudinal strength but susceptibility to transverse splitting, and its porous, moisture-absorbent nature, bamboo is prone to deformation and dimensional instability. Such characteristics pose limitations in applications requiring high structural precision (Zheng *et al.* 2023). Nevertheless, bamboo also offers notable advantages, including excellent splitting performance, high mechanical strength, elasticity, and bending capacity, thereby enabling rich pattern formation and structural expression in woven products. Designers and artisans have long utilized these properties to create a wide range of flat and three-dimensional daily-use and decorative items (Wu and Han 2023). These material characteristics directly shape the logic of bamboo weaving as a craft system. They further influence how its techniques can be translated into contemporary product applications.

Data from e-commerce reviews and interviews show that consumers frequently comment on attributes such as splintering, edge roughness, stiffness versus flexibility, surface smoothness, wearing comfort, and lightweight feel when evaluating bamboo-woven fashion accessories (Wei *et al.* 2025). These perception dimensions are directly linked to the intrinsic physical characteristics of bamboo such as its anisotropic tendency to split, moisture-induced deformation, and variable flexibility. The perception dimensions also associated with craft-related factors such as fiber-splitting precision, sanding quality, and edge finishing. Importantly, the aesthetic judgments expressed in user reviews, including "beautiful," "well-crafted," and "refined design" are not isolated stylistic preferences; rather, they are the experiential manifestation of how material constraints and craftsmanship performance are perceived in real use. By translating these perception-based insights into design-evaluable indicators, the study incorporates material limitations into the construction of a Delphi and AHP framework, ensuring that the resulting design-adaptability model simultaneously reflects both the technical feasibility of bamboo weaving and the practical expectations of fashion-accessory consumers.

Bamboo weaving, as a material–technique system, combines the intrinsic properties of bamboo with manual processing strategies that directly influence surface texture, pattern formation, flexibility, and visual expression (Gao *et al.* 2024). In fashion accessories, the suitability of bamboo weaving is not determined solely by material performance, but also by the degree to which material characteristics and weaving techniques can be effectively adapted to contemporary design requirements. However, current design practices for bamboo-woven accessories remain largely experience-driven, and systematic evaluation tools for assessing such adaptability are lacking.

In this study, material–technique adaptability is defined as the capacity of a bio-based material and its associated craft technique to be translated into contemporary product applications while maintaining functional feasibility, material expression, and sustainability attributes (Rognoli *et al.* 2022). Establishing an operable evaluation framework for such adaptability is essential for promoting the efficient utilization and sustainable deployment of bamboo resources in value-added product design.

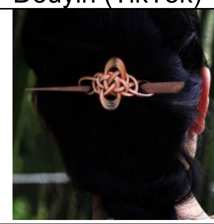
Building upon a previously established consumer perceived value model derived from grounded theory (Wei *et al.* 2025), this study applied the Delphi method and Analytic Hierarchy Process (AHP) to construct a quantitative evaluation framework for the material–technique adaptability of bamboo weaving in sustainable fashion accessories. The proposed framework was put together with the goal of evaluating the contemporary transformation and sustainable utilization of bamboo-based materials. The Delphi method was employed to refine and validate evaluation indicators through expert consensus, while AHP enabled the systematic weighting of multi-level criteria, a methodological combination widely applied in design evaluation and material selection studies involving complex adaptability and decision-making contexts (Liao *et al.* 2025; Yuan *et al.* 2025; Zhang *et al.* 2025). Recent research has further demonstrated the methodological versatility of the Delphi-AHP combination. For instance, a sustainability-oriented evaluation framework for Yixing Zisha pottery integrated with AIGC technologies was developed using this combined approach (Pan *et al.* 2025). Similarly, an evaluation system for the digital communication of intangible cultural heritage has been constructed based on Delphi and AHP, emphasizing authenticity and transmission value (Yan *et al.* 2025). In the field of consumer product design, a systematic and innovative design-strategy framework and evaluation toolset was established to help designers identify key factors and develop products that meet consumer needs within shorter development cycles (Yao *et al.* 2022). In sustainable wearable-technology research, the integration of the fuzzy Delphi method with the DEMATEL technique has been used to prioritize user-centered design criteria and identify key product-design indicators aligned with sustainable health-management goals (Liao *et al.* 2025). Together, these studies highlight the expanding role of Delphi-based consensus building and AHP-based weighting in addressing complex design-evaluation challenges across craft, cultural-creative, and wearable-technology domains.

This combined approach has also been used to develop sustainable textile design frameworks (Gbededo and Liyanage 2020) and to identify key factors in sustainable fashion supply-chain management (Garcia *et al.* 2022), demonstrating its suitability for structured decision-making in sustainability-oriented design research. The proposed framework aims to support the contemporary transformation and sustainable utilization of bamboo-based materials. In doing so, the study bridges the gap between the technical realities of bamboo as a bio-based material and the experiential expectations of fashion-accessory consumers, ensuring that the adaptability indicators reflect both material feasibility and user-driven design value.

MATERIALS AND METHOD

To ensure methodological clarity, the expert evaluation conducted during the Delphi stage was based on a preliminary indicator system derived from the authors' prior grounded theory research. That earlier study analyzed user-generated textual reviews of bamboo-woven fashion accessories, such as earrings, pendants, brooches, and other small wearable items collected from major Chinese e-commerce platforms, to extract consumer perceived-value indicators. Representative samples of these accessory types are presented in Table 1, with item categories, typical forms, and illustrative images provided for contextual reference.

Table 1. Representative Bamboo-Woven Fashion Accessories from E-commerce Platforms

Product Category	Bamboo-woven Brooch	Bamboo-woven Earrings	Bamboo-woven Hairpin	Bamboo-woven Bag
Store name	Xiaokuan Bamboo Worker Taobao.com	Xiaokuan Bamboo Worker Little Red Book	Liaobuqi Craftsman Douyin (TikTok)	Zhjiang Taobao.com
Pictures				
Price (USD)	22.3	50.4	13	56

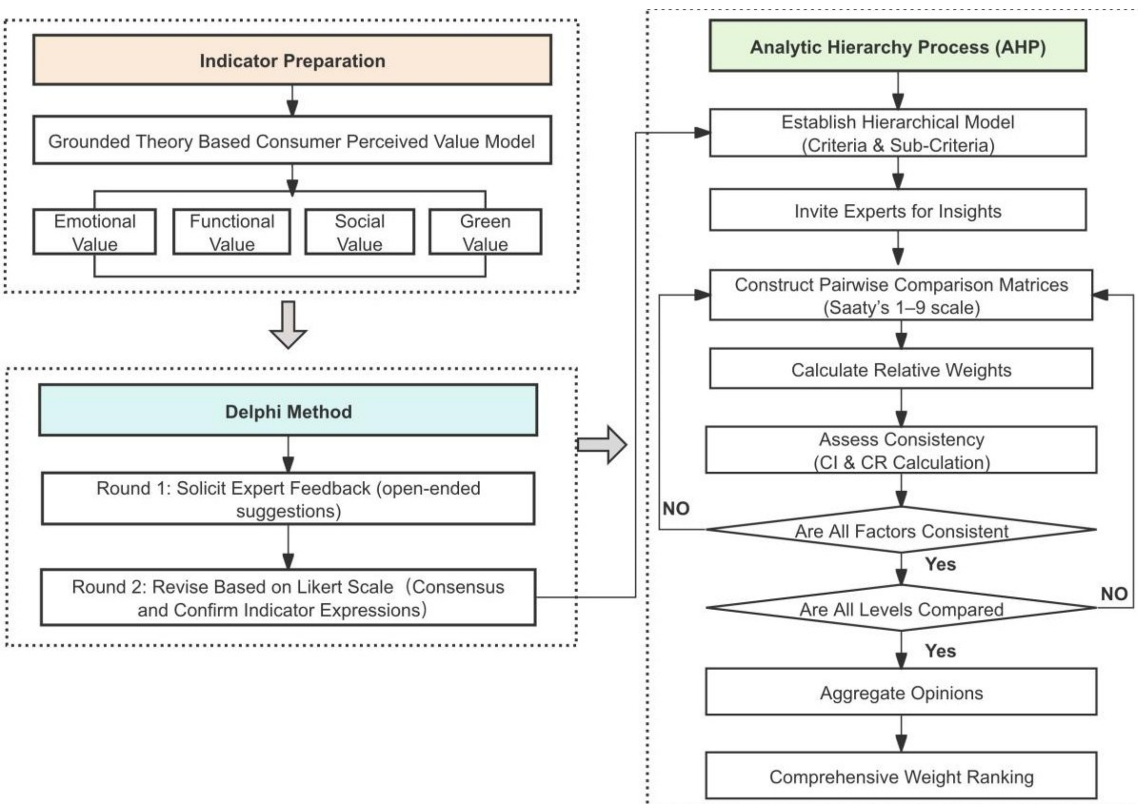


Fig. 1. The process of developing the framework

In the present study, the experts did not evaluate specific commercial products or e-commerce items. Instead, they assessed the relevance, clarity, and applicability of the preliminary indicators for evaluating material–technique adaptability, with the objective of refining and validating the indicator framework. No repeated qualitative coding or reanalysis of the original consumer review data was conducted at this stage.

All Delphi data organization, descriptive statistical analyses (Dalkey and Helmer 1963), and Analytic Hierarchy Process (AHP) weight calculations were performed (see Fig. 1) using Microsoft Excel (Microsoft Corporation, Version 2021, Redmond, WA, USA). The analysis incorporated standard Delphi stability indicators (mean and coefficient of variation) and AHP consistency verification following Saaty's CR threshold to ensure methodological rigor. In the second-round Delphi evaluation, experts rated the importance of each indicator using a five-point Likert scale ranging from "not important at all" (1) to "very important" (5). Following the consensus criteria proposed by Diamond *et al.* (2014), indicators with a mean score greater than 3.5 were considered to possess acceptable importance, while a CV below 0.25 indicated a low level of dispersion among experts and, therefore, stable agreement across the panel .

Stage 1: Indicator Preparation

The initial indicator pool was constructed based on a conceptual model of consumer perceived value derived from grounded theory in existing literature (Wei *et al.* 2025). In this stage, the concepts identified through selective coding served as the semantic foundation for development. The selection process focused on ensuring that each indicator corresponds to observable and design-evaluable attributes, such as material behavior and craft performance, to support practical decision-making in material selection and product transformation. This preparatory phase ensured theoretical rigor and conceptual traceability prior to expert consultation.

Stage 2: Delphi Method

The Delphi method was employed to refine, consolidate, and validate the indicator system through iterative anonymous feedback to reduce individual bias (Hsu and Sandford 2007; Brady 2015). A panel of ten experts was invited, covering fashion design, bamboo weaving craftsmanship, cultural and creative product development, and plant-based material research. The inclusion of artisans and material scientists ensured the evaluation incorporated craft-specific and technical perspectives.

Table 2. Detailed Qualifications of the 10 Experts Involved in the Evaluation of the Indicators

Expert ID	Area of Expertise	Affiliation	Years of Experience
E1	Fashion Design	Professor	20
E2	Cultural and Creative Product Design	Associate Professor	23
E3	Cultural and Creative Product Design	Professor	25
E4	Bamboo Weaving Craft	ICH Inheritor	28
E5	Plant-Based Material Research	Lecturer	11
E6	Bamboo Weaving Craft	Artisan	12
E7	Materials Science	Lecturer	13
E8	Graphic Design	Art Teacher	9
E9	Bamboo Weaving Craft	Craft Workshop Manager	20
E10	Bamboo Weaving Craft	Artisan	8

All experts were based in China and represented a balanced combination of academic and craft-industry backgrounds, including university scholars in design and materials, an inheritor of Sichuan bamboo weaving, and practitioners from local workshops. This composition ensured that the panel collectively reflected expertise in material properties, craft feasibility, and product-design applicability, thus supporting the rigor and relevance of the indicator evaluation.

Following recommended panel sizes (Vidal *et al.* 2011), experts participated in two rounds.

Round 1: (Qualitative)

Experts reviewed the initial pool for relevance, clarity, and operability. Indicators lacking direct design-based evaluability (*e.g.*, “warmth” or “sense of ritual”) were removed based on thematic feedback.

Round 2: (Quantitative)

Experts rated the importance of revised indicators using a five-point Likert scale. Only indicators meeting the stability criteria of Mean $\geq$ 3.5 and Coefficient of Variation (CV) $\leq$ 0.25 were retained for the AHP stage (Diamond *et al.* 2014).

Stage 3: Analytic Hierarchy Process

The AHP was used to determine the relative weights of the validated indicators by decomposing the problem into a hierarchical system (Saaty 1990).

1. Hierarchical Model: A three-level structure was built consisting of the goal level, four primary criteria (Emotional, Functional, Social, and Green Value), and seventeen sub-criteria.
2. Pairwise Comparison: Experts independently assessed the relative importance of elements using Saaty’s 1 to 9 fundamental scale.
3. Weight Calculation: The geometric mean method was applied to derive the priority vector for each matrix.
4. Consistency Assessment: To ensure reliability, the Consistency Index (CI) and Consistency Ratio (CR) were calculated. Matrices were only accepted if the CR < 0.10.
5. Group Integration: Individual expert matrices were aggregated using an equal-weighted averaging method to produce the final integrated weight vector for the framework.

RESULTS

Delphi Consultation

Based on the preliminary translation and consolidation of indicators derived from prior literature and the consumer perceived-value dimensions identified through grounded theory, a total of 21 indicators entered the first round of the Delphi survey. During this round, experts noted that several indicators primarily reflected users’ subjective psychological feelings or context-dependent experiences, which cannot be objectively or consistently evaluated based on the product itself. Following expert recommendations, four indicators lacking design-based evaluability, warmth, delight, sense of ritual, and sense of security were removed from the list. These items were semantically closer to emotional responses rather than design attributes that can be directly inferred from material or technique characteristics; therefore, they were judged to be unsuitable as valid measurement items for assessing material-technique adaptability (See Table 3).

Table 3. Indicators Removed in Delphi Round 1

Primary Dimension	Indicator Name	Code	Reason for Removal
Emotional Value	Warmth	C6	Highly subjective; cannot be reliably judged from the product itself
	Delight	C7	Reflects emotional response rather than design attributes
	Sense of Ritual	C8	Strongly context-dependent; lacks design-based observability
	Security	C9	Represents psychological perception rather than product features

In the second round of the Delphi survey, experts were asked to rate the importance of each indicator using a five-point Likert scale. As shown in Table 4, all 17 indicators achieved high mean scores (M > 4.30) with low standard deviations and coefficients of variation (CV < 0.15), indicating a strong level of expert consensus, ultimately constructing the evaluation indicator system for sustainable bamboo-woven fashion accessories design. The system consists of 4 primary criteria and 17 secondary indicators, providing the structural foundation for subsequent AHP-based weight calculation and comprehensive evaluation.

Table 4. Results of the Second-Round Delphi Survey for Indicator Confirmation

Primary Criteria	Secondary Code	Indicator Name	Mean (M)	SD	CV
Emotional Value	C1	Aesthetic appeal of form	4.80	0.42	0.09
	C2	Color coordination	4.60	0.52	0.11
	C3	Pattern	4.80	0.42	0.09
	C4	Texture	4.60	0.52	0.11
	C5	Personalization Customization	4.50	0.53	0.12
Functional Value	C6	Practicality	4.80	0.42	0.09
	C7	Durability	4.50	0.53	0.12
	C8	Comfort	4.70	0.48	0.10
	C9	Lightweight	4.40	0.52	0.12
	C10	Adaptability	4.30	0.48	0.11
	C11	Craft precision	4.80	0.42	0.09
	C12	Material integration innovation	4.60	0.52	0.11
Social Value	C13	Regional identity	4.40	0.52	0.12
	C14	Intangible cultural heritage inheritance	4.70	0.48	0.10
	C15	Social interaction dissemination	4.30	0.48	0.11
Green Value	C16	Material sustainability	4.90	0.32	0.07
	C17	Recyclability biodegradability	4.80	0.42	0.09

Analytic Hierarchy Process

Hierarchical model establishment

Following the Delphi consultation, the final set of evaluation criteria was confirmed and used to establish the hierarchical structure for the AHP. The hierarchy comprised a single goal evaluation of the material-technique adaptability of bamboo weaving for sustainable fashion accessories supported by four primary dimensions: Emotional Value (B1), Functional Value (B2), Social Value (B3), and Green Value (B4). Under these dimensions, 17 secondary indicators (C1 to C17) were organized as design-evaluable criteria. This hierarchical model served as the basis for constructing the subsequent pairwise comparison matrices and conducting the weight calculations in the AHP procedure, as illustrated in Fig. 2.

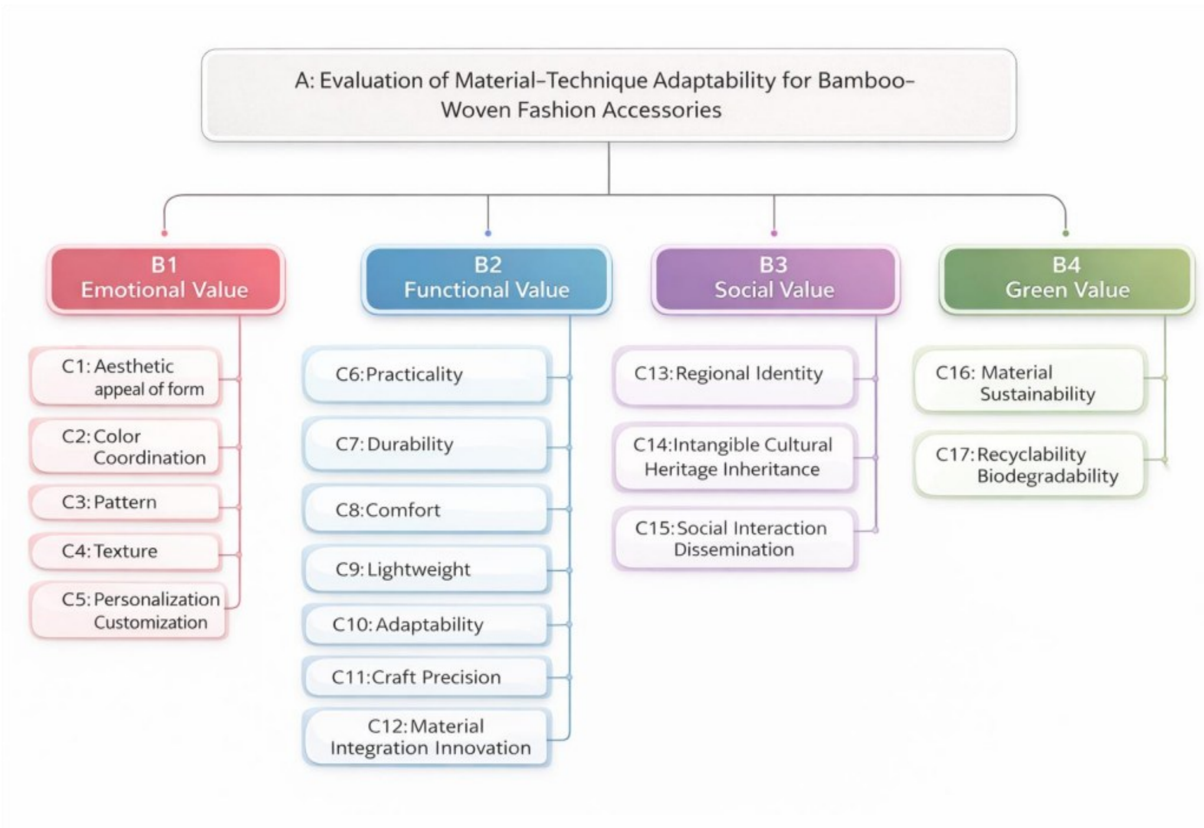


Fig. 2. AHP hierarchical structure for evaluating the material–technique adaptability of bamboo weaving fashion accessories

Consistency test of judgment matrices

Experts conducted pairwise comparisons for each level of indicators and constructed the corresponding judgment matrices. The consistency test results indicate that the consistency ratio (CR) values of all expert judgment matrices were less than 0.1, satisfying the consistency requirement of the AHP. This demonstrates that the expert evaluations exhibited a high level of consistency and reliability. Table 5 summarizes the consistency test results of the primary-level judgment matrices. The CR values (0.0091 to 0.0436) were well below 0.1, demonstrating that the experts' pairwise comparisons satisfy the AHP consistency requirement.

Aggregated weights of primary criteria

Based on the consistency-validated matrices, the individual weight vectors of the 10 experts were aggregated using the equal-weight aggregation approach. The resulting integrated weights for the four primary criteria were as follows (Table 5).

Table 5. Summary of Primary Criteria Weights and Consistency Test Results

Experts	Indicator Name	Weights	λ_{max}	CI	CR
E1	B1	0.4724	4.0506	0.0169	0.019
	B2	0.2854			
	B3	0.1697			
	B4	0.0725			
E2	B1	0.5639	4.1165	0.0388	0.0436
	B2	0.2633			
	B3	0.1178			
	B4	0.055			
E3	B1	0.5623	4.0784	0.0261	0.0293
	B2	0.2581			
	B3	0.1103			
	B4	0.0694			
E4	B1	0.5636	4.1117	0.0372	0.0414
	B2	0.2581			
	B3	0.115			
	B4	0.0765			
E5	B1	0.1292	4.0244	0.0081	0.0091
	B2	0.2543			
	B3	0.0789			
	B4	0.5377			
E6	B1	0.4234	4.0454	0.0151	0.017
	B2	0.2705			
	B3	0.1453			
	B4	0.1608			
E7	B1	0.2854	4.0506	0.0169	0.019
	B2	0.4724			
	B3	0.1697			
	B4	0.0725			
E8	B1	0.4724	4.0506	0.0169	0.019
	B2	0.2854			
	B3	0.1697			
	B4	0.0725			
E9	B1	0.2776	4.0305	0.0102	0.0115
	B2	0.4669			
	B3	0.1602			
	B4	0.0953			
E10	B1	0.4724	4.0506	0.0169	0.019
	B2	0.2854			
	B3	0.1697			
	B4	0.0725			

Table 6. Final Integrated Weights of Primary Criteria

Indicator	B1	B2	B3	B4
Final Weight	0.4223	0.3107	0.1406	0.1285

Secondary indicator weight

The secondary indicators were categorized into four groups, and the relative weights within each group were calculated independently. The first group consisted of indicators C1 to C5. Following the AHP computation steps applied in the primary criteria, 10 integrated weight matrices were generated for this group, from which the final consolidated weight table for indicators C1 to C5 was derived, as shown below (Sees Table 7 and 8).

Table 7. Integrated Weight Matrix for Indicators C1 to C5

Experts	C1	C2	C3	C4	C5
E1	0.3705	0.1852	0.2651	0.0958	0.0834
E2	0.4024	0.2257	0.1711	0.1102	0.0906
E3	0.4174	0.1602	0.2634	0.0975	0.0615
E4	0.1689	0.1088	0.3663	0.2842	0.0718
E5	0.0693	0.2124	0.1191	0.3867	0.2124
E6	0.3674	0.2061	0.2061	0.1254	0.095
E7	0.3762	0.151	0.2482	0.0737	0.151
E8	0.4778	0.2106	0.139	0.0809	0.0917
E9	0.4137	0.0966	0.261	0.1588	0.07
E10	0.3705	0.1852	0.2651	0.0958	0.0834

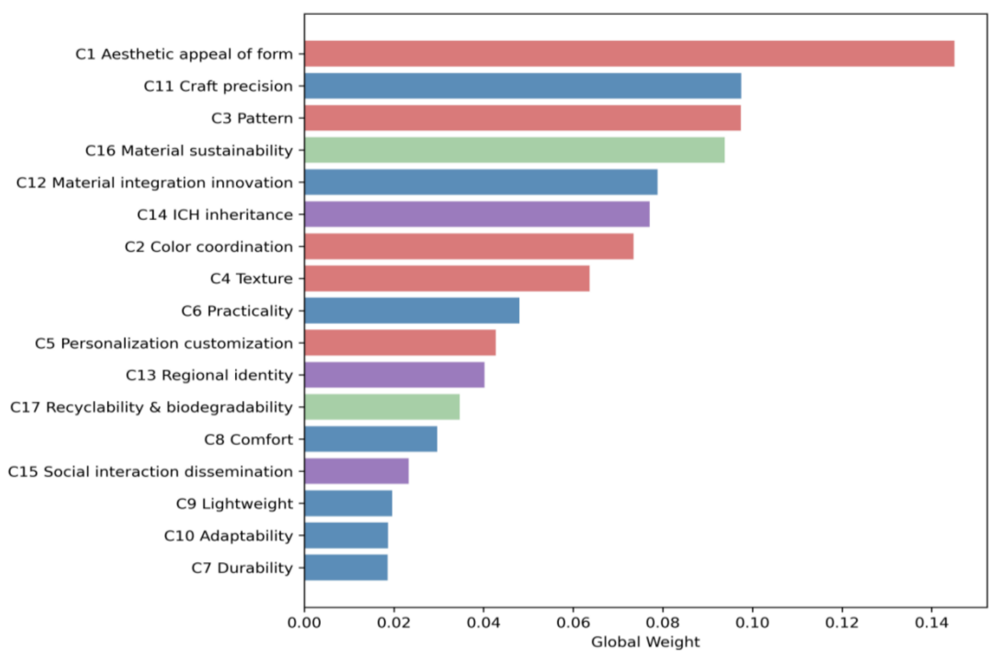


Fig. 3. Global weights and ranking of secondary indicators (C1 to C17) derived from the AHP analysis; Emotional Value (red), Functional Value (blue), Social Value (purple), and Green Value (green)

Table 8. Final Integrated Weights of Secondary Indicators C1 to C5

Indicator	C1	C2	C3	C4	C5
Final Weight	0.3434	0.1742	0.2304	0.1509	0.1011

The subsequent groups, C6 to C12 and C13 to C15, C16 and C17, were processed using the same calculation procedure. The resulting weights for these groups are summarized below (see Table 9 and Fig. 3).

Table 9. Weights of All Indicators

Primary Criteria	Weight	Secondary Indicators	Local Weight	Global Weight	Rank
B1: Emotional Value	0.4223	**C1: Aesthetic appeal of form**	0.3434	**0.1451**	**1**
		C2: Color coordination	0.1742	0.0735	7
		C3: Pattern	0.2304	**0.0974**	**3**
		C4: Texture	0.1509	0.0637	8
		C5: Personalization Customization	0.1011	0.0427	10
B2: Functional Value	0.3107	C6: Practicality	0.1545	0.0480	9
		C7: Durability	0.0598	0.0186	17
		C8: Comfort	0.0955	0.0297	13
		C9: Lightweight	0.0630	0.0196	15
		C10: Adaptability	0.0602	0.0187	16
		C11: Craft precision	0.3134	**0.0975**	**2**
		C12: Material integration innovation	0.2536	**0.0788**	**5**
B3: Social Value	0.1406	C13: Regional identity	0.2860	0.0402	11
		C14: Intangible cultural heritage inheritance	0.5486	0.0771	6
		C15: Social interaction dissemination	0.1654	0.0233	14
B4: Green Value	0.1285	**C16：Material sustainability**	0.7300	**0.0938**	**4**
		C17: Recyclability biodegradability	0.2699	0.0347	12

DESIGN PRACTICE AND VALIDATION

Design Practice Overview

Building upon the weighted results of the Delphi-AHP indicator system, this study advanced into design practice by developing a representative prototype to examine the operability of the material–technique adaptability framework. The "Qingshen bamboo-woven shawl cape" was selected as the design carrier because it aligns closely with the core characteristics of Qingshen Bamboo Weaving. This is an intangible cultural heritage craft from Qingshen County, Sichuan, which is renowned for its ultra-fine flat-splitting technique and smooth, paper-thin weaving quality (Jiang 2025).

The shawl's planar unfolding structure matches the craft's strengths in thinness, refinement, and density, while also providing sufficient space for expressing key high-weight indicators such as form aesthetics, pattern articulation, craftsmanship precision, and material innovation. Based on these considerations, three design schemes were developed, featuring geometric structuralization, modular shoulder-based assembly, and cloud-shoulder-inspired draped silhouettes. Together, these prototypes form a concise design exploration matrix that demonstrates how high-weight indicators can guide contemporary bamboo-woven fashion accessory development.

Design Schemes Drafts

Guided by the five high-weight indicators identified through the AHP analysis—C1Aesthetic appeal of form, C3 Pattern Expression, C11 Craft Precision, C12 Material Integration Innovation, and C16 Material sustainability, three design schemes were developed to explore different pathways of morphological logic, craft feasibility, and material–technique integration (Table 10).

Scheme A adopts a geometric, structured cape silhouette that reinterprets the traditional Qingshen hui-zi pattern into a contemporary geometric visual language. By extracting the original bamboo tone and transforming it into a continuous geometric lattice, the design achieves a modern, fashion-oriented aesthetic while remaining grounded in the core characteristics of Qingshen flat weaving. This planar configuration maximizes the technique's inherent advantages in density control and structural stability, resulting in the highest level of controllability in craft precision (C11). The clear geometric form reinforces Aesthetic appeal of form (C1), while the orderly arrangement of geometric motifs significantly enhances pattern (C3).

Scheme B employs a shoulder-based modular structure that integrates denim with bamboo-woven elements. The panda motif is deconstructed into several small weaving modules and assembled onto the denim shoulder base, creating a focused cultural visual identity. This cross-material composition demonstrates strong performance in material-integration innovation (C12) and maintains cultural recognizability in pattern(C3). Meanwhile, the durability of denim combined with the renewability of bamboo enhances the scheme's material sustainability (C16).

Scheme C draws inspiration from the traditional "cloud-shoulder" silhouette, constructing a centrally expanding draped configuration enriched with representative Qingshen floral-and-bird line-art patterns. The design integrates a contemporary Chinese-chic aesthetic sensibility, which enhances its decorative tension within the aesthetic appeal of form (C1) and strengthens cultural symbolism in pattern (C3).

To ensure the rigor of design scheme selection, expert evaluation was conducted following internationally recognised guidelines indicating that small expert panels (3 to 7 members) can produce stable and reliable judgments (Hallowell and Gambatese 2010; Okoli and Pawlowski 2004). Accordingly, five experts with strong relevance to Qingshen bamboo weaving and cultural-creative product design were selected from the Delphi panel. Their assessments consistently identified Scheme A as the most feasible and adaptable option, noting its superior performance in weave-density control, structural continuity, technical implementability, and aesthetic inclusiveness. Thus, Scheme A was chosen for prototype development and further validation.

Table 10. Three Design Scheme Drafts

Design Scheme	Key Indicators Addressed	Inspiration Prototype	Morphological Extraction	Final Sketch
A	C11/C1 /C3			
B	C12/C3 /C16			
C	C1 /C3 /C16			

Prototype Testing and Validation

Based on the expert evaluation that identified Scheme A as the most feasible and adaptable option, a physical prototype of the Qingshen bamboo weaving shawl was developed and subsequently subjected to user testing. The evaluation aimed to examine how the high-priority indicators perform within real production and wearing contexts. This testing followed the AHP principle of priority verification, focusing on five key high-weight indicators: C1Aesthetic appeal of form , C3 Pattern Expression, C11 Craft precision, C12 Material Integration and Innovation, and C16 Material Sustainability.

(a) (b) (c)

Fig. 4. Prototype of the Qingshen bamboo-weaving shawl: (a) Flat layout view; (b) Three-dimensional structural drape view; (c) On-body wearing view of the prototype.

All assessments were recorded using a five-point Likert scale, and both the mean and standard deviation (SD) were calculated to evaluate overall performance and response consistency. A total of five participants were recruited for prototype testing: three target users, one associate professor specializing in fashion and cultural-creative product design, and one intangible cultural heritage (ICH) inheritor of Sichuan bamboo weaving. This participant structure enabled the study to capture both authentic user experience and expert feedback from design and craft perspectives, thereby forming a comprehensive "user-design-craft" evaluation framework. The sample size also aligns with Nielsen's widely cited principle that testing with five users can uncover the majority of usability issues

(Nielsen, 2000; Woolrych and Cockton 2001). The testing outcomes were visualized using a radar chart (Fig. 5) to illustrate performance trends across the five high-priority indicators.

Likert-scale results were interpreted following established statistical guidelines, where high mean scores accompanied by low standard deviations indicate strong evaluator consensus (O'Neill 2017). In this study, the indicators showed consistently high Means (4.20-5.00) and low SD values (0.00-0.49), reflecting a high level of agreement among participants.

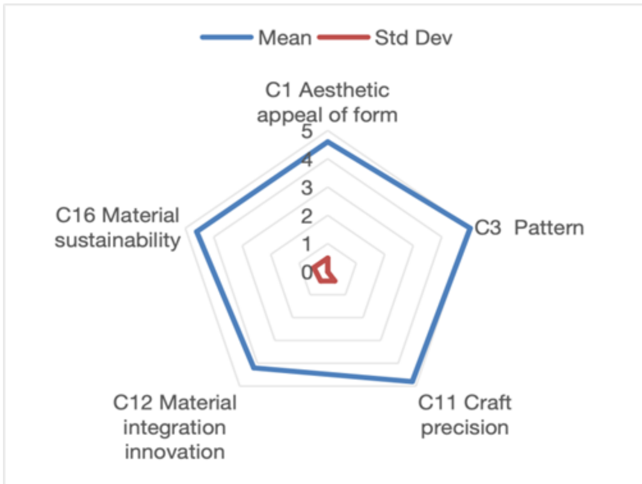


Fig. 5. Radar plot of prototype evaluation results across five high-weight design criteria. Blue indicates mean scores (Mean), and red indicates standard deviation (SD) across five participants

DISCUSSION

This study employed the Delphi method and AHP to construct a quantitative evaluation framework for assessing the material-technique adaptability of bamboo-weaving in sustainable fashion accessories. Through integrating expert judgment with a structured weighting process, the framework revealed how different value dimensions contributed to the effective utilization of bamboo as a bio-based material in contemporary product design.

Dominance of Perceptible Expression

At the primary-criteria level, Emotional Value received the highest weight (0.4223), exceeding functional, social, and green value dimensions. This finding indicates that bamboo-woven fashion accessories are evaluated primarily through perceptible material expression rather than utilitarian performance. From a material perspective, this suggests that the success of bamboo weaving in fashion-related applications depends largely on how material properties, such as flexibility, surface texture, and visual rhythm, are manifested through weaving techniques. This outcome aligns with Norman's (2004) established emotional design theory that emphasizes the dominance of visceral and reflective responses in the evaluation of aesthetic-driven products and highlights the importance of material expression in value-added bioresource applications.

Technical and Aesthetic Synergy

At the secondary indicator level, Aesthetic appeal of form (C1, 0.1451), Craft Precision (C11), and Pattern (C3) ranked among the most influential factors. These indicators directly reflect the visibility and controllability of bamboo weaving as a material–technique system. Zabulis *et al.* (2025) argue that craftsmanship is typically assessed based on visible qualities, such as structural coherence, detail density, and surface articulation. In the case of bamboo weaving, the linear morphology of bamboo strips enables precise pattern generation and surface modulation, making craftsmanship quality a critical determinant of perceived value and adaptability in fashion accessories (Gao *et al*. 2024).

The Role of Sustainability and Innovation

Indicators related to Material Sustainability (C16) and Material Integrated Innovation (C12) also achieved high global weights, underscoring the growing importance of sustainability considerations in bamboo-based product design (Dutta *et al.* 2025). Although green value ranked lower at the primary-criteria level, its key sub-indicators exerted substantial influence on overall evaluation outcomes. These findings are consistent with insights from design-adaptability studies, where environmental considerations are shown to act as complementary attributes that strengthen user trust and acceptance, while aesthetic and experiential qualities remain the primary determinants of design judgment (Koller *et al.* 2011; Manu *et al.* 2022).

Functional Baselines *vs.* Value-added Differentiation

In contrast, indicators associated with durability, comfort, and functional adaptability received comparatively lower weights. This suggests that such attributes as baseline requirements, while basic material performance must meet minimum usability thresholds, differentiation and adaptability are achieved primarily through technique-driven material expression (Lee and Koubek 2012; Doi 2025). This emphasizes that the utilization of bamboo is not governed solely by intrinsic material properties, but by the interaction between those properties and the craft techniques that translate them into experiential forms.

CONCLUSIONS

This study successfully developed a systematic evaluation framework for bamboo-woven fashion accessories by integrating the Delphi method and the analytical hierarchy process (AHP). Through translating theoretical dimensions of consumer perceived value into design-evaluable indicators, the research provides an operable approach for assessing bamboo weaving as a sophisticated bio-based material–technique system.

1. Drivers of adaptability: The results demonstrate that the contemporary adaptability of bamboo weaving is primarily driven by perceptible material expression and craftsmanship quality.
2. Prioritized indicators: Factors, such as Aesthetic appeal of form (C1), craft precision (C11), and pattern (C3), emerged as the most important indicators, while material sustainability and integrated innovation serve as critical supporting pillars for market viability.

3. Functional baselines*:* Functional attributes, including durability and comfort, were found to act as essential baseline requirements rather than primary differentiators in the design evaluation stage.
4. Methodological shift: This framework advances the field by shifting the focus from purely descriptive or performance-oriented studies of bamboo toward a decision-oriented evaluation model. It offers a structured tool for evaluating the design adaptability of bamboo-based materials and techniques in creative industries, particularly in value-added and low-energy craft applications.
5. Validation through design practice: The application of the framework to the national-level intangible cultural heritage craft of Qingshen bamboo weaving further confirms its practical value, demonstrating that the evaluation model effectively guides design translation and supports the development of feasible, culturally grounded, and aesthetically coherent bamboo-woven fashion accessory prototypes.

Practical Implications and Future Outlook

The proposed framework offers practical guidance for designers and product developers to optimize material expression and align bamboo-based products align bamboo-based products with contemporary design requirements and market expectations. While the framework demonstrates high consistency based on expert evaluation, future research may further enhance the theoretical and methodological robustness of this framework from a sustainability perspective by incorporating established sustainability analysis models, expanding the expert panel to include sustainability and lifecycle specialists, and integrating lifecycle thinking to strengthen the sustainability justification for bamboo-woven fashion accessories. In addition, future studies should also examine the practical feasibility and potential pathways for industrial scale-up, so as to assess how the identified design strategies could be translated into broader production contexts. Ultimately, this study establishes a methodological foundation for the contemporary transformation of bamboo resources, contributing to the broader advancement of bio-based material design.

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