AHP-TOPSIS-based Decoding of Tang-Sancai Cultural Factors and Their Adaptability Evaluation for Wood-based Cultural-Creative Products

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Existing Tang Sancai cultural-creative products usually directly replicate artifact patterns without quantitative screening and scientific evaluation of cultural elements. Although wood-cellulose and solid-wood substrates serve as mainstream low-carbon sustainable carriers, a standardized design system adapting Tang Sancai visual elements to wood-based materials remains absent. This study constructs a practical framework for translating Tang Sancai cultural factors and compares the substrate adaptability between ceramics and wood-based materials. Tang Sancai relic samples from multiple regions were collected, and cultural factors covering color, pattern, and form were extracted. An AHP-TOPSIS integrated model based on 12 cultural-factor indicators was adopted to calculate factor weights and evaluate multiple design schemes, including wood-pulp beverage packaging, a mouse-pad visual-reference scheme, a solid-wood ornament and a ceramic reproduction. Material-science requirements including biodegradability, printing fidelity, cost and lightweighting were considered in the preliminary design of schemes. Composite Mixed Patterns, kiln-change glazes and blue glaze were identified as core design factors. The wood-pulp beverage packaging achieved optimal comprehensive performance. Wood-based panels showed potential advantages in pattern reproduction. This work provides a quantitative paradigm for traditional-ceramic-derived ICH product development and fills the research gap in translating ceramic cultural symbols for wood-based low-carbon cultural-creative applications.

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INTRODUCTION

"Cultural Genes" is an interdisciplinary concept derived from Dawkins' theory of memes (Li *et al.* 2020). Traditional cultural genes are the stable, inheritable core visual and spiritual units within a national cultural system, forming the underlying logic for the modern transformation of traditional culture (Fomin 2019). Tang Sancai originated during the High Tang period, a time of deep cultural integration between China and the outside world. Its unique low-temperature lead-glaze technique produces richly layered glaze colors, complex decorative patterns, and distinctive vessel forms, making it a quintessential embodiment of Tang Dynasty visual aesthetics (Wang *et al.* 2025). Currently, the development of Tang Sancai cultural and creative products is plagued by a lack of diversity: most designs directly replicate the complete forms and surface patterns of cultural relics,

relying solely on ceramic substrates (Fan *et al.* 2025). They lack deconstruction and reconstruction of colors and decorative symbols, and have not conducted suitability studies using green, low-carbon materials (Hariharan *et al.* 2025).

At this stage, the ICH cultural and creative industry is transitioning toward sustainable, biodegradable materials, which—thanks to renewable raw materials, ease of processing, and natural biodegradation—are gradually replacing energy-intensive ceramics and non-biodegradable plastics as mainstream substrates. Existing research on wood-based cultural and creative products has largely focused on two-dimensional, monochromatic patterns such as paper-cutting, wood carving, and ink painting. However, there is a significant research gap regarding the adaptability of these materials to Tang Sancai's multi-layered kiln-change effects and multi-colored, intermingling glaze textures: the mottled, layered effects from natural glaze flow during firing cannot be fully replicated through conventional wood panel printing or lamination; surface coating and coloring processes compress glaze color gradation, creating an inherent trade-off between visual fidelity, environmental sustainability, and industrial production costs. At the same time, existing evaluation systems for traditional cultural elements remain limited to ceramics as the sole medium and do not incorporate suitability metrics for wood-based cellulose substrates, making it impossible to provide quantitative guidance for the practical design of low-carbon Tang Sancai cultural and creative products on a wood-based substrate (Xu *et al.* 2025).

Based on these gaps, this paper uses the theoretical framework of traditional cultural genes to deconstruct Tang Sancai's visual elements into three gene categories—color, pattern, and form—and establishes a research pathway of "gene classification—quantitative evaluation of wood-based material compatibility—multi-media redesign." By using AHP to calculate cultural factor weights and TOPSIS to evaluate design proposals across ceramic, wood pulp, and solid wood substrates. This study identifies optimal strategies for adapting Tang Sancai visual symbols to wood-based cellulose materials, providing a standardized research paradigm for wood-based ICH cultural and creative product development. This study does not aim to reproduce the artistic or market value of precious ancient Tang-Sancai relics with mass-produced wood-based products. Instead, it extracts and decomposes cultural visual factors from high-value ancient artworks, to provide quantitative design guidance for affordable, mass-producible wood-based cultural-creative products for public popularization of traditional culture.

Despite abundant existing studies on Tang-Sancai aesthetics and cultural-creative product development, there remain critical knowledge gaps regarding quantitative cultural-symbol translation for mass-producible wood-based products. Most prior work stays at qualitative pattern imitation, lacking systematic hierarchical decomposition of visual cultural factors, and rarely adopts combined multi-criteria decision-making methods (AHP-TOPSIS) to quantitatively evaluate the adaptability of traditional ceramic cultural symbols for low-carbon, mass-manufacturable wood-cellulose substrates. Existing evaluation frameworks are mostly oriented toward ceramic carriers and cannot provide actionable quantitative design guidance for cross-material cultural-creative transformation. To fill these gaps, this study integrates AHP weighting and TOPSIS multi-attribute evaluation to realize the decoding, weighting screening and adaptability ranking of cultural visual elements, so as to translate intangible ceramic cultural symbols into design references suitable for affordable mass-produced wood-based products. For the first time, this work constructs a complete closed-loop paradigm of "cultural-factor extraction-AHP weighting-TOPSIS adaptability evaluation-cross-material scheme redesign" for

Tang-Sancai heritage, which provides a replicable multi-criteria decision-making workflow for transforming traditional ceramic visual heritage into mass-producible cellulose-based cultural-creative derivatives, and is not limited to the Tang-Sancai case itself.

The Craftsmanship and Visual Characteristics of Tang Sancai: Decorative Techniques and Visual Characteristics of Tang Sancai

As a type of low-firing lead-glazed pottery with distinctive characteristics from a specific historical period, Tang Sancai fully embodies the aesthetic and cultural values of Tang Dynasty ceramic craftsmanship (Zhang 2023). In terms of technical characteristics, typical low-firing glazed pottery of the Tang Dynasty used kaolin as the body, minerals such as copper, iron, cobalt, and manganese as colorants, and smelted lead slag and lead ash as flux agents added to a base transparent glaze formed by the fusion of quartz. They are fired at a low temperature of 800 °C, resulting in glaze colors ranging from deep green, light green, emerald green, blue, white, yellow, brown, and ochre (Shen *et al.* 2019). Lead glaze has a relatively high refractive index, low viscosity at high temperatures, and high fluidity. Consequently, the glaze surface has a strong luster, is smooth and even, clear and transparent, and contains few or no bubbles, resembling glass. Ancient Chinese potters took advantage of the transparency of lead glaze; they would often carve exquisite patterns onto the unglazed clay body before applying the glaze. After firing, the underglaze patterns were clearly visible, creating a unique artistic effect that allowed for a wide variety of decorative designs. However, three points are worth noting: First, regarding the terminology: the "cai" (color) in "Sancai" refers not to pigments but to glaze materials. According to the author's research, the term "Tang Sancai" has never appeared in ancient texts; it first emerged during the Republic of China era. It referred to funerary artifacts discovered during the Qing government's construction of the Mengshan section of the Bianluo Railway. These artifacts featured glossy surfaces with vibrant, mottled colors, and were termed "Tang lead-glazed pottery," "multi-colored glazed pottery," and "Tang Sancai". Through a series of misinterpretations and misrepresentations, the name "Tang Sancai" gradually became established and has persisted to this day. Second, regarding the colors of the artifacts: even before the emergence of Tang Sancai, the Northern Qi period had already seen the evolution of Han and Wei-era clay-glazed pottery techniques into porcelain-clay glazed pottery techniques. Among these excavated artifacts, monochrome glazed pottery constitutes a significant portion; consequently, influenced by tradition, a considerable number of monochrome glazed pottery pieces are also found among Tang Sancai artifacts. For example, the yellow and blue monochrome glazed pottery unearthed from the tomb of the Empress at Gongling (Zhang and Pollard 2022). Regarding the raw materials used for the body, traditional views held that the body of Tang Sancai was made of white porcelain clay. However, recent archaeological excavations have revealed that sites producing porcelain-clay-bodied Sancai also contained a small number of earthenware-glazed pottery pieces, located at the traditional Han-Wei kiln sites. Experts have dated these finds to the late 7th century—the heyday of Tang Sancai production. Given that the use of earthenware clay bodies was likely a response to surging market demand at the time, these earthenware-bodied glazed vessels should also be classified as part of the Tang Sancai tradition (Chang *et al.* 2021).

The high artistic achievement of Tang Sancai is closely tied to its diverse decorative techniques, primarily glaze flow and its control. The large amount of lead in the glaze acts as a flux, lowering the melting temperature and enhancing the flow and diffusion of

coloring metal oxides during firing, causing glazes with various colorants to intermingle into mottled, brilliant patterns. Overall, the flowing glaze patterns exhibit either an ordered arrangement or a random, disordered state. Controlling glaze flow offers two key benefits: first, artisans can create distinct patterns and arrangements based on the vessel's form or specific locations; second, it prevents excessive blending of different colored glazes, which could produce bizarre hues. Based on an analysis of representative artifacts from Gongyi in Henan, Tongchuan and Xi'an in Shaanxi, and southwestern Hebei (including Xing Kiln, Jingxing, and Dingxian), the northwestern part (Weixian in Zhangjiakou), and the southernmost region (Handan), the author categorizes the visual forms of Tang Sancai into the following types:

One type is the monochrome style, which is primarily decorated with a single-color glaze; the colors are divided into four: yellow, green, blue, and brown. Among these, Sancai wares from the Xingtai region of Hebei generally use green glaze as the base color, with other colored glazes applied as accents on top. In terms of technique, this method bears similarities to the coloring methods used on flower-glazed porcelain of the same period; however, even within a single color, the shades vary in depth—for example, green can be divided into grass green and dark green, while yellow can be categorized as realgar yellow and brownish yellow.

The second method is the smearing technique, in which tools are used to freely smear glaze onto the surface of the object, creating a textural effect where the glazes blend together. The resulting glaze patches can be divided into two types: the first involves natural flowing and blending between glaze patches, resulting in mottled and vibrant colors. The second features patterns of patches that diffuse outward; the colors of these patches can be either monochromatic or multicolored. The application technique is relatively simple and free-form. There are also forms that combine these two techniques. In particular, the application of glaze on figurines of people and animals often imitates the texture of clothing or the colors of feathers, whereas the application on everyday utensils follows no obvious pattern.

The third is the painting-style technique, which utilizes the colors of the glaze to create patterns on the surface of the object. This can be further divided into dot painting and filled-color painting. Dot painting is relatively simple, involving the dotting of glaze onto the surface to form regular or irregular patterns. The painting-style patterns are quite diverse and even include imitations of dyed and patterned textiles from the same period.

The fourth is the exposed-clay decoration technique, which involves leaving areas of the surface unglazed to create a multi-layered pattern structure through the contrast between the body color and the glaze color. Glaze decoration using this technique can be further divided into monochrome and multicolor exposed-clay styles. Monochrome exposed-body decoration involves creating a pearlescent decorative effect on the surface of a single-color glaze, whereas multicolor exposed-body decoration generally involves artisans organizing the color scheme of the design according to the desired colors for patterns in different areas, a technique that is highly challenging and produces a striking artistic effect (Xia and Yu 2023).

In terms of design, Tang Sancai figurines can be divided into three major categories: figurines, everyday household items, and architectural models. Among these, figurines are the most distinctive. They can be further divided into human and animal figurines. Human figurines include those depicting noblewomen, bodyguards, civil and military officials, and foreign figures, while animal figurines include horses, camels, dogs, chickens, pigs, ducks, lions, and tomb guardian beasts. In terms of household items, Tang Sancai includes cups,

plates, vases, jars, pots, pillows, boxes, and incense burners. Finally, architectural models commonly feature pavilions, terraces, towers; rockeries; houses; courtyards; and latrines. Tang Sancai architectural models were largely influenced by the Han and Wei periods; however, in terms of overall scale and the level of craftsmanship, they represented a noticeable decline compared to the Han dynasties. This indirectly reflects changes in Tang Dynasty burial customs compared to those of the Han and Wei periods, though the purpose of their creation remained the same: to ensure that the deceased could continue to enjoy the splendor of the living world in the afterlife (Fei and Suwanthada 2024).

Advantages and Disadvantages of Wood-Cellulose Substrates for the Visual Translation of Tang Sancai

Wood-cellulose-derived materials encompass categories such as wood pulp-based paper, modified solid wood panels, and fiber-reinforced composite panels. They currently serve as the core substrate system for the development of green, low-carbon cultural and creative products. Compared to traditional ceramic substrates, these materials offer unique adaptability in the application and transformation of Tang Sancai visual symbols. In terms of material application advantages, wood cellulose raw materials are naturally renewable, and products can biodegrade in the natural environment after disposal, aligning with the core requirements for sustainable development in the cultural and creative industry. Panel and paper-based materials are notably lightweight and can be shaped into diverse product forms through various forming processes—such as cutting, die-cutting, and folding—making them suitable for the development of cultural and creative products across multiple scenarios, including packaging, tabletop ornaments, and stationery. At the same time, the surface printing and spray-painting processes for wood-based substrates are well established, and the barriers to industrial-scale mass production are far lower than those of high-temperature ceramic firing processes. According to published literature, wood-cellulose-based materials have theoretical potential for carbon mitigation owing to biomass carbon sequestration, while direct experimental tests on printing durability and quantitative carbon-emission data are beyond the scope of the present study. At the same time, the surface printing and spray-painting processes for wood-based substrates are well established, and the barriers to industrial-scale mass production are far lower than those of high-temperature ceramic firing processes, demonstrating the industrial potential for large-scale implementation of cultural and creative products. However, there are objective limitations in terms of visual reproduction. The natural porous structure of wood-cellulose substrates causes ink adsorption, making it difficult to reproduce the multi-layered, gradient glaze colors formed by the Tang Sancai kiln-change process. While lamination and protective coating processes can enhance color retention, they diminish the translucent, flowing texture created by the natural blending of glazes. Due to constraints imposed by the material's forming process, the wood-based substrate can only accommodate Tang Sancai visual elements that have been simplified into flat designs; it is unable to replicate the complex three-dimensional reliefs and multi-layered, stacked structures found on ceramic artifacts. For original kiln-change patterns featuring rich gradations and intricate textures, direct replication would result in the loss of visual information. Therefore, during the screening of Tang Sancai cultural elements and the design phase of cultural and creative projects, the printability and colorability of wood-based cellulose materials, as well as the constraints of lightweight molding, must be established as foundational evaluation criteria.

Visual elements that are poorly suited to wood-based substrates—such as complex three-dimensional forms and multi-layered, disordered kiln-change textures—should be avoided. Instead, flat patterns with regular lines and simple color gradations, along with monochromatic glaze colors, should be prioritized as core design elements.

EXPERIMENTAL

Theoretical Framework

The Analytic Hierarchy Process (AHP) is a systematic analysis method that combines qualitative and quantitative analysis, proposed by American operations researchers in the 1970s (Ngoie *et al.* 2025). AHP is a subjective weighting method that calculates scores for each indicator based on expert ratings (Kitila *et al.* 2026), thereby generating a judgment matrix for pairwise comparisons of indicators (Khaira and Dwivedi 2018). Its advanced nature lies in conducting hierarchical weighting and decision analysis of user needs, thereby helping designers balance the relative importance of various user needs and providing data-driven support for subsequent design work (Akter *et al.* 2025). In this study, the expert scoring process not only considered the artistic value of the patterns and colors themselves but also took into account the printability and formability of different cultural elements on wood-based cellulose substrates.

TOPSIS (Technique for Ordering Preference by Similarity to Ideal Solutions) is a comprehensive evaluation and analysis method based on a multi-criteria evaluation matrix that uses measured distances to rank the relative merits of multiple alternatives (Hou *et al*. 2025). This method constructs positive and negative ideal solutions and calculates the relative proximity of each alternative to these ideal solutions to rank and evaluate design alternatives (Taherdoost and Madanchian 2024). This paper incorporates performance indicators related to wood-based materials into the TOPSIS evaluation framework to enable a side-by-side comparison of cultural and creative design proposals using different substrates—namely, ceramics, wood pulp, and solid wood (Faraji Sabokbar *et al.* 2016).

Research Process

This study focuses on translating the cultural elements of Tang Sancai into wood-based, low-carbon cultural and creative products. It establishes a complete, closed-loop research process comprising "factor identification—quantitative evaluation—concept development—selection and validation," and combines the AHP and TOPSIS methods to facilitate the practical transformation of traditional culture from cultural heritage resources into modern cultural and creative products (Cui *et al.* 2025). The first phase involves the hierarchical extraction of cultural factors. First, Tang Sancai artifacts unearthed in Henan, Hebei, Shaanxi, and other regions were cataloged, and artifact samples were organized according to three dimensions: decorative techniques, vessel forms, and glaze color expressions; Next, three categories of foundational cultural genes—color, pattern, and form—were identified. Typical glaze colors (yellow, green, blue, and brown), decorative patterns (petal motifs, grid patterns, and mixed textures), and three major form categories (figurines, daily-use vessels, and architectural elements) were analyzed. This process involved the decomposition of visual symbols and the extraction of sample images to establish a Tang Sancai cultural factor repository. During this extraction, visual elements suitable for wood-based printing processes were preliminarily screened.

In the second phase, an evaluation system was constructed using the Analytic Hierarchy Process (AHP). With the decoding of Tang Sancai cultural factors as the overarching goal, three criteria layers—color, pattern, and form—were established, comprising 12 sub-indicators. Experts from the fields of archaeology, design, and woodworking were invited to use the 1-9-point scale to conduct pairwise comparisons and scoring. Multiple judgment matrices were integrated using the geometric mean method; after passing the consistency test, the comprehensive weights for each indicator were calculated, and high-weight core design factors—such as Composite Mixed Patterns, Intermingled-Glaze Textures, and blue glaze—were selected. The third phase involved the practical design of cultural and creative products. Guided by the weight-based ranking results, high-weight cultural elements were selected for simplification, reconstruction, adaptation, and redesign. Four distinct cultural and creative product designs were developed: a mouse pad, wood pulp beverage packaging, a solid wood ornament, and a ceramic reproduction. These designs achieved the visual translation of Tang Sancai colors and patterns onto various modern media, including ceramics, wood pulp, and solid wood. The fourth phase employed the TOPSIS method for quantitative evaluation and selection. The 12 cultural factor indicators were combined with material science metrics—such as the environmental sustainability of wood-based substrates, printability, and mass production costs—to form a unified evaluation system. Experts were organized to score the four proposals and traditional artifact samples, constructing a standardized evaluation matrix (Tran *et al.* 2024). Following the normalization in Equation (7), each normalized indicator value is multiplied by the corresponding AHP-derived weight ωj from Table 11 according to Equation (8), to construct the weighted normalized decision matrix before calculating positive-ideal and negative-ideal solutions.

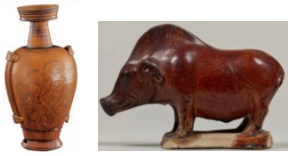
The positive and negative ideal solution distances and relative proximity of each proposal were calculated, and a ranking of proposals was established based on their proximity. Ultimately, the optimal design proposal was selected, and the applicability of the entire extraction and evaluation process to the development of wood-based cultural and creative products was verified. The entire process integrates qualitative cultural exploration with quantitative data analysis, providing a standardized pathway for the modern design of traditional ceramic culture adapted to wood-based media.

Extraction of Color Elements from Tang Sancai Culture

The coloring process for Tang Sancai involves using metal compounds as pigments. When added in specific proportions to a lead-containing compound, they fuse with quartz to form a base transparent glaze. This base transparent glaze appears white without the addition of metal compounds, but when different metals such as copper, iron, and cobalt are added, it produces a variety of colors. Due to the unstable firing atmosphere in Tang Sancai kilns and variations in glaze formulations, the coloration of Tang Sancai glazes is quite variable.

The colors are classified into four main color families: yellow, brown, green, and blue; however, each family has further subcategories. In selecting color-element symbols for Tang Sancai, two typical sample hues were collected from each color family for artifact-sample observation and visual extraction. These collected color samples were further summarized into four representative color evaluation indicators (C1 to C4) for the subsequent AHP assessment. The extraction of color genes is shown in Table 1.

Table 1. Color Gene

Name	Sample Examples	Color Extraction
Brown		
Green		
Yellow		
Blue		

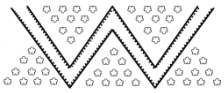
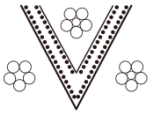
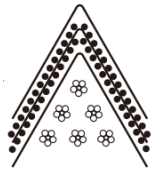
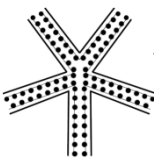
Cultural Analysis of Tang Sancai Patterns

Tang Sancai features a rich variety of patterns. The most common motifs are floral. The primary reason for their widespread appearance in Tang Dynasty applied arts was a shift in the public's aesthetic perspective. Beginning in the Tang Dynasty, the traditional aesthetic sensibilities of the Chinese people gradually shifted from religious-style depictions of animals and figures to an appreciation of natural flora. During the Tang Dynasty, the nation flourished, and among the aristocracy, the customs of flower appreciation, garden excursions, and banquets became prevalent; peonies, lotuses, and the "Baoxiang" flower emerged as popular aesthetic symbols throughout society. Ceramics, gold and silverware, murals, and textiles commonly featured floral motifs as decorative themes. Tang Sancai, used as funerary and decorative ceramics, closely followed the aesthetic trends of the era and extensively reproduced floral patterns. Influenced by the spread of Buddhism, the Baoxiang flower and the lotus became central symbols of Buddhism during the Tang Dynasty, symbolizing purity, rebirth in the Pure Land, and good fortune. With Buddhism widely revered throughout the Tang Dynasty, lotus motifs were ubiquitous in temple sculptures and the decoration of religious artifacts. Tang Sancai ware was often used as funerary objects, with floral motifs expressing the wish for the deceased to attain a peaceful rebirth and for their blessings to endure (Lyu *et al.* 2021). At the same time, the low-temperature lead glaze of Tang Sancai features a rich color palette, with soft, nuanced shades of green, red, yellow, and brown that are ideally suited for depicting the graceful, layered, and intricate forms of flowers and foliage. The mottled texture created by the natural flow of the glaze perfectly enhances the vivid and full visual impact of the floral motifs, making this technique exceptionally well-suited for such depictions.

Floral patterns can be divided into three types: one consists of floral motifs created by artisans using the "dot-painting" technique; another consists of floral motifs formed by

artisans using the "reserved white" technique; and the most complex type is the "Baoxiang" pattern, created by artisans first carving the design onto the interior of the plate with a chisel and then filling the carved areas with glaze in the colors required for the pattern. Next are grid patterns, M- and W-shaped zigzag patterns, and Composite Mixed Patterns. These designs are largely inspired by Tang Dynasty dyed and patterned textiles; however, due to fundamental technical differences between the dyeing and weaving processes and the decorative techniques of Tang Sancai, they possess stylistic characteristics distinct from those of the textiles.

Table 2. Pattern Gene

Name	Sample Examples	Pattern Extraction	Factor Extraction
Petal Pattern			
			
			
Grid Pattern			
			
Composite Mixed Patterns			
Zigzag Pattern			

Grid patterns are divided into two types: the first features spacing bands between the grid lines, with white bead-chain patterns connecting the diamond-shaped color blocks, and brown or green spacing bands between the bead-chain patterns; the second leaves blank spaces between the grid squares, with no decorative spacing bands along the intersecting lines. The arrangement of the grid patterns is essentially the same as in the previous type, but the pattern layers and structural composition are relatively simpler. The Composite Mixed Patterns combine the M- and W-shaped zigzag patterns found on Sancai ware with floral motifs and dot patterns to create a new design featuring diagonal compositions. These diagonal compositions not only lend the decorative elements of Sancai ware a stronger sense of dynamism and rhythm but also showcase the ingenious design concepts and ability to fuse diverse elements demonstrated by Tang Dynasty artisans. Finally, there are the glaze color, texture, and pattern types. This type of pattern is the most distinctive. Artisans apply two or three different colored glazes to the surface of the vessel in a freehand or controlled manner. During high-temperature firing, the different glazes blend together, creating various glaze color and texture effects. Through careful screening, this study has identified the three most common combinations: yellow-green, yellow-blue, and brown-green. The pattern gene extraction results are shown in Table 2.

Extraction of Cultural Elements from the Forms of Tang Sancai

This study categorized figurative elements into human and animal figures, architectural and landscape motifs, and everyday objects (Yan *et al.* 2018). Human figures tend to be less decorative, so only servant figurines with exaggerated expressions and gestures were selected. Animal figurines sampled horses, camels, lions, wild ducks, and fish. Architectural and landscape motifs are rare in Sancai ware, so houses and rockeries with distinctive designs were selected. For everyday household vessels, this study selected the three most numerous types: vases, jars, and plates. Tang Sancai jars feature rounded, full-bodied forms, typified by the "Wan Nian" jar; their spherical shapes highlight the elegant, luxurious Tang Dynasty style. In contrast, the Sancai Baoxianghua flat-bodied jug draws from Western Regions gold and silverware.

Due to the continuous import of gold and silverware from regions such as Sogdiana, the Sassanid Empire, and ancient Rome, the Tang imperial court had already widely adopted gold and silverware in daily life as early as the Early and High Tang periods. After the Early Tang, the use of gold and silverware began to show a trend toward institutionalization; consequently, gold and silverware motifs are very common in Sancai ware. In the design of plates, Tang Sancai plates extensively feature diamond-shaped motifs, which possess strong aesthetic appeal. Complete three-dimensional figurines and complex architectural models are not suitable for printing or carving on wooden bases; instead, they are better suited for extracting flat silhouettes for use in cultural and creative products on wooden bases. The extraction of design elements is shown in Table 3.

Table 3. Styling Gene

Name	Sample Examples	Shape Extraction	Factor Extraction
Figurines of People and Animals			
			
			
			
			
			
Architectural Landscape Design			
			

Name	Sample Examples	Shape Extraction	Factor Extraction
Designs of Everyday Tableware			
			

Establishing a Hierarchy of Design Indicators for Evaluation

This study employed the Analytic Hierarchy Process (AHP) to preliminarily determine the weights of factors at each criterion level. The hierarchical model was constructed by transforming the Tang Sancai cultural factor map; the specific construction steps are as follows: (1) "Tang Sancai Cultural Factor Decoding T" was designated as the objective level of the decision-making process; (2) the Tang Sancai cultural factors "Color Elements (C)," "Pattern Elements (P)," and "Form Elements (S)" were designated as the criterion levels; (3) Twelve indicator layers were established under the second-level indicators. The expert scoring process took into account both artistic expressiveness and compatibility with wood-based substrates. Based on the above steps, the hierarchical model for decoding Tang Sancai cultural factors was constructed, as shown in Table 4.

Table 4. Tang Sancai Culture Factor Decoding Hierarchy

Target Layer	Policy Layer	Metrics Layer
Decoding the Cultural Elements of Tang Sancai (T)	Color Elements (C)	Brown Glaze C1
		Green Glaze C2
		Yellow Glaze C3
		Blue Glaze C4
	Pattern Elements (P)	Intermingled-Glaze Textures P1
		Petal Patterns P2
		Grid Patterns P3
		Zigzag Patterns P4
		Composite Mixed Patterns P5
	Styling Elements (S)	Human and Animal Figures S1
		Architectural and Landscape Motifs S2
		Everyday Utensils S3

Constructing the Decision Matrix and Calculating Weights

A total of 10 professors and experts in the field were invited to conduct the research and evaluation, including 3 professors specializing in archaeology, 5 professors specializing in design, and 2 researchers specializing in wood processing. A 1 to 9 rating scale was used to conduct pairwise comparisons of the importance of indicators at each level; the rating scale is shown in Table 5.

Given the n factors associated with the higher-order factor z are x_1, x_2, …, x_n, where

i, j = 1, 2, …, n, a_{ij} denotes the importance ratio of factor x_i relative to factor x_j with respect to z. Based on these ratios, a complete pairwise comparison matrix A for these n factors with respect to the higher-order factor z was constructed as shown in Eq. 1,

$$A_{n\times n}=\begin{bmatrix} a_{11} & a_{12} & a_{1..} & a_{1n} \\ a_{21} & a_{22} & a_{2..} & a_{2n} \\ a_{..} & a_{..} & a_{..} & a_{..} \\ a_{n1} & a_{n2} & a_{n..} & a_{nn} \end{bmatrix} \quad (1)$$

Table 5. Judgment Matrix Scale

Scale	Meaning	Scale Legend
1	Equally important	Both factors are equally important for the specified attribute
3	Slightly more important	The former factor is slightly more important than the latter
5	Significantly more important	The former factor is significantly more important than the latter
7	Strongly more important	The former factor is markedly more important than the latter
9	Extremely important	The former factor is absolutely more important than the latter
2，4，6，8	Use when compromising	The midpoint value between two adjacent judgments

By integrating the professional judgements of multiple experts, the geometric mean method was employed to combine the judgement matrices constructed by each expert. This method effectively ensures the reliability of the consistency test for the final integrated matrix. The specific procedure involves taking the individual expert scoring matrices formed by the m experts participating in the evaluation (m = 1, 2, ..., k), multiplying the corresponding elements in each row and column, and then taking the mth root of the resulting product to obtain a unique comprehensive integrated judgement matrix. The specific mathematical formula is expressed as in Eq. 2,

$$\overline{A}=\left(\prod_{k=1}^{m} a_{ij}^{k}\right)^{\frac{1}{m}} \quad (2)$$

where $\overline{A}$ is represents a comprehensive integrated judgment matrix obtained by taking the m-th root of the product of corresponding elements from judgment matrices provided by multiple experts.

Based on the fundamentals of matrix theory, the geometric mean method (also known as the square root method) was employed to calculate the weights of the single decision matrix that has been established through expert consensus. This method has been proven in practice to offer a high degree of reliability and computational efficiency. The specific mathematical formula is given in Eq. 3,

$$W_i=\frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}} \quad , \quad i=1,2,3..,n \quad (3)$$

where W_i is the weight vector component obtained after normalizing the classical formula root method, showing the relative importance of each indicator in this layer compared to the corresponding factor in the upper layer.

Due to the inherent complexity of real-world problems and the inherent diversity of human cognition, experts find it difficult to specify an absolutely precise ratio between two factors; they can only make reasonable estimates based on experience. This inevitably leads to a certain degree of deviation between the values in the judgement matrix and the actual ratios that would exist under ideal conditions. Consequently, it is virtually impossible to ensure that the judgement matrix is entirely consistent.

The consistency ratio (CR) is widely adopted in academia as an objective standard for assessing the consistency of a judgment matrix; the CR is defined as the ratio of the consistency index (CI) to the random consistency index (RI) of the same order. When the calculated CR value is less than 0.1, this indicates that the decision matrix possesses an acceptable level of consistency and requires no adjustment; conversely, a team of experts must review and revise the original decision matrix until the final calculation meets the scientific requirement of CR < 0.1. The formulas are given in Eqs. 4 and 5,

$$CI=\frac{\lambda_{max}-n}{(n-1)} \quad (4)$$

$$CR=\frac{CI}{RI}=\frac{\lambda_{max}-n}{(n-1)RI}<0.1 \quad (5)$$

where the maximum eigenvalue is denoted by λ_{max}, and the decision matrix under examination is denoted by n. The calculation is shown in Eq. 6. The average random consistency index is denoted by RI; it is positively correlated with the order of the decision matrix, as shown in Table 6.

$$\lambda_{max}=\sum_{i=1}^{n}\frac{[\overline{A}W]_i}{nW_i} \quad (6)$$

RI stands for the average random consistency index, and its specific value is closely related to the order n of the decision matrix. The standard RI values corresponding to decision matrices of different orders are shown in Table 4. These values were determined through extensive random simulation experiments and provide a scientific reference standard for consistency testing.

Table 6. Average Consistency Index Table

Matrix order	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54

First, Table 7 presents the criterion-layer weights for three primary dimensions: color elements (C), pattern elements (P), and styling elements (S), calculated from the judgment matrix scored by experts. After calculating and ensuring that the judgment matrices constructed by the 10 experts all passed the consistency test (CR < 0.1), matrix aggregation was performed on the 10 judgment matrices according to Eq. 2. Using Eqs. 3, 4, 5, and 6, the weights and consistency for the resulting integrated judgment matrix were calculated, as shown in Table 7.

Table 7. Color Elements (C) — Shape Elements (S) Weight Calculation Result

	Weight	λ_{max}	CI	CR
Color Elements (C)	0.2387	3.087	0.044	0.085 < 0.1
Pattern Elements (P)	0.5125			
Styling Elements (S)	0.2488			

The consistency ratio CR of the C-P-S criteria-level judgment matrix is 0.085, which is below the commonly-accepted threshold value of 0.1 for AHP. Nevertheless, the value is close to the critical threshold, reflecting partial divergence in expert subjective preferences when comparing color, pattern and styling dimensions. We adopted geometric mean to aggregate multiple expert judgment matrices to mitigate individual subjective bias.

Next, the weights for the color elements (C), pattern elements (P), and form elements (S) were calculated separately. Using Eq. 2, matrix ensemble processing was applied to the 10 judgment matrices, all of which passed the consistency test (CR < 0.1). Based on Eqs. 3, 4, 5, and 6, the weights and consistency for the resulting judgment ensemble matrix were calculated; the results are shown in Tables 8 through 10.

Table 8. Color Element Judgment Matrix and Weights

(C)	C1	C2	C3	C4	Weight	λ_{max}	CI	CR
C1	1	1/2	0.32	0.25	0.0895	4.179	0.060	0.0674
C2	2	1	0.27	0.29	0.1259			
C3	3.13	3.68	1	0.36	0.2857			
C4	4	3.48	2.77	1	0.4989			

Table 9. Pattern Element Judgment Matrix and Weights

(P)	P1	P2	P3	P4	P5	Weight	λ_{max}	CI	CR
P1	1	1.43	1.96	3.03	1	0.2790	5.030	0.008	0.0071
P2	0.70	1	2.33	2.17	0.70	0.2181	λ_{max}	CI	
P3	0.51	0.43	1	0.87	0.35	0.1058	5.030	0.008	
P4	0.33	0.46	1.15	1	0.38	0.1057	λ_{max}	CI	
P5	1	1.43	2.83	2.61	1	0.2914	5.030	0.008	

Table 10. Shape Element Judgment Matrix and Weights

(S)	S1	S2	S3	Weight	λ_{max}	CI	CR
S1	1	1.35	1.32	0.3990	3.009	0.004	0.0077
S2	0.74	1	0.76	0.2716	λ_{max}	CI	
S3	0.76	1.32	1	0.3294	3.009	0.004	

Finally, weighted calculations were performed on each element of the indicator layer to determine the composite weights of the indicator layer; the results are shown in Table 11. The composite weight values of the indicator layer elements were ranked in Table 11; the results are shown in Fig. 1.

Table 11. Overall Weight of the Indicators

Level 1 Indicators	Relative Weight W1	Secondary Indicators	Relative Weight W2	Combined Weight W1*W2
Color Elements (C)	0.2387	Brown Glaze C1	0.0895	0.0214
		Green Glaze C2	0.1259	0.0301
		Yellow Glaze C3	0.2857	0.0682
		Blue Glaze C4	0.4989	0.1191
Pattern Elements (P)	0.5125	Intermingled-Glaze Textures P1	0.2790	0.1430
		Petal Patterns P2	0.2181	0.1118
		Grid Patterns P3	0.1058	0.0542
		Zigzag Patterns P4	0.1057	0.0542
		Composite Mixed Patterns P5	0.2914	0.1493
Styling Elements (S)	0.2488	Human and Animal Figures S1	0.3990	0.0993
		Architectural and Landscape Motifs S2	0.2716	0.0676
		Everyday Utensils S3	0.3294	0.0820

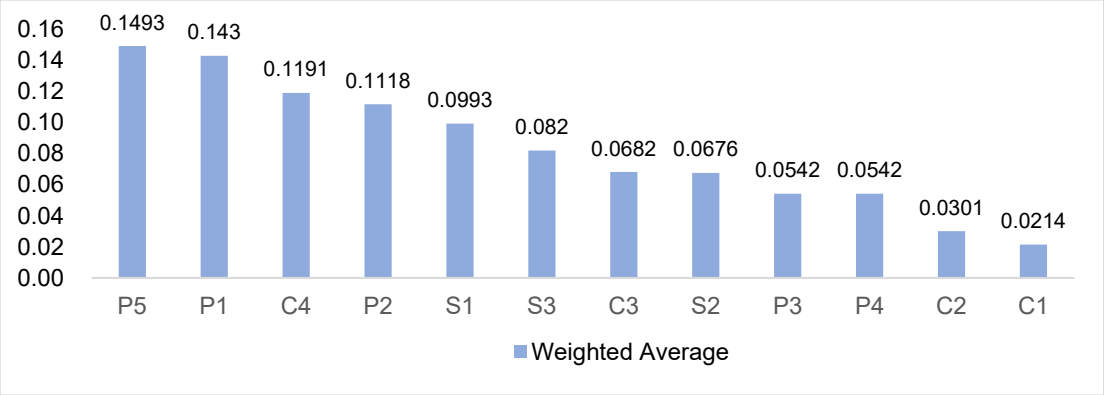


Fig. 1. Comprehensive weight ranking

RESULTS AND DISCUSSION

Design Proposal for Tang Sancai Cultural Elements

Based on the AHP weighting results, four distinctive cultural and creative design proposals were developed. These include a Silk Road "yao bian" mouse pad, wood pulp beverage packaging, a solid wood tabletop ornament, and a reproduction of traditional ceramics, providing examples for TOPSIS-based design optimization. The pattern generation process is shown in Fig. 2. It should be emphasized that the optimized wood-based cultural-creative schemes in this paper are mass-oriented popular derivatives. They inherit visual cultural elements from Tang-Sancai relics, but they cannot reach the unique craftsmanship and historical-cultural value of authentic ancient ceramic artifacts.

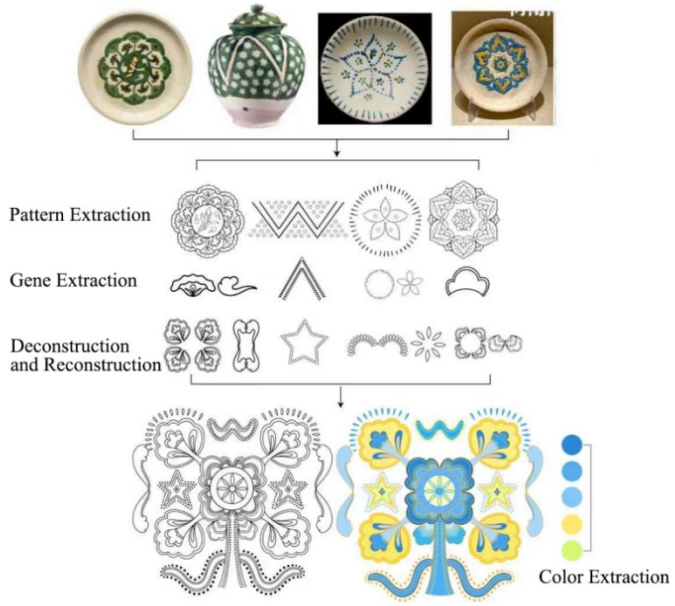


Fig. 2. Pattern generation process

Option 1: it serves as a visual-reference scheme; its substrate is not wood-cellulose material, and only its decorative surface adopts Tang-Sancai visual patterns for comparative evaluation. This mouse pad centers on a composite pattern of Tang Sancai motifs and the textural qualities of kiln-changed glaze, with blue glaze as the primary color, complemented by yellow, green, and brown glazes to enrich the visual depth. The design draws on the distinctive Composite Mixed Patterns of broken-line motifs paired with floral elements found on Tang Sancai artifacts, retaining the dynamic rhythm created by the diagonal composition. The complex kiln-change blurring effects of the original artifacts are moderately simplified to recreate the mottled texture resulting from the intermingling of glazes. The central composite motif is placed at the heart of the composition, while gradient kiln-change textures spread across the four corners. A minimalist grid pattern along the edges provides a visual conclusion. During the design process, the intricate and minute decorative details of ancient porcelain were simplified, and the saturation of the glaze colors was moderately softened to recreate the natural kiln-change artistic effects of Tang Sancai on a modern medium. The work integrates the cultural aesthetics of the Silk Road during the High Tang period, eschewing the approach of directly replicating figurines and animal-shaped vessels, and is adapted for use in home and office settings. This pattern set can be further developed into a series of wood-based desktop cultural and creative products.



Fig. 3. Option 1: Tang Sancai composite pattern mouse pad

Option 2 is a wood pulp-based beverage packaging design using modified wood pulp cellulose as the base material. The wood-pulp beverage-packaging scheme (Option 2) draws on materials from the well-established beverage-carton industry. Commercially available beverage cartons are predominantly manufactured from bleached kraft pulp fibers, in which lignin components have been chemically removed during pulping. In practical industrial production, the paperboard substrate is typically laminated on both sides with polymer films, mainly consisting of polyethylene layers together with additional optional transparent functional layers for barrier-property improvement. The present conceptual design adopts this mature substrate system as the material foundation for cultural-pattern printing. Wood pulp is renewable, biodegradable, printable, and suitable for large-scale industrial production. The design prioritizes petal patterns and M/W-type mixed geometric patterns screened for wood-based printing, using blue glaze and yellow glaze as the primary colors for flat printing. For complex kiln-change glaze textures, the design simplifies these patterns, forgoing multi-layered glaze effects difficult to replicate on wood pulp paper, instead using color-separated printing to simulate blending glazes. The composition balances packaging functions with traditional cultural expression, tailoring pattern layout to folding and die-cutting requirements. While ensuring visual distinctiveness, it leverages the low-carbon, eco-friendly advantages of wood-based materials, making it a core wood-based cultural and creative solution for mass production. Figure 4.



Fig. 4. Option 2: Beverage packaging made from wood pulp paper

Conceptual render of the wood-pulp beverage-packaging scheme (Option 2). It should be noted that this is a cultural-adaptation conceptual prototype rather than a final

commercial production version. In real-world industrial applications, brand logos, product ingredient labels and mandatory regulatory information will occupy partial surface area. Layout partitioning strategies are required to balance cultural decorative motifs and commercial-mandatory printing contents.

Option 3 is a design for a solid wood tabletop ornament that uses modified solid wood panels as the base material, fully leveraging the craft characteristics of the solid wood substrate—namely, its suitability for carving, spray painting, and printing. The classic animal forms of Tang Sancai horses and camels are simplified into flat silhouettes, omitting the complex facial features and clothing details typical of figurines. Paired with high-contrast Composite Mixed Patterns and a blue glaze as the primary color, the design employs a combination of surface printing and spot spraying on the panels to simulate the glaze effects of Tang Sancai. Due to the inherent limitations of solid wood panels, this proposal can effectively reproduce flat patterns with clear lines but struggles to replicate the complex, multi-layered kiln-change and flowing textures of the original ceramics; the color transparency is less pronounced than that of ceramic glazes. This proposal is better suited for small-batch, mid-to-high-end cultural and creative product development; however, due to the high cost of panel processing, it is not suitable for large-scale, widespread application.



Fig. 5. Option 3: Solid wood Tang Sancai silhouette desk ornament

Option 4 involves the reproduction of traditional ceramics for cultural and creative products. As the control group, this option fully replicates the form of the Tang Sancai camel figurine and the multi-layered, kiln-transformed glaze texture. The ceramic firing process fully reproduces the original artifacts' rich glaze color layers and flowing, blurred texture, achieving the highest visual fidelity; however, it is energy-intensive, and the finished products have a certain defect rate.

The products are relatively heavy, do not biodegrade naturally, and involve high mass production and transportation costs. They do not align with the research objectives for green, sustainable wood-based cellulose materials and serve as the traditional medium control group for comparative evaluation.



Fig. 6. Tang Sancai camel figurine ceramic replica cultural and creative product

Optimizing Design Options

The four design proposals mentioned above were incorporated into the TOPSIS comprehensive evaluation system. The evaluation indicator system consists of two parts. The 12 cultural factor indicators were adopted for TOPSIS evaluation. Material-related properties including biodegradability, printing fidelity, cost and lightweighting were considered as pre-screening constraints in scheme design phase, rather than direct evaluation indicators of the TOPSIS matrix, to form a complete research framework. A total of 10 experts from the fields of archaeology, product design, and wood processing were invited to score the four design proposals. Scoring was based on a 0 to 10 point scale, with higher scores indicating superior performance of the proposal on the corresponding indicator. The initial scores for each indicator are shown in Table 12.

Table 12. Initial Evaluation Matrix

Evaluation Criteria	Option 1	Option 2	Option 3	Option 4	Sample Evaluation
C1	4.8	5.10	3.70	4.20	3.90
C2	5.00	5.20	4.40	4.30	4.00
C3	4.80	4.10	4.20	4.50	4.30
C4	5.10	4.30	3.90	4.10	3.80
P1	5.10	6.00	4.30	4.00	4.10
P2	4.00	5.10	4.40	5.10	4.20
P3	3.90	5.40	4.10	4.50	4.00
P4	3.80	5.50	4.20	4.70	4.10
P5	4.10	5.20	4.60	4.90	4.30
S1	3.90	5.80	4.00	4.20	3.80
S2	4.00	5.00	4.30	4.60	4.10
S3	4.10	5.10	5.90	4.50	5.00

Supplementary note: Expert individual scores were aggregated via arithmetic mean; scoring rubric ranges from 0 to 10 (0 = poorest cultural-factor adaptability, 10 = best cultural-factor adaptability). Raw scores for the "Sample Evaluation" column are listed in this table. The weights used for weighted-TOPSIS calculation originate from Table 11.

The positive ideal solution, negative ideal solution, and relative proximity for each scenario were calculated separately, following the specific steps outlined below.

First, the ratings from the 10 experts were averaged to convert the survey results into an initial rating matrix F, as shown in Table 12. The initial rating matrix was standardized as shown in Eq. 7,

$$R_{ij} = {F_{ij}}\Big/{\sqrt{\sum_{i=1}^{m} F_{ij}^2}} \qquad i = 1,2,\cdots,m;\ j = 1,2,\cdots,n \tag{7}$$

where R_{ij} is the standardized multi-indicator evaluation matrix obtained after experts score it under the TOPSIS method, which was used for multi-dimensional comprehensive evaluation of each cultural and creative plan.

Using the target weights W_J of each evaluation indicator, the weighted normalization matrix Z_{ij} was calculated as shown in Equation (8).

$$Z_{ij} = W_j R_{ij} \qquad i = 1,2,\cdots,m;\ j = 1,2,\cdots,n \tag{8}$$

The positive ideal solution Z^+ and the negative ideal solution Z^- were computed as shown in Eqs. 9 and 10,

$$Z^+ = (Z_1^+, Z_2^+, \cdots Z_n^+) \tag{9}$$

$$Z^- = (Z_1^-, Z_2^-, \cdots Z_n^-) \tag{10}$$

The Euclidean distance was used to calculate the distance of each solution from the ideal solution, where D_i^+ represents the distance to the positive ideal solution and D_i^- represents the distance to the negative ideal solution. From this, the relative proximity C_i of each solution to the ideal solution is determined, as shown in Eqs. 11 through 13,

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (Z^+ - Z_{ij})^2} \tag{11}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} (Z^- - Z_{ij})^2} \tag{12}$$

$$C_i = {D_i^-}\Big/{D_i^+ + D_i^-} \tag{13}$$

Finally, the priority of each design scheme was determined by calculating the value of C_i; a larger C value indicates that the scheme is closer to the optimal solution. As shown in Table 13, Scheme 2 was the optimal solution. Among the four design schemes generated using the AHP (Analytic Hierarchy Process), the sample scheme ranked the lowest, demonstrating that the design translation practice of Tang Sancai cultural factors proposed in this study had good application potential in terms of analytical methods.

Table 13. Positive and Negative Ideal Solutions and Relative Closeness

Evaluation Criteria	Optimal Solution Distance D_i^+	Negative Ideal Solution Distance D_i^-	Relative Proximity C	Sort Results
Option 1	4.044	2.369	0.389	2
Option 2	1.330	4.605	0.773	1
Option 3	3.905	2.062	0.310	4
Option 4	3.596	2.071	0.347	3
Evaluation Samples	4.426	1.044	0.159	5

Analysis of Evaluation Results and Comparison of Carriers

This work provides a quantitative factor-decoding paradigm for developing affordable, mass-produced wood-based cultural-creative derivatives inspired by Tang-Sancai heritage, rather than replicating antique ceramic relics. The TOPSIS calculation results show that the wood pulp-based beverage packaging offers the best

overall suitability. This solution not only preserves the core cultural and visual characteristics of Tang Sancai but also fully leverages the material advantages of wood cellulose substrates—including low carbon footprint, ease of printing, and suitability for mass production—striking a balance between the expression of traditional culture and the use of eco-friendly materials. It is the design solution with the highest overall value. It should be noted that the wood-pulp beverage-packaging scheme shown in Fig. 4 is a conceptual design focusing on cultural-factor adaptability evaluation. For real commercial launch, large-format brand logos, product-specification descriptions and statutory labelling information will take up part of the packaging surface. To mitigate interference with Tang-Sancai visual effects, partition-based layout could be adopted. The idea is to assign dedicated areas for commercial and regulatory text, while reserving relatively independent display zones for Tang-Sancai decorative motifs. This partition layout provides a feasible way to reconcile cultural-heritage visual expression and daily commercial-packaging requirements.

The solid wood tabletop ornament received a moderate overall score. While solid wood offers excellent texture, limitations in processing costs and the ability to replicate glaze colors and textures mean it is suitable only for small-scale cultural and creative product development. The Silk Road kiln-change mouse pad has good visual appeal, but since its substrate is not a wood-cellulose material, it is included solely as a visual reference sample. Although traditional ceramic reproductions demonstrate the strongest ability to reproduce glaze colors and textures, they scored very low on environmental performance, lightweight design, and production cost metrics, resulting in the poorest overall evaluation. The ranking mainly reflects the performance of schemes on 12 Tang-Sancai cultural-factor indicators. Material-science properties such as biodegradability, printing fidelity, cost and lightweighting have been taken into account during scheme design and screening. Different from other wood-related proposals, Option 1 (mouse pad) acts purely as a visual-reference control: its substrate is not wood-cellulose, and only the pattern effect is included for comparative evaluation of cultural-factor adaptability.

A comparison of ceramic and wood-based cellulose substrates shows ceramics excel in reproducing complex Tang Sancai kiln-change effects, such as flowing and multi-layered glaze fusion, with color gradation and translucency that wood-based materials find difficult to achieve. However, ceramics have notable drawbacks: high energy consumption, non-biodegradability, heavy weight, and high mass production costs. Wood-based cellulose materials, represented by wood pulp and solid wood panels, are renewable, biodegradable, lightweight, versatile in processing, and cost-controllable for mass production, aligning better with green cultural and creative industry trends. However, constrained by ink absorption and surface coating processes, wood-based materials are suitable only for simplified, regular two-dimensional patterns; the complex kiln-change and blurring textures of the original artifacts cause varying degrees of visual information loss.

When translating Tang Sancai cultural elements into wood-based cultural and creative products, one cannot directly replicate all visual effects of the original ceramic artifacts. Instead, cultural elements must be selected, simplified, and reconstructed, prioritizing high-weight factors such as blue glaze, Composite Mixed Patterns, and petal motifs—well-suited to wood-based printing processes—while moderately simplifying complex kiln-change textures and intricate three-dimensional forms. This balances cultural authenticity with the technical limitations of wood-based materials. The TOPSIS evaluation results in this chapter also validate the rationality of the AHP cultural factor

screening process described earlier, demonstrating that this research workflow—comprising "factor extraction," "weighted evaluation," and "multi-medium optimization"—can effectively guide the adaptation of Tang Sancai culture into cultural and creative products on wood-based cellulose substrates.

Strengths and Limitations of the Study

This paper focuses on decoding and translating Tang Sancai cultural factors. Using AHP and TOPSIS, it establishes a framework for extracting, evaluating, designing, and selecting traditional cultural factors tailored to wood-based materials. The study's strengths are threefold. First, it breaks from conventional Tang Sancai research focused solely on ceramic media by incorporating printing characteristics, forming constraints, and environmental attributes of wood-based substrates into factor screening and design evaluation. This enables quantitative cross-comparison between ceramic and wood-based media, addressing the lack of quantitative evaluation methods for translating ceramic intangible cultural heritage visual symbols onto wood-based materials. The findings provide a reusable analytical paradigm for developing low-carbon, wood-based cultural products. Second, the study synthesized expert opinions from archaeology, design studies, and wood processing, using AHP to calculate the weights of Tang Sancai's color, pattern, and form factors. This distinguishes the suitability of different visual elements for wood-based substrates, preventing design from relying solely on subjective experience. Finally, by evaluating four comparative designs—mouse pads, wood pulp beverage packaging, solid wood ornaments, and ceramic reproductions—using TOPSIS, the study validated the feasibility of applying core cultural factors such as Composite Mixed Patterns and blue glaze to wood-based products. It identified wood pulp paper-based packaging as the optimal product direction, with conclusions possessing direct practical value.

This study still has certain limitations. At the material level, design and evaluation were limited to wood pulp paper and standard modified solid wood panels; new wood-based materials such as modified cellulose composites and wood-based 3D printing were not included, nor was their potential to replicate kiln-change glaze textures explored. Process variables such as surface coloring and lamination were not treated as independent control variables, and color reproduction differences resulting from various printing and spraying techniques require further investigation. In terms of cultural samples, the Tang Sancai samples primarily originated from major excavation sites in Henan, Hebei, and Shaanxi. The scope was somewhat limited, and niche regional Sancai decorative elements were not included in the factor extraction system. In terms of evaluation dimensions, expert scoring carries a certain degree of subjectivity. Future work could incorporate objective physicochemical test data from color difference tests and printed physical samples to reduce subjective bias in the evaluation system. Another practical difference between Tang-Sancai ceramic relics and wood-based printed prototypes lies in color stability. The enduring colors of Tang-Sancai originate from high-temperature-fired inorganic metal-oxide pigments within glaze, which deliver excellent light-fastness for long-term display. By contrast, the visual patterns on wood-based and mouse-pad-style schemes in this study are realized via printing inks. Commercially available jet-printing inks generally have lower fade-resistance under prolonged indoor ambient light, *e.g.* daily window-side illumination as shown in Fig. 3. Potential color fading should be considered for products intended for semi-permanent indoor display. Color fastness and anti-fading performance testing are beyond the scope of the present research, which focuses on cultural-factor adaptability evaluation. Future work could select high-light-fastness printing materials or

surface protective coating processes to mitigate fading risks for long-term-display-oriented cultural-creative products.

Given the limitations of this study, future research can be expanded in two directions. On the one hand, integrating surface modification processes for modified wood cellulose substrates, physical prototyping tests can investigate process parameters' impact on the color reproduction of Tang Sancai kiln-change textures, enhancing the wood-based carrier's ability to reproduce complex ceramic visual textures. On the other hand, Tang Sancai artifact collection should be expanded to include more artifacts excavated from various regions, enriching the cultural factor database. At the same time, physicochemical testing indicators should be introduced to establish a comprehensive evaluation system combining subjective assessment with objective material testing, promoting the more scientific and diverse application of traditional ceramic intangible cultural heritage in wood-based cultural and creative products. Looking ahead, future development of Tang Sancai-inspired cultural creative products could follow a "two-pathways" approach. The first pathway relies on low-cost, mature industrial manufacturing technologies, embedding Tang Sancai colors and decorative patterns into mass-produced affordable commodities such as beverage packaging. This pathway prioritizes popularization and market accessibility, yet is constrained by existing industrial substrate and printing conditions. The second pathway targets hand-finished or limited-run "art-object-style" products, such as high-end display-oriented special gifts. This pathway opens more possibilities for exploring innovative material selection and multi-material composite combinations, pursuing higher artistic expression for Tang Sancai heritage. Our present study mainly focuses on the first mass-oriented pathway; further research is needed to establish evaluation frameworks suitable for the art-object-oriented development pathway.

Prospects for Future Research

This study achieved quantitative evaluation and design translation of Tang Sancai cultural elements on wood-cellulose-based substrates; however, due to limitations in sample conditions and processing parameters, many areas warrant further exploration. At the material and process level, future research could focus on modified wood-based composites, chemically modified wood pulp, and wood-based 3D printing materials. Techniques such as surface coating modification and specialized ink printing could improve ink adsorption properties, allowing attempts to reproduce complex glaze textures of Tang Sancai, thereby narrowing the color reproduction gap between wood-based and ceramic substrates. Physical test samples can also be prepared, and physicochemical testing — such as color difference meters and surface topography analysis — can characterize pattern and color reproduction. Incorporating objective material test data into the evaluation model can mitigate bias from subjective expert scoring. In terms of cultural resource exploration, future work could expand Tang Sancai sample collection to include niche artifacts from different regions and periods, expanding the cultural factor database and uncovering regional decorative patterns and color systems. Furthermore, the evaluation framework is versatile. The research paradigm—"AHP/TOPSIS cultural factor decoding combined with wood-based substrate compatibility evaluation"—can be adapted to other intangible cultural heritage visual resources, such as painted pottery, lacquerware, and ancient murals. This will enable exploration of translation patterns of traditional artistic symbols onto wood-based cellulose substrates, expanding research boundaries of eco-friendly wood-based cultural and creative products. At the industrial implementation level,

future work can incorporate consumer preference surveys to supplement the evaluation system with user perceptions, market costs, and audience demands. This will establish a complete chain spanning cultural decoding, material adaptation, and market application, enabling research findings to better align with product development, and providing theoretical and practical support for enterprises developing low-carbon, intangible cultural heritage-inspired wood-based products.

CONCLUSIONS

1. The results indicate that wood the pulp-based beverage packaging prototype offered the best overall adaptability, successfully balancing the visual expression of Tang Sancai culture with the material advantages of wood. Although ceramic substrates excel at reproducing glaze color and texture, they suffer from high energy consumption, non-biodegradability, and high mass production costs. Ordinary solid wood panels are suitable for small-batch cultural and creative product development but have limited capacity to replicate complex kiln-change patterns. Within the present evaluation framework oriented toward mass-producible wood-based cultural-creative transformation, the wood-pulp beverage packaging scheme achieved higher comprehensive proximity scores than the ceramic replica (Option 4). It should be emphasized that wood-pulp packaging and ceramic replicas serve fundamentally different functions and target distinct audiences in real-world applications. Printing decorative patterns on paper-board substrates is technically less complex than manufacturing three-dimensional ceramic artifacts. Nevertheless, both categories of products possess irreplaceable practical and cultural value in modern society. The scoring ranking only reflects performance under this specific evaluation goal, and cannot be generalized as an overall value judgment between wood-based and ceramic Tang-Sancai derivatives.
2. The study confirmed that when applying traditional ceramic intangible cultural heritage visual symbols to wood-based cultural and creative carriers, visual information cannot be directly replicated; cultural elements must be selected, simplified, and reconstructed according to the technical characteristics of wood-based materials (Yuan and Chai 2019).
3. The research process outlined in this paper fills a gap in quantitative research on the translation of traditional ceramic cultural symbols in the field of wood-based cultural and creative products.
4. The study provides new insights for the contemporary development of Tang Sancai cultural and creative products and offers a reference research paradigm for transforming other traditional intangible cultural heritage visual resources onto wood-based sustainable materials.

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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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