Application Evaluation and Design Translation of Modified Agroforestry Biomass-based Materials in Rural Homestay Interiors in Northern China

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To address insufficient regional cultural expression and experience-dependent material selection in rural homestays in Northern China, this study evaluates the application and design translation of modified agroforestry biomass-based materials. An integrated decision-making framework combining analytic hierarchy process (AHP) and multi-criteria evaluation was developed to link material attributes, user demands, and interior applications. The study focuses on furniture, spatial interfaces, and integrated interior environments, excluding building structural renovation and envelope thermal performance. An integrated AHP-based decision-making framework was developed across four dimensions: agroforestry biomass substrate, functional performance, local aesthetics, and comprehensive adaptability. The results support a shift from experience-driven selection to data-informed decision-making as a means to identify tourists' sensory comfort and local raw material accessibility as key considerations for design application.

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INTRODUCTION

Against the global backdrop of addressing climate change, the low-carbon transformation of rural spaces has become a vital component of national strategies. Northern China is endowed with abundant agroforestry biomass resources. These resources have potential environmental value and distinctive rural textures, while carrying unique regional cultural genes (Ma *et al*. 2026). However, choosing how to conduct engineered modification of these biomass resources remains a critical research challenge. Such modification should not only satisfy the material stability requirements of Northern rural interior environments but also maintain aesthetic continuity in spatial design. This issue represents an interdisciplinary challenge between decorative space studies and bio-based materials engineering.

Existing studies have accumulated substantial empirical experience regarding modification processes of biomass materials and performance evaluation of modified timber, yet research on decision-making for the application of biomass materials in specific tourism spaces remains insufficient. During the actual modification and design of rural homestays, designers are often confined to intuitive perception or engineering experience, lacking a scientific, quantifiable auxiliary decision-making system (Shen *et al*. 2024). Such an "experience-driven" material selection model results in a dual dilemma: after applying

biomass materials to many homestay spaces, the expected physical stability fails to materialize, alongside mismatched functional adaptation and loss of cultural connotations.

Current academic discussions on rural homestay spatial design mostly have focused on a single dimension of spatial planning or cultural translation. They seldom have addressed the quantitative coupling mechanism linking "material performance – process adaptability – users' psychological perception". Significant gaps persist in existing research when handling multi-objective constraints and constructing complex evaluation index systems, with a lack of effective mathematical models to eliminate subjective fuzziness in design decision-making. This creates long-term separation and dislocation between material selection, market demand, and spatial experience (Wang *et al.* 2026). For this reason, bridging the aforementioned separation of "materials – processes – perception" and establishing systematic, scientific selection decision-making has become a critical scientific issue requiring urgent resolution. In this study, rural homestays refer to small-scale tourism accommodation spaces that rely on rural natural environments and regional cultural resources, provide short-term lodging services through local residents or operating entities, and express regional characteristics through interior spatial design.

Introducing multi-criteria decision-making methods has become a mainstream academic consensus for resolving complex material selection challenges at the intersection of agroforestry bio-based materials and spatial design (Milošević *et al.* 2020). Among these methods, the Analytic Hierarchy Process (AHP) is widely adopted in ecological building material assessment and spatial performance optimization due to its rigorous mathematical logic when handling qualitative and quantitative multi-objective complex systems (Mohamed and Marzouk 2025). Against this backdrop, this paper constructs an interdisciplinary decision-making framework for the application of modified biomass materials, systematically incorporating four multi-dimensional evaluation index dimensions: agroforestry biomass substrate, physical modification performance, local aesthetic value, and comprehensive functional adaptability. Through constructing judgment matrices and conducting rigorous consistency tests, the framework effectively reduces overreliance on subjective experience in traditional decision-making, accomplishing a scientific transition from qualitative sensory judgment to rigorous quantitative decision-making (Sun *et al*. 2024). This opens a scientific path balancing ecological performance and cultural narration for engineered remodeling of biomass resources and sustainable design of rural homestays in Northern China (Li and Puntien 2025). Existing studies have mainly focused on the modification processes and performance evaluation of biomass materials, while decision-making approaches for their application in specific rural spatial environments remain insufficient. Therefore, this study constructs an integrated decision-making framework based on AHP and multi-criteria evaluation.

From the perspective of material application, the relatively large variations in temperature and humidity in Northern China require interior furniture and interface materials to have adequate dimensional stability and processing adaptability. Therefore, temperature deformation adaptability was incorporated into the functional performance evaluation system in this study. However, this study did not directly conduct experiments on material dimensional stability or processing performance, and these properties require further verification through material testing in future research.

EXPERIMENTAL

This study constructed a scientific design decision-making framework integrating the sequence of "questionnaire survey – Analytic Hierarchy Process – multi-criteria expert evaluation". In this study, the questionnaire survey was not directly used for AHP weight calculation but was employed for preliminary demand identification and evaluation index selection. By categorizing and analyzing tourists' feedback regarding homestay spatial experiences, material perceptions, and cultural demands, an initial set of evaluation indicators was established. Subsequently, the final AHP evaluation system was developed through integration with relevant studies and expert revisions. First, questionnaire surveys were adopted to obtain first-hand quantitative data based on tourists' perceived value of Northern rural culture, biomass aesthetics, and homestay spatial comfort, laying perceptual support for the construction of the evaluation index system. Second, AHP was adopted as the core quantitative tool. Complex rural cultural tourism elements were scientifically categorized into four sub-criterion layers: agroforestry biomass substrate (Y_1), functional performance (Y_2), local aesthetics (Y_3), and comprehensive adaptability (Y_4). Judgment matrices were built and consistency tests performed to accurately determine weight allocation of each factor, guiding the prioritized application of modified biomass-based materials in spatial design.

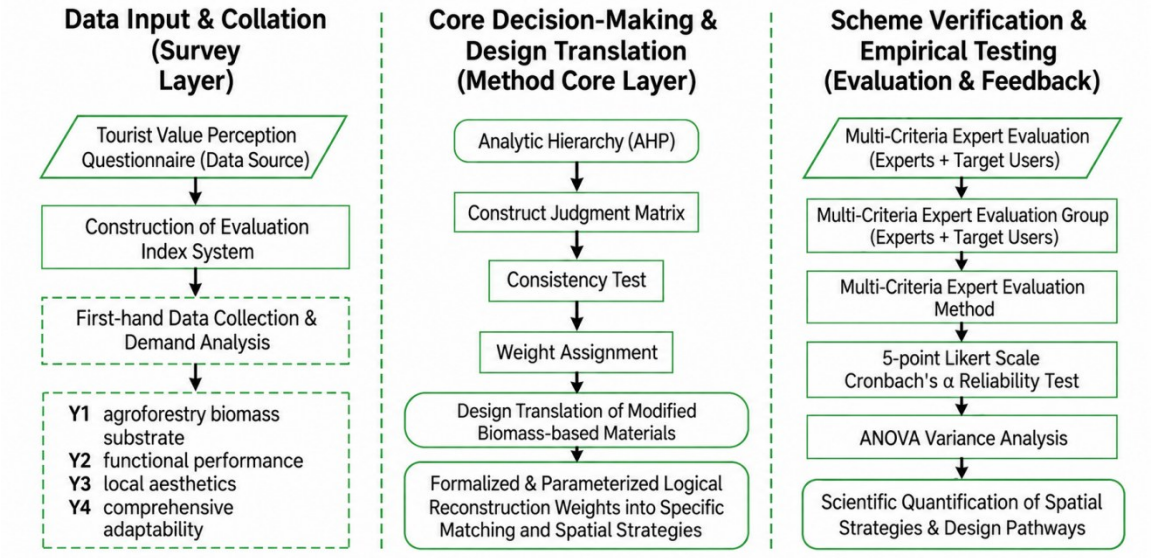


Fig. 1. Research framework flowchart

Finally, after design strategy generation, the multi-criteria expert evaluation method was adopted. A design strategy evaluation group consisting of experts and target homestay users conducted blind evaluation using the 5-point Likert scale. Through Cronbach's α coefficient and one-way analysis of variance (ANOVA), the design pathway was empirically validated across multiple dimensions, including custom furniture adaptability, tourists' sensory comfort, low-carbon recyclability, uniqueness of rural textures, accessibility of local raw materials, and interior design integration (Fig. 1).

Research Logic

The questionnaire survey, AHP evaluation, and design strategy development in this study constitute three consecutive but functionally distinct research stages.

The first stage is the demand identification stage. The questionnaire survey was used to identify tourists' primary concerns regarding the ecological attributes of materials, spatial experience, regional cultural expression, and functional adaptability in rural homestay environments. The questionnaire data were not directly used to calculate the AHP weights.

The second stage is the indicator construction and weight analysis stage. Based on the concerns identified through the questionnaire, and in combination with relevant literature and expert revisions, an AHP evaluation system was established comprising four criterion layers: agroforestry biomass substrate, functional performance, local aesthetics, and comprehensive adaptability. Experts then conducted pairwise comparisons to construct judgment matrices and calculate the weights of each indicator.

The third stage is the design translation stage. According to the ranking of the comprehensive AHP weights, the high-weight indicators were translated into specific design requirements, which were further developed into three material application strategies at the furniture level, spatial-interface level, and integrated interior level.

Therefore, the questionnaire results were not directly transformed into the three design strategies. Instead, a continuous methodological chain was established: questionnaire-based demand identification–AHP weight determination–key indicator extraction–design strategy development.

RESEARCH PROCESS

Survey Design

To ensure that the constructed evaluation index system accurately reflects actual market demand and tourists' real perceptions, this assessment evaluated the value perceptions of the new-generation tourists dominated by post-90s cohorts regarding homestay experiences. The survey participants in this study mainly consisted of tourists with prior rural homestay experience. The questionnaire focused on the perceived value of applying modified agroforestry biomass-based materials in homestay spaces, covering four aspects: ecological attributes of materials, spatial visual experience, regional cultural identity, and functional requirements. The questionnaire data were used to identify key factors influencing tourists' perceptions and provide a foundational basis for the subsequent construction of the AHP evaluation index system.

A rigorous questionnaire survey and field investigation were conducted in this study. The preliminary questionnaire was designed around four dimensions, including material ecological attributes, spatial visual experience, cultural identity, and functional requirements. High-frequency factors were categorized and integrated to establish the Y_1–Y_4 evaluation dimensions. The primary objective of the survey was to obtain tourists' value preferences regarding rural homestays in Northern China, thereby providing empirical support for the identification and refinement of the AHP evaluation indicators.

A total of 398 questionnaires were distributed, with 351 valid responses recovered. The sample covered new-generation tourists primarily born in the 1990s, whose age, education, and travel frequency distributions align with core consumer characteristics of current rural homestays in Northern China, which supports the representativeness of the subsequent data analysis. Statistical analysis revealed an overall Cronbach's α coefficient of 0.872, indicating excellent overall reliability and confirming measurement reliability of survey data (Fig. 2).

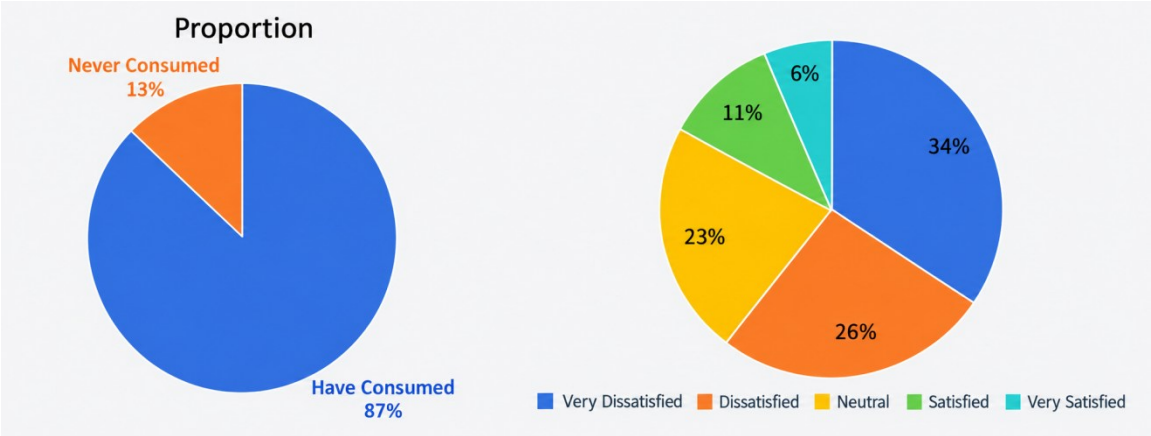


Fig. 2. Results of market survey and sample characteristic data

Empirical assessment based on the survey was used to identify prominent efficiency gaps in current spatial and furniture configuration of rural homestays in Northern China, manifested as systematic imbalance across four core dimensions:

1. Insufficient linkage between agroforestry biomass substrate and raw material accessibility leading to lack of emotional resonance;
2. Deficient functional performance (*e.g.*, temperature deformation resistance and mechanical load compliance for Northern climates) causing failure to adapt to harsh local climatic conditions;
3. Absent expression of local aesthetics (*e.g.*, Northern folk patterns and natural texture tactility) resulting in disconnection from regional cultural context;
4. Systematic spatial maladjustment in comprehensive adaptability (Spatial furniture adaptability; Interior visual coordination; Tourists' sensory comfort).

The above bottlenecks clarify the innovation orientation for materials. The above findings indicate that the application of modified agroforestry biomass-based materials in rural homestays should consider both material adaptability and regional cultural expression. This provides a basis for integrating material selection, spatial function, and local cultural characteristics in subsequent design applications. This enables ecological reconstruction of indoor spaces while deeply coupling functional evolution and brand-driven high-quality requirements of rural homestays in Northern China.

To reduce the bias caused by researchers' subjective judgments during the selection of evaluation indicators, a preliminary survey was conducted before the formal AHP evaluation to identify tourists' primary concerns regarding rural homestay spatial experiences. The questionnaire focused on four aspects: material cognition, spatial experience, cultural perception, and functional requirements. Tourists' key concerns were identified through importance ratings and open-ended feedback.

The results of the questionnaire were systematically summarized and analyzed. The findings indicated that tourists' evaluations of rural homestay spaces mainly focused on material ecological value, regional cultural expression, spatial comfort experience, and furniture functional adaptability. Among these factors, "environmental attributes" and "resource recycling" reflected tourists' concerns regarding the ecological value of materials and were therefore categorized into the agroforestry biomass substrate dimension. Factors such as "natural textures" and "regional characteristics" represented the cultural expression value of materials and were incorporated into the local aesthetics dimension. Factors including "spatial comfort" and "overall coordination" reflected tourists' spatial

experience requirements and were assigned to the comprehensive adaptability dimension (Table 1).

Table 1. Mapping of Questionnaire Factors and AHP Indicator

Tourist Concern Factors	Code	Indicator
Environmental attributes	Y14	Low-carbon recyclability
Natural textures	Y12	Uniqueness of rural textures
Spatial comfort	Y44	Tourists' sensory comfort

By integrating relevant literature and expert opinions, four criterion layers were ultimately established: agroforestry biomass substrate (Y1), functional performance (Y2), local aesthetics (Y3), and comprehensive adaptability (Y4). A corresponding sub-indicator system was further developed.

Hierarchical Classification of Evaluation Indices

The AHP constitutes a classic quantitative method for resolving multi-criteria complex decision-making problems; it is capable of addressing the challenge that non-quantified design judgments cannot be precisely evaluated during modernization transformation of traditional wood-based craftsmanship (Yang *et al*. 2023). Regional cultural expression was also incorporated into the evaluation system to reflect the local aesthetic and cultural characteristics of rural homestays in Northern China.

Following the core AHP logic proposed by Saaty (1990), this study constructed a three-level hierarchical evaluation system: target layer, criterion layer, and index layer. To fully reflect local resource characteristics of rural areas in Northern China and reasonably build a demand hierarchy model for rural homestay design strategies, multiple factors including forest resource characteristics, regional ecological environments, agroforestry product attributes, and local cultural landscapes must be fully considered. Relevant material attributes identified from previous studies were organized within the AHP hierarchy, and the AHP was adopted to hierarchically organize biomass material resources. Unlike traditional AHP applications in material performance evaluation, this study focused on the comprehensive application decision-making of modified agroforestry biomass-based materials in rural homestay spaces.

By establishing a cross-scale evaluation relationship among material attributes, spatial applications, and user experience, the proposed approach enhances the interpretability of design decisions. Biomass resources in rural Northern China were categorized into four primary elements: agroforestry biomass substrate (Y1), functional performance (Y2), local aesthetics (Y3), and comprehensive adaptability (Y4). Each category was further subdivided to complete systematic segmentation of sub-element layers (Table 2).

The four criterion-level indicators presented in Table 2 were developed through theoretical synthesis based on previous studies related to biomass material applications, interior spatial design, and rural environmental evaluation. Specifically, considering the key influencing factors of modified agroforestry biomass-based materials in rural homestay applications, the evaluation dimensions were classified into four aspects:

Table 2. AHP Hierarchical Structure Table

Element Layer	Sub-element Layer
Y1 Agroforestry Biomass Substrate	Y11 Local Raw Material Accessibility; Y12 Uniqueness of Rural Textures; Y13 Modification Adaptation Potential of Materials; Y14 Low-Carbon Recyclability
Y2 Functional Performance	Y21 Mechanical Load Compliance; Y22 Temperature Deformation Resistance for Northern Climates; Y23 Material Environmental Safety; Y24 Convenience of Custom Processing
Y3 Local Aesthetics	Y31 Natural Texture Tactility; Y32 Expression of Northern Folk Patterns; Y33 Coordination with Rural Color Tones
Y4 Comprehensive Adaptability	Y41 Spatial Furniture Adaptability; Y42 Spatial Visual Coordination; Y43 Cultural Integration; Y44 Tourists' Sensory Comfort

(1) Agroforestry Biomass Substrate (Y1) characterizes the material source attributes and resource utilization value, with a focus on the availability, recycling potential, and ecological value of agroforestry biomass resources.

(2) Functional Performance (Y2) evaluates the fundamental application capabilities of modified biomass-based materials for interior applications, including mechanical performance, environmental adaptability, and processing performance.

(3) Local Aesthetics (Y3) reflects the relationships among materials, regional culture of Northern rural areas, natural textures, and spatial visual expression.

(4) Comprehensive Adaptability (Y4) evaluates the application performance of materials within specific homestay spaces, including furniture application, spatial coordination, and tourists' experience.

The four criterion-level indicators correspond respectively to four key dimensions: "material source–material performance–cultural expression–spatial application," forming a progressive evaluation structure from material attributes to spatial experience.

Construction of Judgment Matrices

Within judgment matrix construction, the importance ratio of factor a_i relative to factor a_j is denoted r_{ij}; the inverse comparison is expressed as $1/a_{ij}$. This study adopted integers 1 to 9 and their reciprocals as scale values to conduct pairwise comparative judgment of evaluation indices including material performance and local cultural attributes. A description of matrix scales is presented in Table 3.

To improve the objectivity of AHP judgment matrix construction, this study established an AHP expert evaluation group consisting of 32 experts from materials science, architectural design, and interior environmental art. The experts conducted pairwise comparisons of the evaluation indicators to construct the judgment matrices. Specialists scored the application performance, environmental adaptability, and cultural expressiveness of modified agroforestry biomass-based materials in homestays for element and sub-element layers. Pairwise comparative analysis of each index was conducted based on specialist scoring results, weight values for each modified strategy and design element within the hierarchy were calculated, and a scientifically sound AHP model and weight allocation table for all evaluation indices (Table 4) were ultimately constructed.

Table 3. Matrix Scale Descriptions

Scale	Definition	Explanation
1	Equal Importance	Factor a_i and a_j are equally important relative to each other.
3	Slightly More Important	Factor a_i is slightly more important than factor a_j.
5	Obviously More Important	Factor a_i is obviously more important than factor a_j.
7	Strongly More Important	Factor a_i is strongly more important than factor a_j.
9	Extremely More Important	Factor a_i is extremely more important than factor a_j.
2, 4, 6, 8	Intermediate Values	Intermediate judgment values between adjacent scales above.
Reciprocal Comparison	Reverse Comparative Judgment	If comparison of a_i to a_j yields a_{ij}, comparison of a_j to a_i yields $a_{ji}=1/a_{ij}$.

To quantify the degree of importance of each evaluation index for the application of modified agroforestry biomass-based materials in homestay spaces and mitigate absolute subjectivity of specialist judgment, all weight data underwent two rounds of anonymous revision *via* the Delphi method, ensuring the consistency ratio (CR) of judgment matrices falls far below the 0.1 threshold. Such data processing helps improve the consistency of the derived weight system of this study for homestay renovation projects across different regions. Weight data from pairwise comparison of indices Y1 (Agroforestry Biomass Substrate), Y2 (Functional Performance), Y3 (Local Aesthetics), and Y4 (Comprehensive Adaptability) within the matrix are presented below (Table 4).

Table 4. Judgment Matrix for Biomass Material Design Elements

Index	Y1	Y2	Y3	Y4	Single-Layer Weight
Y1	1	2	3	1/2	0.2785
Y2	1/2	1	1	1/3	0.1415
Y3	1/3	1	1	1/4	0.1174
Y4	2	3	4	1	0.4626

Consistency Test

Consistency testing is required to measure thought consistency of evaluation scores and compatibility of judgment matrices. Prior to consistency testing, the maximum eigenvalue λ_{max} of the matrix must be calculated *via* Eq. 1:

$$\lambda_{\max} = \frac{1}{n}\sum_{y=1}^{n}\frac{[A\omega]_y}{\omega_y} \quad (1)$$

Consistency testing is subsequently performed to judge whether the matrix satisfies consistency criteria. Calculation of the consistency index CI follows Eq. 2:

$$CI = \frac{\lambda_{\max}-n}{n-1} \quad (2)$$

The CI values approaching zero correspond to higher judgment matrix consistency,

while values deviating from zero indicate poorer consistency. The consistency ratio CR is calculated *via* Eq. 3:

$$CR = \frac{CI}{RI} \quad (3)$$

The RI (average random consistency index) was retrieved from the standard consistency index table. When CR < 0.1, the judgment matrix passed the consistency test. Equations 1 to 3 were applied to conduct consistency testing on biomass material design Strategy judgment matrix A. The calculations yielded a CI = 0.0215 and CR = 0.0239 (note: CR = CI/RI, RI = 0.9 when n = 4), confirming the judgment matrix satisfies consistency criteria with valid test results. Sub-layer AHP testing was then performed; CR values for all sub-element judgment matrices were 0.062, 0.081, 0.045, and 0.058, respectively. These values were all less than 0.1, verifying all sub-criterion layers passed consistency testing. Comprehensive weight values and rankings for all design elements were ultimately derived by multiplying primary layer weight values with sub-layer weight values (Table 5).

Table 5. Total Index Weights and Weight Rankings

Element Layer	Element Weight	Sub-element Layer	Sub-element Weight	Comprehensive Weight	Ranking
Y1	0.2785	Y11	0.2931	0.0816	5
		Y12	0.2952	0.0822	4
		Y13	0.1114	0.0310	11
		Y14	0.3003	0.0836	3
Y2	0.1415	Y21	0.2025	0.0287	12
		Y22	0.1830	0.0259	13
		Y23	0.4505	0.0637	8
		Y24	0.1640	0.0232	14
Y3	0.1174	Y31	0.5247	0.0616	9
		Y32	0.1416	0.0166	15
		Y33	0.3338	0.0392	10
Y4	0.4626	Y41	0.4490	0.2077	1
		Y42	0.1761	0.0815	6
		Y43	0.1490	0.0689	7
		Y44	0.2259	0.1045	2

Based on the ranking of the comprehensive weights presented in Table 5, this study further selected the higher-ranked indicators as the main basis for design translation. Among them, Spatial Furniture Adaptability (Y41), Tourists' Sensory Comfort (Y44), Low-Carbon Recyclability (Y14), Uniqueness of Rural Textures (Y12), Local Raw Material Accessibility (Y11), and Spatial Visual Coordination (Y42) were identified as the primary factors guiding the subsequent design applications. As these indicators respectively concern furniture adaptability, material attributes, spatial coordination, and overall experience, they were not mechanically assigned to three separate strategies. Instead, according to the scale of material intervention in the interior space and its design role, they were translated into three types of application strategies: furniture-level application, spatial-interface-level application, and integrated interior application. The specific relationships are shown in Table 6.

Table 6. Translation of Key AHP Indicators into Design Application Strategies

Key AHP Indicator	Comprehensive Weight	Focus of Design Translation	Corresponding Strategy
Y41 Spatial Furniture Adaptability	0.2077	Furniture scale, use relationships, and spatial adaptability	Strategy A
Y44 Tourists' Sensory Comfort	0.1045	Overall spatial experience	Strategy C
Y14 Low-Carbon Recyclability	0.0836	Material selection and resource recycling	Strategies A/B/C
Y12 Uniqueness of Rural Textures	0.0822	Material texture and local expression	Strategies A/B
Y11 Local Raw Material Accessibility	0.0816	Application of local materials	Strategies A/B/C
Y42 Spatial Visual Coordination	0.0815	Coordination among materials, furniture, and spatial interfaces	Strategies B/C

DESIGN APPLICATION STRATEGIES

To further translate the indicator weights obtained from the AHP into actionable interior design decisions, this study divided the design translation of modified agroforestry biomass-based materials in rural homestays into three progressive levels according to the scale of material application. The three strategies do not represent three different material products, but rather reflect the application of the same type of modified agroforestry biomass-based material at different scales of interior design.

Strategy A is the furniture-level application strategy, which focuses on the form development, material texture expression, and furniture adaptability of modified biomass-based materials in individual furniture items such as side tables. Its design validation is presented in Fig. 3.

Strategy B is the spatial-interface-level application strategy, which focuses on the application of modified biomass-based materials in larger-scale interior elements, such as reception counters, background interfaces, and spatial nodes. Its design validation is presented in Fig. 4.

Strategy C is the integrated interior application strategy, which establishes overall coordination among furniture, materials, colors, and spatial atmosphere to examine the integration potential of modified biomass-based materials within a complete rural homestay interior environment. Its design validation is presented in Fig. 5.

Therefore, the three strategies form a progressive relationship according to the sequence "individual furniture–spatial interface–integrated interior environment", and are used to verify the translatability of the AHP evaluation results across different design scales.

Design Concept

Guided by the weight ranking derived from AHP calculations, this study prioritized top-ranked core elements as the core orientation for homestay design strategies. Local Northern Chinese cultural symbols and material properties of modified agroforestry biomass-based materials were scientifically translated, comprehensively balancing visual aesthetics, functional experience, and cultural expressive efficiency of the design. Weight analysis results indicated that comprehensive adaptability (Y_4, weight = 0.4626) and agroforestry biomass substrate (Y1, weight = 0.2785) dominated design decision-making,

with functional performance (Y2) and local aesthetics (Y3) respectively serving as technical safeguards and visual supplements.

At the sub-element layer, this study focused on the six core indices with highest comprehensive weights: Spatial Furniture Adaptability (Y41), tourists' sensory comfort (Y44), low-carbon recyclability (Y14), uniqueness of rural textures (Y12), local raw material accessibility (Y11), and Spatial Visual Coordination (Y42). These indices were systematically translated into concrete spatial design strategies. The design broke the limitations of homogenized, crudely shaped furniture in traditional rural homestays, Considering the processing adaptability of modified biomass-based materials, this study applied parametric and modular design approaches to core spatial nodes, including front desk counters, guest room side tables, and background walls, achieving deep integration of spatial function and aesthetics. Meanwhile, drawing on abundant forestry residues and crop straw resources in Northern China, local sourcing and cyclic utilization are realized *via* modification processes, reducing carbon footprints from transportation while converting green low-carbon attributes into brand premium for homestay spaces.

Furniture Design

To verify the practical application value of the AHP evaluation results, this study translated modified agroforestry biomass-based materials into furniture node designs based on the ranking results of comprehensive weights. As shown in Fig. 3, the side table strategy is not an existing furniture case but a design validation strategy developed based on the indicators of Y_{41} Spatial Furniture Adaptability, Y_{12} Uniqueness of Rural Textures, and Y_{14} Low-Carbon Recyclability. By extracting the natural morphological characteristics of Northern rural areas, the strategy transforms the material textures and application characteristics of modified biomass-based materials into spatial furniture expressions.

During design practice, equal emphasis was placed on furniture functionality, aesthetic expression, and activation and visualization of local rural culture to eliminate homogenization. Taking forest element application as an example, side table designs extract clustered tree morphologies, transforming irregular support frames into structures integrating storage and decorative functions. Retained wood grain textures achieve high stylistic consistency with overall interior spaces (Fig. 3).



Fig. 3. Strategy A: Furniture-level application strategy

Front desk counter designs adopt regular columnar log arrangements to form enclosed main bodies, highlighting solid structural integrity and natural texture tactility,

effectively enhancing visual depth of spatial interfaces. This design combines the visual and applicative properties of modified agroforestry biomass-based materials with contemporary reception-space functions; countertops and internal compartments deliver efficient storage and reception practicality, optimizing overall spatial efficiency. This process converts forest resources of Northern China into tangible furniture forms, not only enabling deep empowerment of custom furniture design by cultural tourism resources but also establishing a regionally distinctive integrated rural cultural tourism design methodology that achieves harmonious coexistence among architecture, interior spaces, and natural environments (Fig. 4).



Fig. 4. Strategy B: Spatial-interface application strategy

Interior Design Practice

Rural homestays represent more than geographically defined accommodation spaces, they constitute cultural entities carrying local cultural identity and emotional belonging. Similar to Figs. 3 and 4, the guest room spatial strategy presented in Fig. 5 is also a simulation-based design proposal developed from the evaluation system. It further verifies the application potential of modified agroforestry biomass-based materials within an integrated spatial environment. Guided by weight analysis, homestay interior design is based on Northern Chinese rural culture, agroforestry bio-based materials, and forest natural landscapes as its core themes. Against the backdrop of cultural-tourism integration, design addresses not only material functionality but also introduces Baudrillard's "sign consumption" theory to transform homestays into large-scale cultural "meaning fields". Spatial narration connects tourists' cultural demands and spatial experience at a profound level; cultural empowerment elevates functional spaces into immersive atmospheric venues, effectively increasing added value of cultural consumption while fulfilling strategic objectives of promoting regional characteristic culture.

Guest room design deeply excavates top-ranked rural Northern Chinese culture and biomass aesthetics according to weight data, constructing authentic natural rural atmospheres through color palettes, materials, and furnishings. Spaces adopt earth tones and natural wood hues as primary color strategies, complemented by regional, eco-friendly materials, including stone, wooden stumps, and modified wood-based materials, to restore authentic textural qualities of Northern forests and rural areas. Design details integrate circular woven hangings, wooden stump side tables, natural linen round rugs, and dried flower furnishings as local cultural symbols, enriching multi-dimensional cultural layers

and forest imagery from visual and tactile perspectives. Such spaces simultaneously deliver folk experience and cultural communication functions, bridging cultural content and tourists' emotional resonance through cultural gaze, psychological congruence, and local interactive experience, realizing optimal allocation of spatial value under the perspective of cultural-tourism integration (Fig. 5).



Fig. 5. Strategy C: Integrated interior application strategy

STRATEGY VERIFICATION

Evaluation Framework and Index System

To verify the effectiveness of the modified material application path constructed around four core elements: agroforestry biomass substrate (Y1), functional performance (Y2), local aesthetics (Y3), and comprehensive adaptability (Y4), a multi-criteria expert evaluation framework was established for this study. To align evaluation results precisely with AHP quantitative conclusions derived in the preceding chapter, the six core indices exerting the most significant influence on rural homestays and custom furniture in Northern China (ranked highest by comprehensive weight) were selected as evaluation criteria for expert assessment: Spatial Furniture Adaptability (Y41), tourists' sensory comfort (Y44), low-carbon recyclability (Y14), uniqueness of rural textures (Y12), local raw material accessibility (Y11), and Spatial Visual Coordination (Y42).

During the design strategy validation stage, a separate design strategy evaluation group was established, consisting of 20 professionals in rural architectural design, furniture craftsmanship research, and homestay operation, together with 20 target tourists who had prior rural homestay experience. This evaluation group did not participate in the AHP weight calculation and was only responsible for evaluating the application effects of Strategy A, Strategy B, and Strategy C using a 5-point Likert scale. Reliability testing of

collected data yields an overall Cronbach's α coefficient of 0.885, with all dimensional coefficients exceeding 0.8, confirming favorable internal consistency and statistical validity of the evaluation system.

Statistical Results and Inter-Strategy Difference Analysis

Descriptive statistical results (Table 7) demonstrated high recognition scores for all three homestay spatial design strategies across all evaluation dimensions (mean scores ranging from 4.35 to 4.80). Strategy A (side tables), Strategy B (front desk counter), and Strategy C (integrated spatial Strategy) all received highly favorable overall evaluations.

In-depth analysis focusing on the six core indices ranked highest by AHP comprehensive weights revealed distinct strategy strengths: Strategy A achieved standout performance in low-carbon recyclability (Y14 = 4.75), fully embodying the core decarbonization advantages of forestry residues as bio-based materials; Strategy B received the highest score for Spatial Visual Coordination (Y42 = 4.80), suggesting that its spatial-interface design was positively perceived in terms of visual integration; Strategy C peaked in tourists' sensory comfort (Y44 = 4.80), indicating favorable performance in overall spatial experience.

One-way ANOVA indicated no statistically significant differences among the three strategies for Spatial Furniture Adaptability (Y41) and Local Raw Material Accessibility (Y11) ($p > 0.05$). The relatively high mean scores across all three strategies indicate generally favorable evaluations for these two indicators. Statistically significant inter-Strategy differences existed for uniqueness of rural textures (Y12) and Spatial Visual Coordination (Y42) ($p < 0.05$), stemming from objective disparities in visual communication and immersive experience generated by varying furniture forms and spatial node process complexity.

Result Discussion and Applicability of Modified Biomass-based Materials

The evaluation results indicate that the proposed four-element-driven design pathway can support the coordination of local cultural expression and material application requirements.

Physical performance and processing adaptability

Structural stability and processing adaptability were considered important requirements for the application of modified biomass-based materials in complex-shaped furniture. However, these properties were not directly tested in this study and require further experimental verification. The evaluation results mainly support the importance of local raw-material accessibility (Y11) in material application.

Local aesthetics and low-carbon transformation

The evaluation results indicate that natural texture expression (Y12) was positively evaluated in the furniture application strategies. The results also suggest that low-carbon recyclability (Y14) is an important consideration in the application of modified biomass-based materials. In this study, this indicator primarily reflects material sourcing, local resource utilization, and potential recyclability rather than experimentally verified improvements in warping resistance or wear performance (Table 7).

High evaluation scores across the three strategies indicate generally positive perceptions of their spatial, cultural, and material application characteristics (Y1 agroforestry biomass substrate, Y_2 functional performance). Specifically, Strategy A

attained the maximum score for low-carbon recyclability (Y14 = 4.75) for the following core engineering logic: Regarding low-carbon recyclability, the evaluation in this study focuses not on specific adhesive systems or formaldehyde emission performance, but on material sources, the utilization of local resources, and potential recyclability. Since this study did not conduct tests on adhesive formulations, formaldehyde emissions, or life-cycle environmental performance, the formaldehyde emission levels or environmental advantages of specific material systems cannot be directly determined based on the present results. The relevant material properties require further experimental verification.

Table 7. Weighted Indicators Quantitative Evaluation Data

Evaluation Dimension	Strategy A (Side Tables)	Strategy B (Front Desk Counter)	Strategy C (Integrated Spatial Strategy)
Y41 Spatial Furniture Adaptability	4.60	4.55	4.65
Y14 Low-Carbon Recyclability	4.75	4.40	4.50
Y12 Uniqueness of Rural Textures	4.40	4.60	4.55
Y11 Local Raw Material Accessibility	4.55	4.45	4.70
Y42 Spatial Visual Coordination	4.35	4.80	4.60
Y44 Tourists' Sensory Comfort	4.50	4.70	4.80

At the level of mechanical and processing adaptability, temperature and humidity adaptability was considered an important material application requirement for Strategies B and C under Northern climatic conditions (Y22). Large seasonal temperature differences and dry indoor air during the heating season may increase the risk of shrinkage, swelling, warping, and cracking in conventional solid timber. Therefore, temperature deformation adaptability was incorporated into the functional performance evaluation system. However, this study did not directly test the dimensional stability or processing performance of the modified biomass-based materials, and these properties require further experimental verification.

This study demonstrates that introducing AHP into biomass-based material application design effectively resolves inadequate pre-evaluation of material adaptability inherent in traditional perceptual design. Compared with existing decorative finishing research, the model developed herein incorporates temperature deformation resistance for northern climates as a mandatory indicator within functional performance (Y2), delivering reference significance for indoor material engineering research in the built environment field. Notably, although the model verifies Strategy effectiveness, cost-benefit ratios for large-scale production require detailed refinement in follow-up research.

CONCLUSIONS

1. *Methodological Framework:* This study established a material application decision-making framework integrating questionnaire-based demand identification, analytic hierarchy process (AHP) weight analysis, design strategy development, and multi-criteria evaluation. The questionnaire was primarily used to identify tourists' concerns regarding the ecological attributes of materials, spatial experience, regional cultural expression, and functional adaptability. Based on these results, an AHP evaluation system was developed by incorporating relevant literature and expert opinions.
2. *AHP Results:* The AHP results indicate that Comprehensive Adaptability (Y4, 0.4626) and Agroforestry Biomass Substrate (Y1, 0.2785) received relatively high weights in material application decision-making. At the sub-indicator level, Spatial Furniture Adaptability (Y41, 0.2077), Tourists' Sensory Comfort (Y44, 0.1045), Low-Carbon Recyclability (Y14, 0.0836), Uniqueness of Rural Textures (Y12, 0.0822), Local Raw Material Accessibility (Y11, 0.0816), and Spatial Visual Coordination (Y42, 0.0815) constituted the main design considerations.
3. *Design Translation:* Based on the high-weight indicators above, this study developed three progressive material application strategies at the furniture level, spatial-interface level, and integrated interior level. Figures 3 to 5 respectively illustrate the design translation of these strategies in individual furniture, spatial interfaces, and complete rural homestay interior environments, thereby establishing a clear pathway from evaluation results to design applications.
4. *Research Scope:* The main contribution of this study lies in establishing an evaluation and design decision-making method for the interior application of modified agroforestry biomass-based materials in rural homestays, rather than verifying the physical, chemical, or environmental performance of specific material formulations. Since this study did not conduct experiments on formaldehyde emissions, adhesive systems, long-term dimensional stability, or life-cycle carbon emissions, these properties require further verification through material testing and long-term environmental monitoring in future research.

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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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