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KE-FAHP-Based CMF Translation Design for Light-Rail Passenger Compartments Inspired by Liaoning Coastal Vernacular Dwelling Culture: A Case Study of Dalian

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Abstract

To address issues such as semantic weakening, symbolic transplantation, and insufficient consideration of passenger perception in the application of Liaoning coastal vernacular dwelling culture to light-rail passenger-compartment design, this study proposes a Kansei Engineering (KE)- and Fuzzy Analytic Hierarchy Process (FAHP)-guided Color, Material, and Finish (CMF) design-priority translation pathway for integrating regional architectural culture into passenger-compartment CMF design. Taking representative Liaoning coastal vernacular dwellings as cultural samples and the Dalian light-rail passenger compartment as the application case, characteristics were first identified through a literature review and sample analysis. A total of 117 participants evaluated 12 dwelling images using ten bipolar Kansei descriptor pairs on a seven-point Semantic Differential (SD) scale, and exploratory factor analysis was applied to identify the principal passenger-perception dimensions. Subsequently, 12 experts participated in the FAHP evaluation to determine the relative priorities of six CMF design elements: Color, Material, Texture, Gloss, Pattern, and Surface Treatment, followed by designer-led conceptual CMF design and user evaluation. Results yielded an exploratory three-factor representation comprising Spatial Order, Material Texture, and Stylistic Tension, which accounted for 56.89% of the total variance. Material, Texture, and Color received the three highest FAHP-derived global priorities. User evaluation involving 115 valid participants yielded mean scores between 5.48 and 5.86 across the five evaluation dimensions, all significantly higher than the neutral midpoint of the scale ($p < 0.001$). The proposed framework provides a traceable, expert-guided process for translating regional architectural characteristics into conceptual CMF design decisions while retaining passenger perception as a key evaluative component.

Keywords: Liaoning coastal vernacular dwellings; Kansei Engineering; Fuzzy Analytic Hierarchy Process; light-rail passenger compartment; CMF design

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Academic Editor: Ahmad Sanusi Hassan

Received: 15 August 2026
Revised: 13 October 2026
Accepted: 15 October 2026
Published: 26 October 2026

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1. Introduction

Urban rail transit increasingly functions not only as transportation infrastructure, but also as a public environment through which place identity and regional culture are communicated. However, regional-cultural expression in rail-transit environments often remains constrained by homogenized design language, fragmented use of cultural elements, and the direct transplantation of traditional symbols, indicating a need for more systematic identification, interpretation, and spatial integration of cultural characteristics [1]. Recent studies of subway and railway environments have examined how users perceive and

recognize culturally embedded design elements [2], suggesting that cultural representation and passenger perception should be considered as related but distinct aspects of regional-cultural design.

Vernacular dwellings embody the long-term interaction among regional environmental conditions, everyday life, and local construction traditions. Their courtyard layouts, architectural forms, construction techniques, and use of local materials reflect both environmental adaptation and the organization of daily activities. Courtyard spaces contribute to environmental regulation and activity organization [3], while contemporary interpretations of traditional architectural culture increasingly move beyond formal replication toward the selective extraction and reinterpretation of cultural characteristics [4]. Recent research on Liaoning coastal vernacular dwellings has identified regional characteristics in courtyard organization, architectural form, construction techniques, and material use [5]. These documented characteristics provide the architectural-cultural evidence for the present study and form the basis for the subsequent investigation of passenger perception.

CMF plays an important role in shaping users' perceptions of visual style, material qualities, and affective imagery [6]. Previous studies have applied KE and perceptual analysis to vehicle and passenger-compartment design to investigate users' affective responses and design preferences [7–9]. Controlled studies have further examined perceptual responses to specific CMF-related variables, including seat color, material, texture, surface characteristics, and lighting [10,11]. In parallel, FAHP and related multi-criteria decision-making methods have been used to assess the relative importance of vehicle-interior design factors and support design prioritization [12]. Related studies have also explored cultural expression in transport environments and the translation of regional architectural culture into contemporary design [13–15]. To clarify the methodological differences between the present study and representative related studies, a comparative overview is provided in Table 1.

Despite these advances, existing studies often address cultural-feature identification, passenger perception, CMF evaluation, and design prioritization as separate research tasks. Few studies, however, have integrated regional cultural identification, passenger-perception dimensions, expert-guided CMF prioritization, and subsequent design translation within a single traceable process. To address this gap, this study proposes a Cultural–Passenger–Compartment translation framework for light-rail CMF design based on Liaoning coastal vernacular dwellings, with the Dalian light-rail passenger compartment serving as the application case. Architectural cultural characteristics are first identified through a literature review and sample analysis. Selected dwelling images are then evaluated by passengers using a seven-point SD scale, and exploratory factor analysis (EFA) is applied to identify the principal passenger-perception dimensions. The resulting passenger-perception dimensions are used as the criterion layer in the subsequent FAHP, in which experts assess the relative priorities of six passenger-compartment CMF elements. Finally, the designer integrates the expert-assessed priorities with the identified cultural characteristics to develop a conceptual CMF design, which is subsequently evaluated by users. The methodological contribution lies in structuring cultural-feature identification, passenger-derived perception, expert-guided CMF prioritization, and designer-led translation within a traceable design process.

Table 1. Methodological comparison of representative related studies and the present study.

Reference	Cultural Feature Identification	Passenger/Kansei Analysis	CMF/Design Prioritization	Design Translation	User Evaluation	Main Contribution
Li et al. [14]	Lingnan architectural cultural elements	KANO-based user requirements	AHP-based requirement weighting	Architectural elements Neo-Chinese seating	Expert TOPSIS evaluation	Links regional architectural culture, user requirements, and contemporary furniture design.
Cheng & Guo [15]	Representational culture of subway decorative walls	Commuter cultural and spatial perception	—	—	Questionnaire + data triangulation	Reveals gaps between intended cultural representation and commuter perception.
Qi & Kim [16]	—	Kansei imagery identification	AHP + fuzzy comprehensive evaluation	—	Kansei-based vehicle evaluation	Integrates Kansei Engineering with multi-criteria evaluation of electric-car styling.
Tovillo et al. [17]	—	Perceived quality and visual attention	—	—	Controlled-color IVR + eye tracking + subjective evaluation	Examines perceptual responses to controlled automotive color combinations.
Yohanny et al. [8]	—	Kansei responses to train-compartment visual features	Statistically derived visual specifications	Kansei responses train-compartment design specifications	150-participant SD evaluation	Derives preferred train-compartment visual specifications from Kansei responses.
This study	Architectural cultural-feature identification	Passenger-derived Kansei dimensions	Expert-assessed CMF priorities	Designer-led conceptual CMF translation	User evaluation of the conceptual design	Integrates cultural identification, passenger-derived Kansei dimensions, expert-assessed CMF priorities, designer-led translation, and user evaluation within a traceable framework.

2. Materials and Methods

2.1. Cultural–Passenger–Compartment Translation Framework

Kansei Engineering can establish connections between affective needs and design features through user perceptual evaluation and has been applied in vehicle design research [7]. Building on this foundation, this study develops a "Cultural–Passenger–Compartment" CMF translation framework for translating the cultural characteristics of Liaoning coastal vernacular dwellings into light-rail passenger-compartment design. The framework comprises three interconnected stages: cultural-feature identification and passenger-perception analysis, expert-based prioritization of CMF design elements, and designer-led translation into CMF design decisions, as shown in Figure 1.

- Culture–Passenger: Literature review and architectural-sample analysis were used to identify literature-documented characteristics of Liaoning coastal vernacular dwellings, including courtyard organization, building form, color relationships, material characteristics, decorative elements, and environmental adaptation. Representative dwelling images and screened Kansei descriptor pairs were then used in a Semantic Differential evaluation to obtain passengers' perceptual responses and identify the principal passenger-perception dimensions.
- Passenger–Compartment: Based on the passenger-perception dimensions, the passenger-compartment CMF design was decomposed into six elements: Color, Material, Texture, Gloss, Pattern, and Surface Treatment. Experts conducted fuzzy pairwise

comparisons among indicators at the same hierarchical level, and FAHP was used to derive the local and global weights of the CMF elements under each criterion. These weights represent expert-assessed relative design priorities and provide guidance for subsequent designer-led CMF translation and design decision-making.

- Compartment–Culture: Based on the expert-assessed FAHP priorities, the designer translated the prioritized CMF elements into specific decisions concerning hue, lightness, chroma, material category, texture scale, gloss level, pattern application, surface treatment, and application ratio. These parameter-level decisions were informed by the identified architectural cultural characteristics and conceptually adapted to the functional context and aesthetic requirements of different passenger-compartment interfaces, resulting in a conceptual CMF design proposal.



Figure 1. Cultural–Passenger–Compartment translation framework. The different colors are used to visually distinguish the Culture, Passenger, and Passenger Compartment domains. The dashed circular pathway indicates the Kansei evaluation, FAHP prioritization, and CMF parameter-mapping processes, while the arrows indicate the directional relationships among the main stages of the framework.

First, cultural characteristics of Liaoning coastal vernacular dwellings were identified through a literature review and sample analysis. Representative dwelling images and screened Kansei descriptors were then evaluated using a seven-point SD scale, and EFA was applied to examine the underlying structure of passenger perception.

Second, these dimensions formed the criterion layer of a three-level FAHP model, in which experts evaluated six passenger-compartment CMF elements to determine their relative priorities.

Finally, the designer combined the FAHP-derived priorities with the cultural findings to formulate CMF decisions concerning hue, lightness, chroma, material category, texture scale, gloss level, pattern application, surface treatment, and application ratio. The resulting conceptual CMF design was subsequently evaluated by users, as shown in Figure 2.

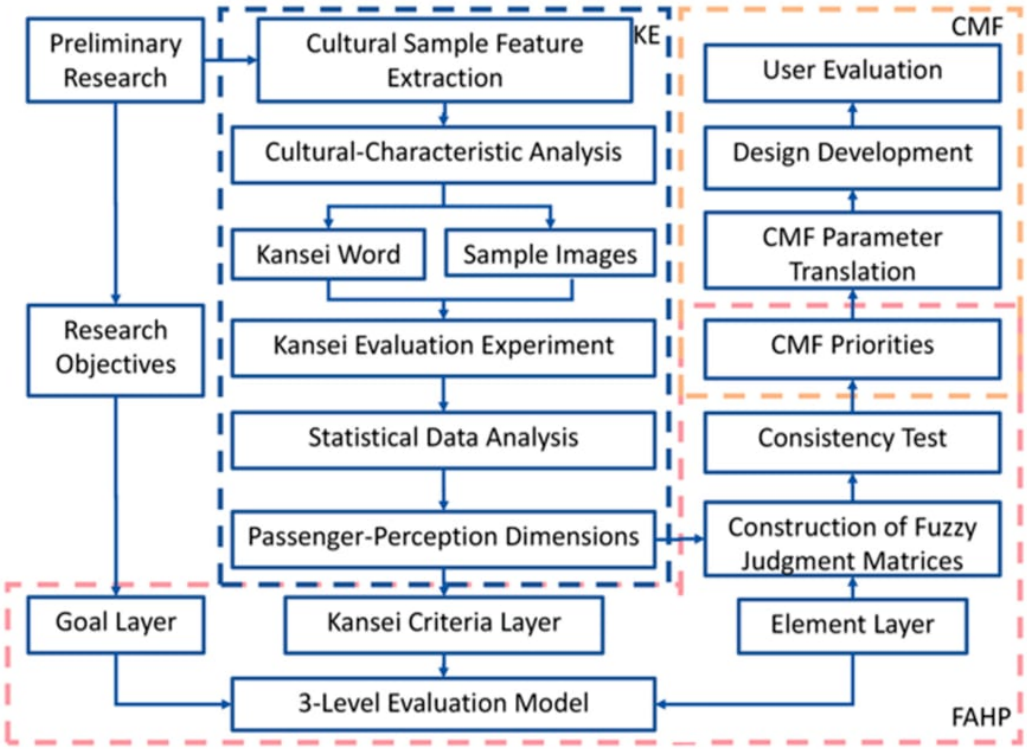


Figure 2. Research framework for CMF translation design.

2.2. Cultural Sample Selection and Architectural Feature Analysis

Liaoning coastal vernacular dwellings were defined as the geographic scope of the cultural samples, while the Dalian light-rail passenger compartment served as the application case for the subsequent CMF translation. Previous studies have reported regional variations in courtyard organization, building form, construction methods, local materials, and decorative features [5,18–21]. These variations reflect differences in geographic conditions, building traditions, and regional cultural development.

The geographic coverage, source types, temporal ranges, numbers of source records, and research roles are summarized in Table 2. An overview of the source and provenance registry for the collected visual materials is provided in Figures A1 and A2 in Appendix A. The readable, item-level registry is provided in Supplementary Table S1.

For sample screening, vernacular dwellings were defined as residential buildings or courtyard compounds with a clear residential function and traceable evidence of their traditional status.

Table 2. Source composition and research roles for candidate cultural-sample identification.

Material Category	Geographic Coverage	Source and Material Type	Temporal Range	No. of Source Records (*n*)	Research Role
Academic research literature	Coastal Liaoning, the Liaodong Peninsula, and related Bohai Rim areas	Peer-reviewed articles, architectural survey materials, and typological and morphological studies	2015–2026	11	To establish references for regional dwelling types and architectural characteristics and to support subsequent architectural-feature identification
Government and cultural-heritage records	Xutun, Dongmatun, Qingdui, Chengzitan, and related areas	Traditional-village lists, cultural-heritage registers, government notices, and official public records	2014–2024	5	To verify the locations, administrative affiliations, and traditional-village or cultural-heritage status of candidate objects
Authoritative and local media materials	Qingdui, Dongmatun/Xutun, Fuzhou Ancient Town, Chengzitan, and related areas	News reports, illustrated features, and images of streetscapes, courtyards, and architectural details	2015–2026	22	To provide traceable visual materials and supplement information on buildings, materials, colors, architectural components, and surrounding environments
Historical, cultural, and archival materials	Mainly Fuzhou Ancient Town and its associated historic buildings and streetscapes	Historical reports, archival photographs, library materials, and local cultural records	Mainly around 2009	3	To support interpretation of the historical context and cross-verify information on extant buildings
Institutional and supplementary records	Dongmatun and Chengzitan	University or institutional websites and related public records	2025	2	To supplement information on candidate-object identity, location, preservation status, and provenance
Reposted and cross-verification materials	Qingdui, Xutun/Dongmatun, and Fuzhou Ancient Town	Reposted news reports, mirrored reports, and other secondary web materials	2015–2022	4	To trace original sources and cross-verify locations, architectural objects, and image provenance

Visual images were treated as the basic unit for sample screening and Kansei evaluation, with source records and visual samples counted separately. The reconstructed sample

registry contained 106 raw image records. One record without a retrievable image and one non-photographic or otherwise invalid webpage asset were excluded. One visual duplicate and four crop variants were then consolidated. The screening yielded 99 canonical candidate visual samples. Different views of the same building were retained when they provided complementary architectural information. The screening criteria are presented in Table 3.

Table 3. Eligibility and final-selection criteria for candidate visual samples.

Screening Criterion	Inclusion Criterion	Exclusion Criterion
Geographic Relevance	The source confirms that the image represents a vernacular dwelling within the defined coastal Liaoning study area.	The location falls outside the study area or cannot be reliably verified.
Dwelling Relevance	The image primarily depicts a vernacular dwelling, courtyard compound, or built environment with a clear residential function.	Religious, industrial, commemorative, defensive, landscape-only, or other non-residential subjects.
Provenance Traceability	The image source or original publication/webpage can be identified and verified.	The image source cannot be traced.
Visual Interpretability	Architectural information such as courtyard organization, roofs, walls, materials, colors, doors/windows, or components can be clearly identified.	The architectural subject is severely obscured, of insufficient resolution, or provides inadequate visual information.
Architectural-Feature Coverage	The image contributes complementary information on spatial, formal, material, or component characteristics.	The image is highly redundant with existing samples and provides no additional architectural information.

Final selection was guided by literature-documented characteristics of Liaoning coastal vernacular dwellings, including spatial organization, building form, roof configuration, structural elements, materials and textures, color relationships, doors and windows, and architectural components. Among visually similar candidates, preference was given to images with clearer provenance, more complete architectural subjects, and fewer visual distractions. Twelve images were selected for the Kansei evaluation, with their locations and source information summarized in Table 4. As some source images were subject to redistribution restrictions, the corresponding source links are provided in Figures A1 and A2 in Appendix A to ensure traceability without reproducing the original images.

To improve comparability, the 12 final visual samples were presented with a consistent aspect ratio and display size. Irrelevant visual distractions were minimized while preserving the principal architectural form, materials, and components.

2.3. Extraction of Passenger Kansei Perceptions

To examine the general structure of passenger perception across the selected Liaoning coastal vernacular-dwelling visual samples, KE was used to evaluate participants' affective responses to the selected images. The aggregated participant-level Kansei ratings were analyzed to characterize general passenger-perception tendencies across the complete stimulus set [7,8].

Table 4. Locations, sources, and temporal information of the final Kansei visual samples.

Sample No.	Location	Source and Category	Source Date Information
1	Gaizhou, Liaoning	Academic research literature	2026
2	Jinzhou, Liaoning	Academic research literature	2026
3	Huludao, Liaoning	Academic research literature	2026
4	Jinzhou District, Dalian, Liaoning	Academic research literature	2023–2025
5	Huludao, Liaoning	Academic research literature	2023–2025
6	Jinzhou, Liaoning	Academic research literature	2023–2025
7	Panjin, Liaoning	Academic research literature	2023–2025
8	Lüshun, Dalian, Liaoning	Academic research literature	2023–2025
9	Wafangdian, Dalian, Liaoning	Governmental/media source	2025
10	Zhuanghe, Dalian, Liaoning	Governmental/media source	2025
11	Wafangdian, Dalian, Liaoning	Governmental/media source	2025
12	Zhuanghe, Dalian, Liaoning	Governmental/media source	2025

The initial Kansei descriptors were collected from two sources. First, recent studies on Kansei Engineering in rail-transit and vehicle-interior design as well as studies on CMF-related perception and design were reviewed [9–11]. Second, open-ended interviews were conducted with eight participants to elicit additional perceptual expressions associated with the visual characteristics of vernacular dwellings. Descriptors obtained from both sources were then processed by duplicate removal, synonym consolidation, antonym pairing, part-of-speech normalization, and polarity standardization. This process yielded an initial pool of 40 candidate bipolar Kansei descriptor pairs. The complete candidate pool, semantic groupings, and treatment of each descriptor pair are reported in Table A1 in Appendix A.

The 40 candidate bipolar descriptor pairs were subsequently reviewed with reference to the literature-documented architectural and visual characteristics summarized in Table 5. Consultation was conducted with 12 experts whose professional backgrounds covered rail transit and industrial design, CMF and material design, and vernacular architecture and regional culture. All experts had at least three years of relevant research or professional experience. The candidate descriptors were evaluated according to four criteria: (1) semantic relevance to the literature-documented architectural and visual characteristics of the vernacular dwelling samples; (2) clarity and comprehensibility; (3) semantic distinctiveness from other candidate pairs; and (4) suitability as SD items for evaluating passengers' visual responses to the visual samples. The expert review was conducted to clarify semantic boundaries, assess the relevance of candidate expressions, and identify representative descriptor pairs for subsequent screening.

Table 5. Correspondence between architectural cultural characteristics and Kansei semantic cues.

Building Characteristics	Form Attributes	Kansei Semantic Cues
Courtyard Enclosure and Spatial Depth	Enclosure, Spatial Layering	Stability, Continuity
Brick and Stone Walls and Timber Structures	Natural Texture, Structural Stability	Plainness, Heaviness
Continuous Arrangement of Components	Linearity, Rhythm	Stability, Harmony
Natural Colors of Local Materials	Low Color Saturation, Material Authenticity	Naturalness, Restraint

Candidate descriptors with substantial semantic overlap were grouped based on semantic similarity, and a representative bipolar pair was retained for each group where ap-

propriate. For example, Rough–Smooth, Rough–Delicate, Coarse–Delicate, and Unrefined–Refined represented closely related perceptions of surface texture and refinement, and Rough–Delicate was retained as the representative pair. The same procedure was applied to the remaining candidates. Semantically overlapping pairs were consolidated, whereas descriptors showing insufficient relevance to the literature-documented architectural and visual characteristics, limited semantic distinctiveness, or poor suitability for visual SD evaluation were excluded from the final descriptor set.

Following screening and semantic consolidation, 10 out of the 40 candidate bipolar pairs were retained for the final seven-point SD scale. Of the remaining 30 pairs, nine were consolidated into semantically overlapping retained pairs, while 21 were excluded because of insufficient relevance, limited semantic distinctiveness, or poor suitability for visual SD evaluation. The final 10 bipolar pairs were Enclosed–Open, Compact–Spacious, Regular–Free-form, Continuous–Fragmented, Heavy–Light, Rough–Delicate, Plain–Ornate, Simple–Complex, Restrained–Expressive, and Stable–Dynamic.

Representative images of traditional vernacular dwellings reflecting characteristics such as courtyard organization, structural forms, material textures, and architectural colors were selected. Because the images were obtained from existing documentary sources, their original photographic characteristics, including viewing angle and background context, could not be fully standardized. For questionnaire presentation, the 12 visual samples were displayed using a consistent presentation format and display size while preserving the principal architectural forms, materials, and components. The visual samples used in the Kansei evaluation are shown in Figure 3. A seven-point SD scale was employed, and participants with actual experience of using urban rail transit were invited to evaluate each standardized sample. A score of 1 indicated a strong perceptual tendency toward the adjective on the left, a score of 4 indicated no clear tendency, and a score of 7 indicated a strong tendency toward the adjective on the right. To reduce potential order effects, the dwelling images were presented in randomized order. All bipolar items were coded consistently from 1 for the left-hand adjective to 7 for the right-hand adjective.



Figure 3. Traditional dwelling images used in the Kansei evaluation. Numbers 1–12 correspond to Sample Nos. 1–12 in Table 4.

A total of 152 passenger questionnaires were distributed, of which 117 valid responses were obtained, yielding a valid response rate of 76.97%. Among the passengers, 16 were

aged 18–25 years (13.68%), 36 were aged 26–35 years (30.77%), 31 were aged 36–45 years (26.50%), and 34 were aged 46 years or older (29.06%).

Each participant evaluated all 12 visual samples using the same 10 bipolar Kansei descriptor pairs. Because the image-level ratings were repeated observations within participants, ratings for each descriptor were averaged across the 12 samples for each participant, yielding a participant-level matrix of 117 observations × 10 Kansei variables for EFA. The participant was retained as the unit of analysis, allowing the analysis to characterize general passenger-perception tendencies across the complete stimulus set without treating repeated ratings as independent observations. Averaging reduced image-specific variation, so the EFA should be interpreted as a participant-level representation of general perception across the stimulus set. Descriptive statistics are presented in Table 6.

Table 6. Descriptive statistics of the participant-level Kansei variables.

Bipolar Kansei Descriptor Pair	Mean	SD	Minimum	Maximum
Enclosed–Open	3.996	1.799	1	7
Compact–Spacious	4.129	1.833	1.083	7
Regular–Free-form	4.100	1.932	1	7
Continuous–Fragmented	4.078	1.969	1	7
Heavy–Light	3.798	1.943	1	7
Rough–Delicate	4.090	1.826	1	7
Plain–Ornate	3.808	1.840	1	7
Simple–Complex	4.209	1.740	1.167	7
Restrained–Expressive	3.808	1.704	1	7
Stable–Dynamic	4.260	1.755	1	7

To examine the stimulus-level variation not represented directly in the participant-level EFA, the original image-level ratings were additionally analyzed using cross-classified random-intercept linear mixed-effects models. Participant and dwelling image were specified as crossed grouping factors for each Kansei descriptor, allowing the total variance to be partitioned into participant-level, image-level, and residual components. Variance partition coefficients (VPCs) were calculated to quantify the relative contributions of participant-level, visual-sample-level, and residual variation, as shown in Table 7.

Table 7. Variance partition coefficients from cross-classified mixed-effects models of the image-level Kansei ratings.

Bipolar Kansei Descriptor Pair	Participant VPC	Visual-Sample VPC	Residual VPC
Enclosed–Open	0.588	0.079	0.333
Compact–Spacious	0.606	0.065	0.329
Regular–Free-form	0.650	0.060	0.290
Continuous–Fragmented	0.657	0.059	0.284
Heavy–Light	0.664	0.060	0.276
Rough–Delicate	0.616	0.071	0.314
Plain–Ornate	0.606	0.068	0.327
Simple–Complex	0.574	0.087	0.339
Restrained–Expressive	0.552	0.083	0.365
Stable–Dynamic	0.566	0.084	0.349

Across the 10 Kansei descriptors, participant-level VPCs ranged from 0.552 to 0.664, visual-sample-level VPCs ranged from 0.059 to 0.087, and residual VPCs ranged from 0.276 to 0.365.

As shown in Table 8, the Kansei variables exhibited a range of low-to-moderately strong correlations, indicating varying degrees of association among the descriptors. Several relatively strong associations were observed, including Enclosed–Open with Continuous–Fragmented (r = 0.707), Heavy–Light with Plain–Ornate (r = 0.705), Heavy–Light with Stable–Dynamic (r = 0.706), and Heavy–Light with Rough–Delicate (r = 0.621).

Table 8. Inter-item correlation matrix of the participant-level Kansei variables.

Kansei Variable	Enclosed–Open	Compact–Spacious	Regular–Free-form	Continuous–Fragmented	Heavy–Light	Rough–Delicate	Plain–Ornate	Simple–Complex	Restrained–Expressive	Stable–Dynamic
Enclosed–Open	1.000									
Compact–Spacious	0.519	1.000								
Regular–Free-form	0.429	0.425	1.000							
Continuous–Fragmented	0.707	0.449	0.385	1.000						
Heavy–Light	0.282	0.391	−0.122	0.299	1.000					
Rough–Delicate	0.206	0.27	−0.113	0.287	0.621	1.000				
Plain–Ornate	0.451	0.5	0.145	0.514	0.705	0.612	1.000			
Simple–Complex	0	0.106	−0.119	0.124	0.454	0.39	0.335	1.000		
Restrained–Expressive	−0.025	0.036	−0.200	0.033	0.416	0.282	0.256	0.381	1.000	
Stable–Dynamic	0.167	0.26	−0.199	0.175	0.706	0.467	0.471	0.473	0.407	1.000

Reliability analysis was conducted on the 10 bipolar Kansei descriptor pairs using the 117 valid questionnaires. The overall scale showed satisfactory internal consistency, with a Cronbach's α of 0.809. The suitability of the data for factor analysis was further assessed using the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity [22]. As shown in Table 9, the KMO value was 0.824, and Bartlett's test of sphericity was significant, $\chi^2(45) = 518.442$, $p < 0.001$, indicating that the correlation matrix was suitable for EFA.

Table 9. Reliability and suitability tests for exploratory factor analysis.

Test Items	Indicators	Value
Reliability test	Cronbach's α	0.809
KMO test	Kaiser–Meyer–Olkin measure	0.824
Bartlett's sphericity test	Approximate chi-square value (χ^2)	518.442
	Degree of freedom (df)	45
	p value	<0.001

Exploratory factor analysis was subsequently conducted on the participant-level 117 × 10 matrix using principal axis factoring (PAF) as the extraction method, followed by Varimax rotation. Factor retention was evaluated using the Kaiser eigenvalue criterion, visual inspection of the scree plot, Horn's parallel analysis, and comparison of the two-factor and three-factor PAF solutions [23]. The first three observed eigenvalues of the correlation matrix were 3.983, 2.274, and 0.759, respectively.

The first two eigenvalues exceeded the Kaiser criterion of 1.0, and the scree plot showed a marked decline across the first two factors, followed by a flatter pattern from the third factor onward (Figure 4). Horn's parallel analysis was conducted using a common-factor procedure consistent with the PAF framework. The first three observed common-factor eigenvalues were 3.542, 1.744, and 0.153, compared with the corresponding 95th-percentile random eigenvalues of 0.757, 0.536, and 0.388, respectively.

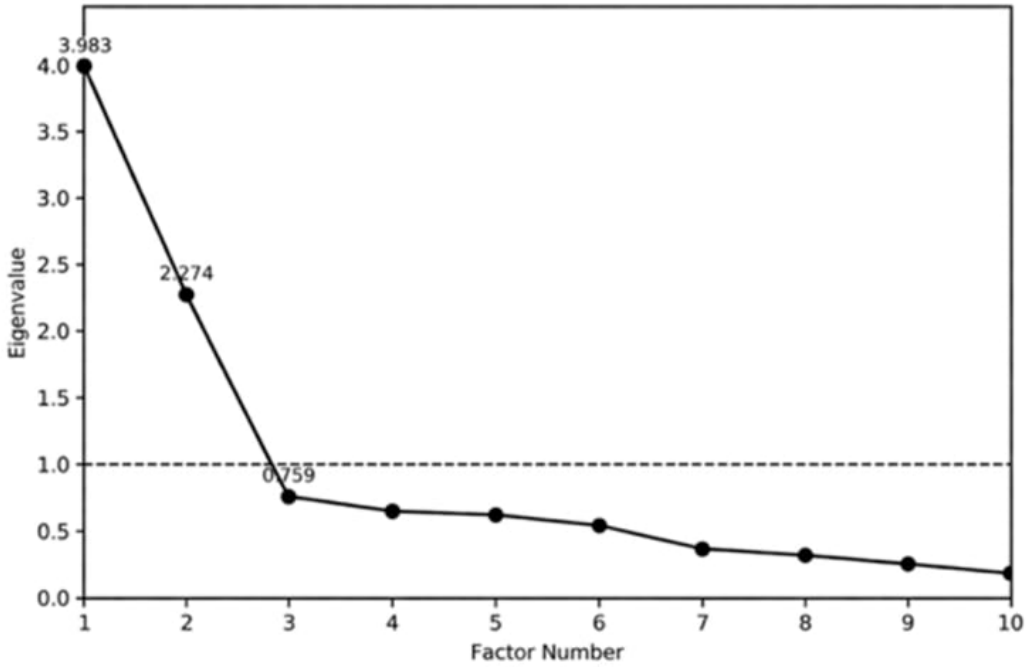


Figure 4. Scree plot of the participant-level Kansei variables. The dashed horizontal line indicates the Kaiser criterion (eigenvalue = 1.0).

All statistical analyses were conducted using IBM SPSS Statistics 29.0. Parallel analysis used 5000 randomly generated datasets and the 95th percentile criterion. The cross classified mixed effects models were estimated using restricted maximum likelihood (REML) with the MIXED procedure in IBM SPSS Statistics 29.0.

In this two-factor solution, the four descriptors related to spatial organization formed a distinct Spatial Order factor, whereas the remaining six descriptors formed a broader second factor combining material/surface perception and stylistic expression. The two-factor solution accounted for 53.79% of the variance, with Cronbach's α values of 0.789 and 0.842. When a three-factor solution was specified, PAF produced an interpretable 4–3–3 item structure corresponding to Spatial Order, Material Texture, and Stylistic Tension, accounting for 56.89% of the total variance. Heavy–Light, Rough–Delicate, and Plain–Ornate loaded primarily on Material Texture, whereas Simple–Complex, Restrained–Expressive, and Stable–Dynamic loaded primarily on Stylistic Tension; the four spatial descriptors remained associated with Spatial Order. To further compare the two competing solutions, RMSR was examined for the PAF solutions. Maximum-likelihood exploratory factor analysis (ML-EFA) was additionally conducted as a sensitivity analysis to obtain RMSEA, TLI, and CFI. The comparative results are summarized in Table 10.

Table 10. Comparison of the two- and three-factor solutions.

Criterion	Two-Factor Solution		Three-Factor Solution		
Variance accounted for	53.79%		56.89%		
PAF RMSR	0.039		0.032		
ML-EFA RMSEA	0.060		0.042		
ML-EFA TLI	0.961		0.980		
ML-EFA CFI	0.977		0.992		
Cronbach's α	Factor 1 0.789	Factor 2 0.842	Factor 1 0.789	Factor 2 0.846	Factor 3 0.685
Factor structure	Spatial Order + broader material/stylistic factor (4 + 6)		Spatial Order + Material Texture + Stylistic Tension (4 + 3 + 3)		

Parallel analysis favored the more parsimonious two-factor solution. Within this sample, the three-factor solution produced lower RMSR and RMSEA values and higher TLI and CFI values than the two-factor solution and provided greater differentiation between material/surface-related perception and broader stylistic expression. Considering these complementary findings, the three-factor structure was retained as an exploratory interpretive solution. The corresponding rotated factor loadings, communalities, and factor interpretations for the three-factor PAF solution are presented in Table 11.

Table 11. Rotated factor loadings and communalities for the three-factor PAF solution.

Bipolar Kansei Descriptor Pair	Factor 1	Factor 2	Factor 3	Communality	Factor Interpretation
Enclosed–Open	0.809	0.174	0.066	0.688	Spatial Order
Compact–Spacious	0.614	0.265	0.145	0.469	Spatial Order
Regular–Free-form	0.630	−0.091	−0.230	0.458	Spatial Order
Continuous–Fragmented	0.708	0.281	0.073	0.586	Spatial Order
Heavy–Light	0.157	0.626	0.617	0.798	Material Texture
Rough–Delicate	0.072	0.686	0.309	0.571	Material Texture
Plain–Ornate	0.406	0.742	0.263	0.785	Material Texture
Simple–Complex	−0.052	0.314	0.489	0.340	Stylistic Tension
Restrained–Expressive	−0.121	0.232	0.480	0.299	Stylistic Tension
Stable–Dynamic	0.055	0.344	0.758	0.695	Stylistic Tension

Factor 1 was primarily defined by Enclosed–Open (0.809), Compact–Spacious (0.614), Regular–Free-form (0.630), and Continuous–Fragmented (0.708). These descriptors primarily reflect perceptions of spatial enclosure, scale, organization, and continuity and were therefore interpreted as the Spatial Order factor.

Factor 2 was primarily defined by Heavy–Light (0.626), Rough–Delicate (0.686), and Plain–Ornate (0.742). These descriptors reflect visually perceived material weight, surface texture and refinement, and the degree of surface or decorative elaboration. Accordingly, this factor was retained as Material Texture. In the present study, Material Texture therefore refers to material- and surface-level visual perception rather than tactile texture alone [24,25]. Although Plain–Ornate may also carry a stylistic connotation, its loading on Factor 2 was interpreted primarily in relation to the visual richness, refinement, and decorative treatment of material surfaces rather than the overall formal style of the architectural composition. Heavy–Light showed substantial loadings on both Material Texture

(0.626) and Stylistic Tension (0.617), indicating residual overlap between material-related visual weight and broader stylistic expression. Its placement under Material Texture was therefore treated as an interpretive assignment based on its conceptual association with material-related visual perception.

Factor 3 was most strongly represented by Stable–Dynamic (0.758), whereas Simple–Complex (0.489) and Restrained–Expressive (0.480) showed more moderate loadings. Together, these descriptors reflect overall formal complexity, expressive intensity, and dynamism and were therefore interpreted as Stylistic Tension. In contrast to Material Texture, which concerns material- and surface-level visual characteristics, Stylistic Tension captures broader stylistic expression at the compositional level [26,27]. The relatively low communalities of Simple–Complex (0.340) and Restrained–Expressive (0.299), together with the factor-specific Cronbach's α of 0.685, indicate weaker psychometric support for this factor. Stylistic Tension was therefore interpreted as an exploratory passenger-perception dimension because the three descriptors collectively characterize a compositional-level perceptual domain that is conceptually distinct from the material- and surface-related perceptions represented by Material Texture. In the two-factor solution, these two perceptual domains were combined into a broader factor, whereas the three-factor representation preserved this distinction.

At the participant level, the exploratory three-factor representation accounted for 56.89% of the total variance, with Spatial Order, Material Texture, and Stylistic Tension accounting for 21.45%, 18.72%, and 16.72%, respectively (Table 12).

Table 12. Factor variance explanation.

Factor	Interpretation	Variance Explained	Cumulative Variance Explained
1	Spatial Order	21.45%	21.45%
2	Material Texture	18.72%	40.17%
3	Stylistic Tension	16.72%	56.89%

2.4. FAHP-Based Prioritization of Passenger-Compartment CMF Design Elements

Based on the exploratory three-factor representation retained from the Kansei analysis—Spatial Order, Material Texture, and Stylistic Tension—FAHP was employed to determine the expert-assessed relative priorities of the CMF design elements for the light-rail passenger compartment [12]. The three dimensions served as the evaluation criteria, while the experts assessed the relative priority of the CMF elements under each dimension. The resulting FAHP weights therefore represent aggregated expert judgments of relative design priority.

With CMF design for a light-rail passenger compartment inspired by Liaoning coastal vernacular dwelling culture defined as the goal layer (A), Spatial Order (B1), Material Texture (B2), and Stylistic Tension (B3) constituted the criterion layer, while Color (C1), Material (C2), Texture (C3), Gloss (C4), Pattern (C5), and Surface Treatment (C6) constituted the element layer. A three-level FAHP hierarchical evaluation model was therefore established, as shown in Figure 5.

2.4.1. Weight Calculation

Twelve experts participated in the FAHP evaluation. Experts were selected based on their research or professional experience in fields directly related to the evaluation framework. According to their primary professional backgrounds, the panel comprised five experts in rail transit and industrial design, three experts in CMF and material design, and four experts in vernacular architecture and regional culture. All experts had more

than three years of relevant research or professional experience. Before the evaluation, the research objectives, hierarchical structure, and definitions of all criteria and CMF design elements were explained to the experts to ensure a common understanding of the evaluation task.

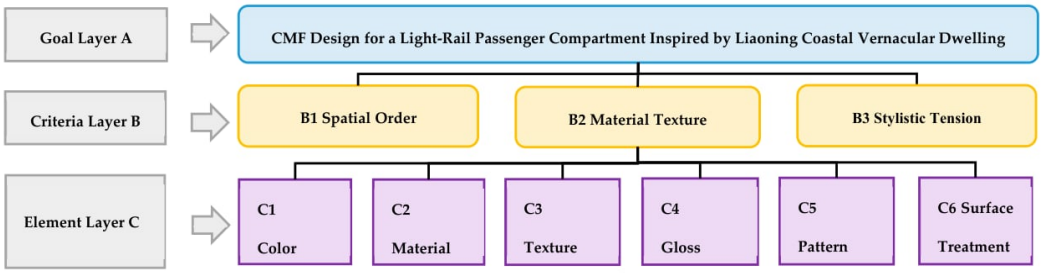


Figure 5. FAHP hierarchical evaluation model.The different frame colors distinguish the goal, criteria, and element layers and do not represent quantitative values or priority levels.

Before fuzzy conversion and group aggregation, the consistency of each expert's original Saaty judgment matrices was assessed using the CR [28]. A CR value below 0.10 was considered acceptable. Each expert completed one 3 × 3 criterion-level matrix and three 6 × 6 element-level matrices. All 48 individual matrices from the 12 experts satisfied this criterion, as shown in Table 13.

Table 13. Individual consistency ratios of the 12 FAHP experts.

Expert	Criterion	B1 Spatial Order	B2 Material Texture	B3 Stylistic Tension
No. 1	0.016	0.092	0.097	0.094
No. 2	0.025	0.059	0.099	0.064
No. 3	0.016	0.072	0.085	0.099
No. 4	0.025	0.099	0.075	0.089
No. 5	0.063	0.072	0.078	0.095
No. 6	0.016	0.082	0.081	0.064
No. 7	0.005	0.096	0.097	0.076
No. 8	0.003	0.066	0.092	0.072
No. 9	0.000	0.090	0.098	0.097
No. 10	0.003	0.090	0.078	0.072
No. 11	0.063	0.098	0.076	0.079
No. 12	0.008	0.052	0.093	0.087

In addition to assessing the internal consistency of each expert's judgment matrices, inter-expert agreement was evaluated using Kendall's coefficient of concordance (W) [29]. Kendall's W was calculated separately for the criterion layer and for the six CMF design elements under Spatial Order (B1), Material Texture (B2), and Stylistic Tension (B3).

As shown in Table 14, Kendall's W was 0.674 for the criterion layer and 0.577, 0.627, and 0.577 for Spatial Order, Material Texture, and Stylistic Tension, respectively. All four concordance tests were statistically significant ($p < 0.001$), indicating meaningful inter-expert concordance.

Pairwise comparisons were conducted using Saaty's 1–9 scale, and the judgments were converted into triangular fuzzy numbers (TFNs) according to the conversion rules presented in Table 15 [30].

Table 14. Inter-expert agreement assessed using Kendall's coefficient of concordance (*W*).

Layer/Dimension	Kendall's *W*	χ^2	*df*	*p*
Criterion layer	0.674	16.167	2	<0.001
Spatial Order (B1)	0.577	34.619	5	
Material Texture (B2)	0.627	37.619	5	
Stylistic Tension (B3)	0.577	34.619	5	

Table 15. Conversion of Saaty's 1–9 scale into triangular fuzzy numbers.

Saaty Scale	Linguistic Judgment	TFN (l,m,u)	Reciprocal TFN
1	Equal importance	(1, 1, 1)	(1, 1, 1)
2	Intermediate	(1, 2, 3)	(1/3, 1/2, 1)
3	Moderate importance	(2, 3, 4)	(1/4, 1/3, 1/2)
4	Intermediate	(3, 4, 5)	(1/5, 1/4, 1/3)
5	Strong importance	(4, 5, 6)	(1/6, 1/5, 1/4)
6	Intermediate	(5, 6, 7)	(1/7, 1/6, 1/5)
7	Very strong importance	(6, 7, 8)	(1/8, 1/7, 1/6)
8	Intermediate	(7, 8, 9)	(1/9, 1/8, 1/7)
9	Extreme importance	(9, 9, 9)	(1/9, 1/9, 1/9)

The TFNs were used to represent the uncertainty inherent in expert judgments. The fuzzy judgment matrix is defined in Equation (1):

$$\tilde{A}^{(k)} = \left(\tilde{a}_{ij}^{(k)}\right)_{n\times n}, \tag{1}$$

where $\tilde{a}_{ij}^{(k)}$ denotes the fuzzy judgment assigned by expert k to the relative importance of indicator i over indicator j. When $i = j$, $\tilde{a}_{ii}^{(k)} = (1,1,1)$. For $i \neq j$, the fuzzy judgment is represented by a triangular fuzzy number, as defined in Equation (2):

$$\tilde{a}_{ij}^{(k)} = \left(l_{ij}^{(k)}, m_{ij}^{(k)}, u_{ij}^{(k)}\right), \tag{2}$$

where $l_{ij}^{(k)}$, $m_{ij}^{(k)}$, and $u_{ij}^{(k)}$ denote the lower, modal, and upper values, respectively, of the triangular fuzzy number representing expert k's judgment of the relative importance of indicator i over indicator j. The reciprocal fuzzy judgment is defined in Equation (3):

$$\tilde{a}_{ji}^{(k)} = \left(\tilde{a}_{ij}^{(k)}\right)^{-1} = \left(\frac{1}{u_{ij}^{(k)}}, \frac{1}{m_{ij}^{(k)}}, \frac{1}{l_{ij}^{(k)}}\right). \tag{3}$$

The accepted expert judgments were aggregated using the component-wise geometric mean [31]. For K experts, the aggregated fuzzy judgment for indicator i relative to indicator j was calculated using Equation (4):

$$\tilde{a}_{ij}^{(agg)} = \left(\left(\prod_{k=1}^{K} {l_{ij}}^{(k)}\right)^{\frac{1}{K}}, \left(\prod_{k=1}^{K} {m_{ij}}^{(k)}\right)^{\frac{1}{K}}, \left(\prod_{k=1}^{K} {u_{ij}}^{(k)}\right)^{\frac{1}{K}}\right), \tag{4}$$

where $K = 12$ denotes the number of experts, and $\tilde{a}_{ij}^{(agg)}$ denotes the aggregated fuzzy judgment of the expert group regarding the relative importance of indicator i over indicator j.

Based on the experts' pairwise comparisons of the three criteria, a fuzzy judgment matrix for the criterion layer was constructed, as shown in Table 16. In addition to the criterion-level matrix, the aggregated fuzzy judgment matrices for the six CMF design elements under Spatial Order (B1), Material Texture (B2), and Stylistic Tension (B3) are presented in Tables 17–19.

Table 16. Aggregated fuzzy judgment matrix for the criterion layer.

Criterion	Spatial Order (B1)	Material Texture (B2)	Stylistic Tension (B3)
Spatial Order (B1)	(1.000, 1.000, 1.000)	(0.253, 0.340, 0.525)	(1.189, 1.658, 2.040)
Material Texture (B2)	(1.906, 2.942, 3.957)	(1.000, 1.000, 1.000)	(3.843, 4.858, 5.868)
Stylistic Tension (B3)	(0.490, 0.603, 0.841)	(0.170, 0.206, 0.260)	(1.000, 1.000, 1.000)

Table 17. Aggregated fuzzy judgment matrix of CMF design elements under Spatial Order (B1).

Spatial Order (B1)	Color (C1)	Material (C2)	Texture (C3)	Gloss (C4)	Pattern (C5)	Surface Treatment (C6)
Color (C1)	(1.000, 1.000, 1.000)	(1.906, 2.942, 3.957)	(1.060, 1.550, 1.944)	(1.260, 2.289, 3.302)	(0.833, 1.000, 1.201)	(1.972, 3.013, 4.032)
Material (C2)	(0.253, 0.340, 0.525)	(1.000, 1.000, 1.000)	(0.481, 0.630, 1.000)	(1.000, 1.414, 1.732)	(0.481, 0.630, 1.000)	(1.060, 1.740, 2.335)
Texture (C3)	(0.514, 0.645, 0.944)	(1.000, 1.587, 2.080)	(1.000, 1.000, 1.000)	(2.684, 3.703, 4.713)	(0.264, 0.360, 0.575)	(2.621, 3.634, 4.642)
Gloss (C4)	(0.303, 0.437, 0.794)	(0.577, 0.707, 1.000)	(0.212, 0.270, 0.373)	(1.000, 1.000, 1.000)	(0.259, 0.352, 0.556)	(0.391, 0.543, 0.944)
Pattern (C5)	(0.833, 1.000, 1.201)	(1.000, 1.587, 2.080)	(1.740, 2.777, 3.792)	(1.799, 2.844, 3.864)	(1.000, 1.000, 1.000)	(1.000, 1.414, 1.732)
Surface Treatment (C6)	(0.248, 0.332, 0.507)	(0.428, 0.575, 0.944)	(0.215, 0.275, 0.382)	(1.060, 1.843, 2.559)	(0.577, 0.707, 1.000)	(1.000, 1.000, 1.000)

Table 18. Aggregated fuzzy judgment matrix of CMF design elements under Material Texture (B2).

Material Texture (B2)	Color (C1)	Material (C2)	Texture (C3)	Gloss (C4)	Pattern (C5)	Surface Treatment (C6)
Color (C1)	(1.000, 1.000, 1.000)	(0.469, 0.609, 0.944)	(0.418, 0.556, 0.891)	(1.060, 1.740, 2.335)	(1.060, 2.069, 3.073)	(0.428, 0.575, 0.944)
Material (C2)	(1.060, 1.642, 2.131)	(1.000, 1.000, 1.000)	(1.698, 2.750, 3.772)	(1.414, 2.450, 3.464)	(7.024, 7.891, 8.739)	(1.123, 1.428, 1.658)
Texture (C3)	(1.123, 1.799, 2.392)	(0.265, 0.364, 0.589)	(1.000, 1.000, 1.000)	(3.772, 4.785, 5.793)	(2.872, 3.884, 4.891)	(1.260, 2.289, 3.302)
Gloss (C4)	(0.428, 0.575, 0.944)	(0.289, 0.408, 0.707)	(0.173, 0.209, 0.265)	(1.000, 1.000, 1.000)	(1.682, 2.711, 3.722)	(0.198, 0.247, 0.329)
Pattern (C5)	(0.325, 0.483, 0.944)	(0.114, 0.127, 0.142)	(0.204, 0.257, 0.348)	(0.269, 0.369, 0.595)	(1.000, 1.000, 1.000)	(0.114, 0.127, 0.142)
Surface Treatment (C6)	(1.060, 1.740, 2.335)	(0.603, 0.700, 0.891)	(0.303, 0.437, 0.794)	(3.043, 4.053, 5.059)	(7.024, 7.891, 8.739)	(1.000, 1.000, 1.000)

Table 19. Aggregated fuzzy judgment matrix of CMF design elements under Stylistic Tension (B3).

Stylistic Tension (B3)	Color (C1)	Material (C2)	Texture (C3)	Gloss (C4)	Pattern (C5)	Surface Treatment (C6)
Color (C1)	(1.000, 1.000, 1.000)	(1.972, 3.013, 4.032)	(1.060, 2.069, 3.073)	(1.642, 2.684, 3.703)	(0.913, 1.189, 1.442)	(1.817, 2.885, 3.915)
Material (C2)	(0.248, 0.332, 0.507)	(1.000, 1.000, 1.000)	(1.642, 2.684, 3.703)	(0.400, 0.561, 1.000)	(0.192, 0.238, 0.313)	(0.391, 0.543, 0.944)
Texture (C3)	(0.325, 0.483, 0.944)	(0.270, 0.373, 0.609)	(1.000, 1.000, 1.000)	(0.333, 0.500, 1.000)	(0.149, 0.175, 0.212)	(0.447, 0.569, 0.841)
Gloss (C4)	(0.270, 0.373, 0.609)	(1.000, 1.782, 2.498)	(1.000, 2.000, 3.000)	(1.000, 1.000, 1.000)	(0.760, 0.891, 1.096)	(1.123, 2.020, 2.872)
Pattern (C5)	(0.693, 0.841, 1.096)	(3.192, 4.207, 5.215)	(4.713, 5.719, 6.724)	(0.913, 1.123, 1.316)	(1.000, 1.000, 1.000)	(1.000, 1.189, 1.316)
Surface Treatment (C6)	(0.255, 0.347, 0.550)	(1.060, 1.843, 2.559)	(1.189, 1.757, 2.235)	(0.348, 0.495, 0.891)	(0.760, 0.841, 1.000)	(1.000, 1.000, 1.000)

The weights were calculated using the fuzzy geometric mean method [32]. For the i-th row of the judgment matrix, the fuzzy geometric mean is calculated as shown in Equation (5):

$$\widetilde{g}_i = \left(\left(\prod_{j=1}^{n} l_{ij}\right)^{\frac{1}{n}}, \left(\prod_{j=1}^{n} m_{ij}\right)^{\frac{1}{n}}, \left(\prod_{j=1}^{n} u_{ij}\right)^{\frac{1}{n}} \right). \tag{5}$$

The fuzzy geometric means were then summed to obtain $\widetilde{G}$, as shown in Equation (6):

$$\widetilde{G} = \sum_{i=1}^{n} \widetilde{g}_i = \left(\sum_{i=1}^{n} {g_i}^L, \sum_{i=1}^{n} {g_i}^M, \sum_{i=1}^{n} {g_i}^U \right), \tag{6}$$

where ${g_i}^L$, ${g_i}^M$ and ${g_i}^U$ denote the lower, modal, and upper values, respectively, of the fuzzy geometric mean for indicator i. The fuzzy weight of the i-th indicator was subsequently calculated using Equation (7):

$$\widetilde{w}_i = \widetilde{g}_i \otimes \widetilde{G}^{-1}, \tag{7}$$

where $\otimes$ denotes multiplication of triangular fuzzy numbers, and $\widetilde{G}^{-1} = \left(\frac{1}{\sum_{i=1}^{n} {g_i}^U}, \frac{1}{\sum_{i=1}^{n} {g_i}^M}, \frac{1}{\sum_{i=1}^{n} {g_i}^L} \right)$ denotes the multiplicative inverse of the triangular fuzzy number $\widetilde{G}$.

2.4.2. Defuzzification and Normalization

To obtain crisp weights suitable for comparison and ranking, the fuzzy weights were defuzzified using the centroid method. Let the fuzzy weight of the i-th indicator be $\widetilde{w}_i = (l_i, m_i, u_i)$. Its defuzzified value is then calculated as $w_i^* = \frac{l_i + m_i + u_i}{3}$. The defuzzified values were then normalized using Equation (8):

$$\hat{w}_i = \frac{w_i^*}{\sum_{j=1}^{n} w_j^*} \tag{8}$$

Using this procedure, the normalized weights of the three criteria and the local weights of the six CMF design elements under each criterion were obtained. Because the reported weights were rounded to three decimal places, minor deviations from 1.000 may occur.

As shown in Table 20, Material Texture (B2) received the highest normalized criterion weight (0.640), followed by Spatial Order (B1) (0.224) and Stylistic Tension (B3) (0.136). The same defuzzification and normalization procedures were then applied at the element level. The resulting fuzzy weights, defuzzified values, and normalized local weights of the six CMF design elements under each criterion are presented in Table 21.

Table 20. Criterion-level FAHP weights after defuzzification and normalization.

Criterion	Fuzzy Weight $\tilde{w}_i$	Defuzzified Value w_i^*	Normalized Weight $\hat{w}_i$
Spatial Order (B1)	(0.150, 0.220, 0.335)	0.235	0.224
Material Texture (B2)	(0.434, 0.647, 0.936)	0.672	0.640
Stylistic Tension (B3)	(0.098, 0.133, 0.198)	0.143	0.136

Table 21. Element-level FAHP local weights under the passenger-perception dimensions.

Criterion	CMF Element	Fuzzy Weight (*l*,*m*,*u*)	Defuzzified Value w_i^*	Local Weight
Spatial Order (B1)	Color (C1)	(0.146, 0.266, 0.451)	0.288	0.260
	Material (C2)	(0.072, 0.125, 0.229)	0.142	0.128
	Texture (C3)	(0.114, 0.196, 0.345)	0.218	0.197
	Gloss (C4)	(0.045, 0.075, 0.148)	0.090	0.081
	Pattern (C5)	(0.135, 0.242, 0.404)	0.260	0.235
	Surface Treatment (C6)	(0.057, 0.096, 0.178)	0.110	0.099
Material Texture (B2)	Color (C1)	(0.071, 0.128, 0.241)	0.147	0.133
	Material (C2)	(0.173, 0.302, 0.491)	0.322	0.293
	Texture (C3)	(0.133, 0.236, 0.407)	0.258	0.235
	Gloss (C4)	(0.046, 0.077, 0.140)	0.087	0.080
	Pattern (C5)	(0.026, 0.041, 0.072)	0.046	0.042
	Surface Treatment (C6)	(0.133, 0.217, 0.369)	0.240	0.218
Stylistic Tension (B3)	Color (C1)	(0.151, 0.288, 0.498)	0.312	0.282
	Material (C2)	(0.054, 0.093, 0.179)	0.109	0.098
	Texture (C3)	(0.040, 0.067, 0.135)	0.081	0.073
	Gloss (C4)	(0.088, 0.169, 0.307)	0.188	0.170
	Pattern (C5)	(0.164, 0.254, 0.397)	0.272	0.245
	Surface Treatment (C6)	(0.075, 0.129, 0.234)	0.146	0.132

As shown in Table 21, the local priorities of the CMF elements varied across the three criteria. Under Spatial Order (B1), Color (C1) and Pattern (C5) received relatively high local weights. Under Material Texture (B2), Material (C2) and Texture (C3) ranked highest, whereas under Stylistic Tension (B3), Color (C1) and Pattern (C5) were prioritized. These local weights were subsequently combined with the criterion weights to calculate the global weights of the six CMF design elements.

2.4.3. Consistency Test

To assess the consistency of the aggregated expert judgment, the modal value m_{ij} of each triangular fuzzy judgment value was used to construct a crisp reciprocal judgment matrix. The maximum eigenvalue, λ_{max} is calculated as shown in Equation (9) [28]:

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(AW)_i}{w_i} \quad (9)$$

The consistency index (CI) is calculated as shown in Equation (10):

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{10}$$

The consistency ratio (CR) is calculated as shown in Equation (11):

$$CR = \frac{CI}{RI}, \tag{11}$$

where A denotes the crisp reciprocal judgment matrix, W denotes the corresponding priority vector, n denotes the order of the matrix, and RI denotes the average random consistency index. For the 3 × 3 criterion-layer matrix, RI = 0.58, whereas for the 6 × 6 element-level matrices, RI = 1.24. A judgment matrix was considered acceptably consistent when $CR < 0.10$; otherwise, the corresponding pairwise comparisons required reassessment.

Using this procedure, consistency was evaluated for the criterion-layer matrix and the three element-level matrices. The resulting CR values were 0.000002 for the criterion layer, 0.058269 for Spatial Order (B1), 0.068621 for Material Texture (B2), and 0.062922 for Stylistic Tension (B3). All four CR values were below 0.10, indicating that the aggregated criterion-level and element-level judgment matrices satisfied the consistency requirement and were retained for the subsequent FAHP weighting analysis.

2.4.4. Global Weighting and Ranking of Design Elements

Let w_{B_k} denote the normalized weight of criterion B_k, and let $w_{C_j|B_k}$ denote the local weight of CMF element C_j under criterion B_k. The global weight of C_j is calculated as shown in Equation (12):

$$W_{C_j} = \sum_{k=1}^{3} w_{B_k} w_{C_j|B_k}, \tag{12}$$

where W_{C_j} denotes the global weight of CMF element C_j. The six elements were ranked according to their resulting global weights. The global weights represent expert-assessed design priorities within the FAHP hierarchy.

As shown in Table 22, Material (C2) received the highest global weight (0.229), followed by Texture (C3) (0.204) and Color (C1) (0.182). These were followed by Surface Treatment (C6) (0.180), Pattern (C5) (0.113) and Gloss (C4) (0.092). The global weights of Color and Surface Treatment were relatively close.

Table 22. Global weights of the CMF design elements.

Design Elements	Spatial Order (B1) Local Weight	Material Texture (B2) Local Weight	Stylistic Tension (B3) Local Weight	Global Weight
Color (C1)	0.260	0.133	0.282	0.182
Material (C2)	0.128	0.293	0.098	0.229
Texture (C3)	0.197	0.235	0.073	0.204
Gloss (C4)	0.081	0.080	0.170	0.092
Pattern (C5)	0.235	0.042	0.245	0.113
Surface Treatment (C6)	0.099	0.218	0.132	0.180

These rankings guided the subsequent designer-led CMF translation, with greater emphasis placed on the higher-priority elements in material selection, texture organization, and color relationships.

2.4.5. Sensitivity Analysis

A criterion-weight sensitivity analysis was conducted to assess the stability of the global ranking of the six CMF design elements. Each criterion weight was independently

varied by ±10% from its baseline value, while the remaining two weights were proportionally adjusted to maintain a total of 1.000. The element-level local weights were held constant, and the global weights were recalculated under six perturbation scenarios. An additional criterion-omission scenario was examined by setting the weight of Stylistic Tension (B3) to zero and proportionally renormalizing the weights of Spatial Order (B1) and Material Texture (B2), as shown in Table 23.

Table 23. Criterion-weight sensitivity analysis of the global CMF-element priorities.

Scenario	B1	B2	B3	C1 Color	C2 Material	C3 Texture	C4 Gloss	C5 Pattern	C6 Surface Treatment
Baseline	0.224	0.640	0.136	0.182	0.229	0.204	0.092	0.113	0.180
B1 − 10%	0.202	0.659	0.140	0.179	0.232	0.205	0.092	0.109	0.182
B1 + 10%	0.246	0.622	0.132	0.184	0.226	0.204	0.092	0.116	0.177
B2 − 10%	0.264	0.576	0.160	0.190	0.218	0.199	0.094	0.125	0.173
B2 + 10%	0.184	0.704	0.112	0.173	0.241	0.210	0.090	0.100	0.186
B3 − 10%	0.227	0.650	0.122	0.180	0.231	0.206	0.091	0.111	0.180
B3 + 10%	0.220	0.630	0.150	0.183	0.227	0.202	0.093	0.115	0.179
B3 Omitted	0.259	0.741	0.000	0.166	0.250	0.225	0.080	0.092	0.187

Material (C2) and Texture (C3) remained first and second across all scenarios, while Pattern (C5) and Gloss (C4) consistently remained fifth and sixth. Among the ±10% perturbation scenarios, Color (C1) and Surface Treatment (C6) exchanged the third and fourth positions under B1 − 10% and B2 + 10% and were tied under B3 − 10% at the reported three-decimal precision. In the additional B3-omission scenario, Material and Texture remained the two highest-ranked elements, while Surface Treatment and Color occupied the third and fourth positions, respectively. Overall, the principal priority pattern remained stable, whereas the ordering of the middle-ranked elements was more sensitive to changes in criterion weights and structure.

3. Cultural Imagery and FAHP-Guided CMF Translation

The local FAHP weights of the CMF design elements under each passenger-perception dimension were used to establish relative design priorities for the subsequent CMF translation. To ensure a consistent prioritization rule, the six elements were ranked in descending order by their normalized local weights, and the three highest-ranked elements were designated as primary translation carriers; the remaining three were retained as complementary design considerations. Rather than directly replicating external cultural symbols, the translation process sought to connect the identified cultural characteristics with appropriate CMF design attributes [33]. Guided by the FAHP-derived priorities, the designer subsequently translated the prioritized CMF elements into specific design decisions concerning hue, lightness, chroma, material category, texture direction, pattern density, gloss level, and surface-treatment techniques [34]. These parameter-level decisions represent designer-led interpretations informed by the cultural analysis and FAHP priorities.

Based on the FAHP results, the local weight $w_{C_j|B_k}$ reflects the expert-assessed relative priority of CMF design element C_j under passenger-perception dimension B_k. For the subsequent design translation, this local weight was used as the design-priority coefficient R_{kj}, as shown in Equation (13):

$$R_{kj} = w_{C_j|B_k}, \tag{13}$$

where R_{kj} represents the relative design priority of CMF design element C_j under passenger-perception dimension B_k. A higher value of R_{kj} indicates a higher expert-assessed priority for considering the corresponding CMF element in the subsequent design translation. This coefficient serves as a prioritization guide rather than an empirical measure of a causal or predictive relationship between the CMF element and passenger perception.

- FAHP-guided translation of Spatial Order, as shown in Figure 6a: Spatial Order was translated with reference to courtyard enclosure, axial organization, spatial depth, and component sequence. Color (C1, 0.260), Pattern (C5, 0.235), and Texture (C3, 0.197) were prioritized according to their local FAHP weights. These priorities informed the use of color zoning, differentiated lightness levels, continuous texture organization, and regular visual repetition to express continuity, order, and spatial hierarchy within the passenger compartment;
- FAHP-guided translation of Material Texture, as shown in Figure 6b: Material Texture was translated with reference to the natural colors, visual textures, and surface characteristics of local materials such as brick, stone, and wood. Material (C2, 0.293), Texture (C3, 0.235), and Surface Treatment (C6, 0.218) were prioritized. Accordingly, stone-like and wood-grain visual expressions, fabric textures, and embossed surface treatments were incorporated to develop the material and surface character of the CMF proposal;
- FAHP-guided translation of Stylistic Tension, as shown in Figure 6c: Stylistic Tension was translated with reference to low-chroma color relationships, simplified decoration, restrained formal expression, and visual stability. Color (C1, 0.282), Pattern (C5, 0.245), and Gloss (C4, 0.170) were prioritized. These priorities informed the use of low-chroma color relationships, simplified pattern expressions, predominantly matte surfaces, and limited accent colors to create a restrained yet visually layered stylistic expression.

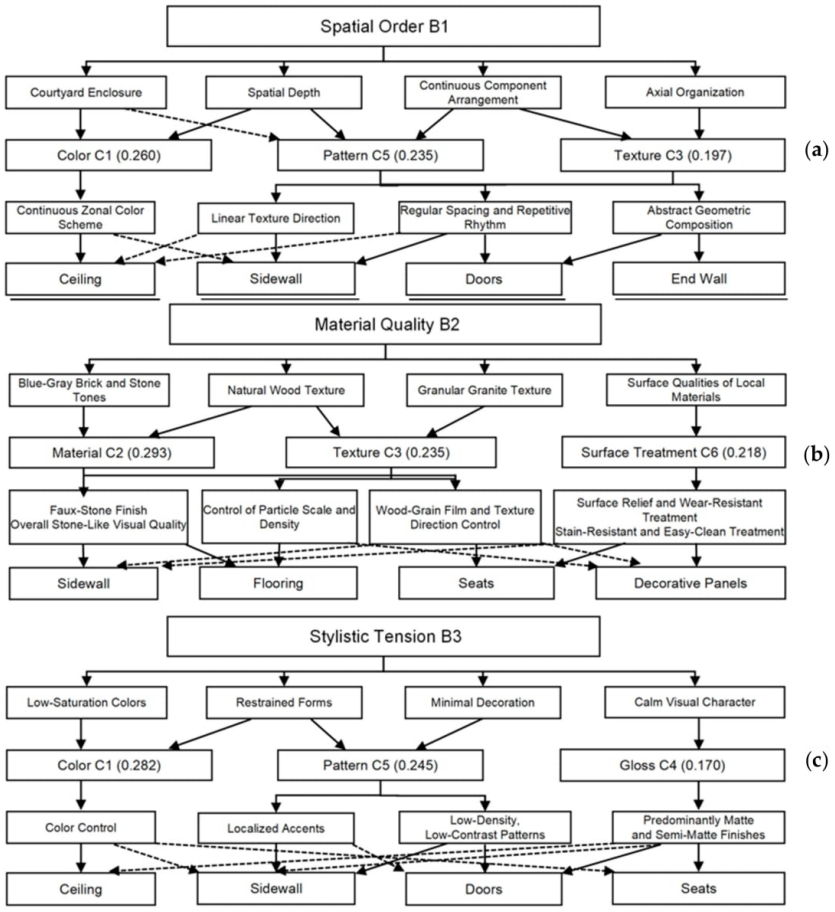


Figure 6. FAHP-guided CMF translation for the three passenger-perception dimensions: (**a**) Spatial Order; (**b**) Material Texture; (**c**) Stylistic Tension.

4. Conceptual CMF Design Scheme for the Light-Rail Passenger Compartment

The conceptual CMF design proposal was developed for the application context of the Dalian Metro Line 12 passenger compartment. The vehicle configuration was referenced to the Dalian Route 202 extension-line rapid-transit vehicle developed by CRRC Dalian for the former Route 202 rail-line extension project, which was subsequently renamed Dalian Metro Line 12 [35]. The reference vehicle is a standard B2-type vehicle with a maximum operating speed of 100 km/h and a lightweight integral load-bearing welded stainless-steel carbody [36]. The use of high-strength stainless steel was reported to address the humid and relatively saline coastal operating environment along the route and to enhance corrosion resistance.

Guided by the passenger-perception dimensions and expert-assessed FAHP priorities, selected characteristics of Liaoning coastal vernacular dwellings—including courtyard order, structural rhythm, brick-, stone-, and wood-related visual characteristics, and a restrained low-chroma aesthetic—were translated into conceptual CMF decisions for the passenger compartment. The FAHP results established the relative priorities of Color, Material, Texture, Gloss, Pattern, and Surface Treatment under the three passenger-perception dimensions and informed subsequent decisions concerning color zoning, material expression, texture organization, pattern application, gloss control, and surface treatment. The relationships among the FAHP-derived priorities, cultural references, design decisions, and applied interior interfaces are shown in Table 24.

Table 24. Traceability between FAHP-derived CMF priorities and conceptual design decisions.

Passenger-Perception Dimension	Prioritized CMF Element	Local Weight	Cultural Reference	Design Decision	Applied Interface
Spatial Order	Color (C1)	0.260	Courtyard enclosure and spatial hierarchy	Grayish-white and blue-gray zoning with differentiated lightness	Ceiling, sidewalls
	Pattern (C5)	0.235	Axial organization and component repetition	Regular linear and repetitive geometric organization	Ceiling, doors, end walls
	Texture (C3)	0.197	Structural continuity	Continuous low-contrast texture organization	Ceiling, sidewalls
Material Texture	Material (C2)	0.293	Brick, stone, and wood characteristics	Wood-grain, stone-inspired, and fabric-related material expression	Seats, panels, flooring
	Texture (C3)	0.235	Natural surface characteristics	Fine-grained, woven, and wood-grain texture expressions	Flooring, seats, panels
	Surface Treatment (C6)	0.218	Natural surface characteristics	Embossed surface-treatment concepts	Interior panels
Stylistic Tension	Color (C1)	0.282	Restrained low-chroma aesthetic	Low-chroma gray-blue palette with limited accent colors	Overall interior
	Pattern (C5)	0.245	Simplified regional expression	Low-density abstract geometric patterns	Doors, end walls
	Gloss (C4)	0.170	Visual restraint	Predominantly matte and low-gloss surface effects	Interior surfaces

Based on these priority–decision relationships, the corresponding CMF applications were developed for the ceiling, sidewalls, doors, seats, flooring, and end walls. The resulting CMF design requirements were then used as the basis for preliminary visual exploration. Midjourney was employed during this stage to generate initial visual drafts reflecting the established color relationships, material expressions, textures, patterns, and overall

stylistic direction. The generated drafts were reviewed by the designer, and the selected design direction was subsequently developed and modeled in Autodesk 3ds Max. V-Ray was used for material, lighting, and rendering settings. The rendered images were then manually refined in Adobe Photoshop for visual-detail adjustment and final presentation. The resulting conceptual CMF design is shown in Figure 7.



Figure 7. Conceptual CMF design proposal for the Dalian Metro Line 12 light-rail passenger compartment.

The resulting scheme is presented as a conceptual design rather than a production-ready engineering solution. Candidate materials and finishes would require further specification and verification against applicable rail-vehicle requirements before practical implementation, including the fire-protection requirements specified in CJ/T 416—2012 [37].

- Spatial Order design of the ceiling and sidewalls, as shown in Figure 8a: Under Spatial Order, Color (C1, 0.260), Pattern (C5, 0.235), and Texture (C3, 0.197) received the highest local FAHP weights. Accordingly, the ceiling employs a continuous longitudinal composition, symmetrical layouts, regular spacing, and repetitive linear organization to express axial order and spatial continuity. A grayish-white base with low-chroma blue-gray accents provides differentiated lightness and restrained contrast, while continuous low-contrast textures on the sidewalls reinforce spatial enclosure and continuity;
- Flooring and surface-treatment concept, as shown in Figure 8b: The flooring uses a dark-gray, fine-grained, stone-inspired texture to contrast with the lighter ceiling and sidewalls while maintaining low visual complexity. The treatment references the material characteristics of Liaoning coastal vernacular dwellings without directly reproducing traditional stone surfaces;
- Material Texture design of the seats and decorative panels, as shown in Figure 8c: Under Material Texture, Material (C2, 0.293), Texture (C3, 0.235), and Surface Treatment (C6, 0.218) received the highest local FAHP weights. Low-chroma gray-blue

fabric with fine woven textures is applied to the seats, while light wood-grain finishes and selective embossed treatments are used on seat-end and wall panels. These treatments reinterpret brick-, stone-, and wood-related visual characteristics through contemporary material and surface expressions;

- Stylistic Tension and cultural-pattern design of the doors and end walls, as shown in Figure 8d: Under Stylistic Tension, Color (C1, 0.282), Pattern (C5, 0.245), and Gloss (C4, 0.170) received the highest local FAHP weights. The doors and end walls therefore employ a restrained low-chroma gray-blue palette, low-density abstract geometric patterns, and predominantly matte or low-gloss surfaces. Courtyard boundaries, axial relationships, and repeated architectural components are abstracted into fine-line geometric patterns to provide subtle regional visual cues.



Figure 8. FAHP-guided CMF applications in the conceptual light-rail passenger-compartment design: (**a**) Spatial Order design of the ceiling and sidewalls; (**b**) Flooring and texture concept; (**c**) Material Texture design of the seats and decorative panels; (**d**) Stylistic Tension and cultural-pattern application to the doors and end walls.

5. User Evaluation of the Proposed CMF Design

To assess participants' perceptions and acceptance of the proposed CMF design for the light-rail passenger compartment, a user evaluation was conducted using the final design renderings. Responses were screened before analysis. Questionnaires were excluded if they were incomplete, contained substantial missing responses, or showed clearly patterned responses indicating insufficient engagement, such as invariant responses across the evaluation items. After screening, 115 out of the 130 returned questionnaires were retained, corresponding to a valid response rate of 88.46%. The questionnaire was anonymous and participation was voluntary. Before beginning the survey, participants were informed of the study purpose, the anonymous nature of the questionnaire, and the use of the collected data. Consent was implied by their voluntary completion of the questionnaire.

Participants were recruited through online questionnaire distribution, networks of individuals with urban-rail travel experience, offline recruitment, and relevant university

and professional networks. Group membership was determined according to self-reported educational, research, or occupational background. The final sample comprised 62 general passengers (53.91%), 26 design practitioners or researchers (22.61%), and 27 cultural-tourism or regional-culture practitioners or researchers (23.48%). Of the 115 participants, 49 were male (42.61%) and 66 were female (57.39%). In terms of age, 22 participants (19.13%) were aged 18–25 years, 35 (30.43%) were aged 26–35 years, 31 (26.96%) were aged 36–45 years, and 27 (23.48%) were aged 46 years or older. For Liaoning culture, 25.22% of participants reported low familiarity, 21.74% moderate familiarity, and 53.04% relatively high familiarity. The corresponding proportions for Liaoning coastal culture were 34.78%, 21.74%, and 43.48%, respectively.

The evaluation materials consisted of overall and detailed renderings of the passenger compartment, including the ceiling, sidewalls, doors, seats, and flooring. All images were presented using consistent aspect ratios, resolution, background presentation, and color representation to minimize differences in visual presentation.

The design-evaluation section comprised 14 items across five dimensions: Spatial Order (2 items), Material Texture (3 items), Stylistic Tension (3 items), Perceived Cultural Correspondence (3 items), and Visual Comfort (3 items), as shown in Table 25. The first three dimensions corresponded to the passenger-perception dimensions identified in the preceding Kansei analysis. Perceived Cultural Correspondence assessed the extent to which the proposed design was perceived to correspond with the cultural characteristics of Liaoning coastal vernacular dwellings, whereas Visual Comfort assessed the participants' overall visual experience of the proposed design. The questionnaire employed a 7-point Likert scale, where 1 represented "strongly inconsistent", 4 represented "neutral", and 7 represented "strongly consistent" [38].

Table 25. Items used in the final user-evaluation questionnaire.

Evaluation Dimension	Item Code	Evaluation Item
Spatial Order	a	The zoning and texture arrangement of the ceiling, sidewalls, and door areas are continuous and orderly.
	b	The interface connections and repetitive arrangement among the ceiling, sidewalls, and door areas create a clear sense of spatial hierarchy.
Material Texture	a	The seats, decorative panels, and flooring convey natural and rustic material qualities.
	b	The combination of different materials, textures, and surface finishes is harmonious and creates a clear sense of material layering.
	c	The textures and surface finishes of the major interior components provide a coherent yet distinguishable material character.
Stylistic Tension	a	The overall combination of colors, patterns, and surface finishes conveys a calm and restrained visual character.
	b	The contrast and variation among colors, patterns, and surface finishes create an appropriate degree of visual tension and layering without disrupting the overall coherence of the interior.
	c	The integration of color, texture, and surface characteristics derived from traditional architectural materials with contemporary light-rail design elements creates a distinctive yet coherent stylistic character.
Perceived Cultural Correspondence	a	The passenger-compartment design evokes associations with Liaoning coastal vernacular dwelling culture.
	b	The spatial forms, material textures, colors, and patterns correspond well with the characteristic visual qualities of Liaoning coastal vernacular dwellings.
	c	The regional cultural references are integrated naturally into the modern light-rail interior rather than appearing as isolated decorative symbols.
Visual Comfort	a	The overall color coordination, lightness, and interface contrast of the passenger compartment are comfortable and harmonious.
	b	The texture density, patterns, and surface finishes are appropriate, creating a clear and visually uncluttered overall effect.
	c	The combined effects of color, texture, pattern, and surface finish provide an appropriate level of visual stimulation without causing excessive visual fatigue.

Each evaluation dimension comprised two or three items. For each participant, the score for a given dimension was calculated as the arithmetic mean of the corresponding item scores. Let x_{idr} denote the score assigned by participant i to item r within dimension d, and m_d denote the number of items in dimension d. The participant-level composite score for dimension d was calculated as in Equation (14):

$$X_{id} = \frac{1}{m_d}\sum_{r=1}^{m_d} x_{idr} \tag{14}$$

After the composite scores were obtained for all 115 participants, the mean score for each dimension was calculated as: $\overline{X}_d = \frac{1}{115}\sum_{i=1}^{115} X_{id}$. The standard deviation for each dimension was calculated as: $S_d = \sqrt{\frac{\sum_{i=1}^{115}\left(X_{id}-\overline{X}_d\right)^2}{114}}$. Here, $\overline{X}_d$ represents the mean composite score for dimension d, and S_d represents the dispersion of the participants' composite scores. Higher mean scores indicate more positive evaluations of the corresponding dimension.

The neutral midpoint of the 7-point Likert scale (4) was used as the reference value. The hypotheses were specified as H_0: $\mu d = 4$ and H_1: $\mu d > 4$. A one-sample t-test was conducted for each composite dimension score using: $t = \frac{\overline{X}_d - 4}{S_d/\sqrt{115}}$, with $df = 114$. When $\overline{X}_d > 4$ and the one-tailed test yielded $p < 0.05$, the mean composite score was interpreted as significantly above the neutral midpoint. Parametric analysis of the composite scores was used when the relevant statistical assumptions were adequately satisfied [39].

Item-level performance was examined before the reliability and structural characteristics of the final user-evaluation questionnaire were assessed. As shown in Table 26, the mean, standard deviation, and corrected item–total correlation were calculated for each of the 14 evaluation items.

Table 26. Item-level descriptive statistics and corrected item–total correlations.

Dimension	Item	Mean	SD	Corrected Item–Total Correlation
Spatial Order	a	5.617	0.768	0.549
	b	5.809	0.782	0.549
Material Texture	a	5.765	0.741	0.557
	b	5.904	0.783	0.603
	c	5.922	0.829	0.576
Stylistic Tension	a	5.426	0.795	0.658
	b	5.626	0.853	0.624
	c	5.530	0.940	0.653
Perceived Cultural Correspondence	a	5.426	0.909	0.617
	b	5.478	0.994	0.618
	c	5.522	0.872	0.665
Visual Comfort	a	5.757	0.833	0.584
	b	5.861	0.771	0.613
	c	5.765	0.809	0.576

The reliability and exploratory structural characteristics of the 14-item user-evaluation scale were then examined. Internal consistency was assessed using Cronbach's α and mean inter-item correlations. The KMO measure and Bartlett's test of sphericity were used to assess the suitability of the correlation matrix for component analysis. A theory-specified five-component PCA with Varimax rotation was subsequently conducted to examine whether the observed item structure was consistent with the predefined five dimensions [22].

Cronbach's α ranged from 0.709 to 0.798 across the five dimensions, with an overall value of 0.807. Mean inter-item correlations ranged from 0.501 to 0.572. The KMO value was 0.757, and Bartlett's test of sphericity was significant, $\chi^2(91) = 500.582$, $p < 0.001$, supporting the suitability of the 14-item correlation matrix for exploratory component analysis (Table 27).

Table 27. Internal consistency and suitability for structural analysis of the user evaluation.

Scale/Dimension	Cronbach's α	Mean Inter-Item r
Spatial Order	0.709	0.549
Material Texture	0.750	0.501
Stylistic Tension	0.798	0.572
Perceived Cultural Correspondence	0.790	0.560
Visual Comfort	0.760	0.515
Overall questionnaire	0.807	0.231
Test	**Statistic**	**Value**
Kaiser–Meyer–Olkin measure	KMO	0.757
Bartlett's test of sphericity	χ^2	500.582
	df	91
	p	<0.001

As shown in Table 28, all 14 items loaded most strongly on their intended components. The primary component loadings ranged from 0.768 to 0.851, and the communalities ranged from 0.659 to 0.777.

Table 28. Rotated component loadings for the user evaluation.

Dimension	Item Code	Spatial Order	Material Texture	Stylistic Tension	Perceived Cultural Correspon-dence	Visual Comfort	Communality
Spatial Order	a	0.836	0.188	0.124	0.060	0.131	0.770
	b	0.851	0.039	0.138	0.144	0.109	0.777
Material Texture	a	0.052	0.784	0.080	0.183	0.041	0.659
	b	0.199	0.826	−0.032	−0.004	0.143	0.743
	c	0.008	0.768	0.271	0.071	0.102	0.679
Stylistic Tension	a	0.075	0.087	0.832	0.093	0.119	0.729
	b	0.150	0.101	0.798	0.156	0.001	0.694
	c	0.067	0.094	0.829	0.061	0.141	0.724
Perceived Cultural Correspon-dence	a	0.189	0.086	0.029	0.829	−0.020	0.732
	b	−0.001	0.055	0.175	0.803	0.082	0.686
	c	0.050	0.108	0.105	0.828	0.191	0.747
Visual Comfort	a	0.094	0.229	0.016	0.000	0.801	0.704
	b	0.117	0.063	0.094	0.095	0.813	0.696
	c	0.050	0.001	0.146	0.140	0.792	0.671

The eigenvalues and explained variance of the theory-specified five-component PCA solution are summarized in Table 29.

Table 29. Eigenvalues and explained variance of the theory-specified five-component PCA solution.

Component	Eigenvalue	Variance Explained (%)	Cumulative Variance (%)
Component 1	4.020	28.71	28.71
Component 2	1.712	12.23	40.95
Component 3	1.573	11.24	52.18
Component 4	1.503	10.74	62.92
Component 5	1.199	8.57	71.49

The theory-specified five-component solution accounted for 71.49% of the total variance. The eigenvalues of the five retained components were 4.020, 1.712, 1.573, 1.503, and 1.199, accounting for 28.71%, 12.23%, 11.24%, 10.74%, and 8.57% of the total variance, respectively. The five-component solution was specified a priori on the basis of the five theoretically defined evaluation dimensions. The PCA was used as an exploratory assessment of whether the observed item grouping was consistent with the predefined questionnaire structure.

As shown in Table 30, all five composite dimension scores were significantly above the neutral midpoint of 4 (all $p < 0.001$). Material Texture received the highest mean score (M = 5.864, SD = 0.641). Visual Comfort (M = 5.794, SD = 0.662) and Spatial Order (M = 5.713, SD = 0.682) followed. Perceived Cultural Correspondence received the lowest mean score (M = 5.475, SD = 0.777). Skewness ranged from −0.386 to −0.121 and excess kurtosis from −0.344 to 0.277, indicating only mild distributional asymmetry. The Wilcoxon signed-rank tests yielded the same inference for all five dimensions (all $p < 0.001$).

Table 30. Composite-score statistics and robustness analyses.

Evaluation Dimension	Mean	SD	95% CI	One-Sample *t*	*p* (*t*-Test)	Cohen's *d*	Skewness	Excess Kurtosis	Wilcoxon *Z*	*p* (Wilcoxon)
Spatial Order	5.713	0.682	[5.587, 5.839]	26.934	1.507×10^{-51}	2.512	−0.137	−0.344	−9.283	<0.001
Material Texture	5.864	0.641	[5.745, 5.982]	31.172	6.358×10^{-58}	2.907	−0.386	0.277	−9.330	
Stylistic Tension	5.528	0.729	[5.393, 5.662]	22.456	5.772×10^{-44}	2.094	−0.121	−0.156	−9.196	
Perceived Cultural Correspondence	5.475	0.777	[5.332, 5.619]	20.351	4.670×10^{-40}	1.898	−0.234	−0.163	−9.136	
Visual Comfort	5.794	0.662	[5.672, 5.916]	29.080	7.278×10^{-55}	2.712	−0.265	0.052	−9.325	

To examine differences among participant groups, the five composite dimension scores were compared using Welch's one-way ANOVA, accounting for unequal group sizes and potential heterogeneity of variance. Significant omnibus effects were followed by Games–Howell post hoc comparisons, as shown in Table 31.

Welch's ANOVA showed no significant between-group differences in Spatial Order, Material Texture, Stylistic Tension, or Visual Comfort (all $p > 0.05$). A significant group effect was observed for Perceived Cultural Correspondence (Welch's $F = 6.543$, $p = 0.003$). Games–Howell post hoc comparisons were therefore conducted for this dimension.

As shown in Table 32, the Perceived Cultural Correspondence scores were significantly higher in the cultural-tourism/regional-culture group than in the general-passenger group (mean difference = 0.619, 95% CI [0.209, 1.029], $p = 0.002$).

Table 31. Between-group comparisons of the user-evaluation dimensions.

Evaluation Dimension	General Passengers M ± SD	Design Practitioners or Researchers M ± SD	Cultural-Tourism/Regional-Culture Practitioners or Researchers M ± SD	Welch's *F*	*p*
Spatial Order	5.660 ± 0.689	5.790 ± 0.643	5.761 ± 0.716	0.425	0.656
Material Texture	5.770 ± 0.645	6.040 ± 0.591	5.910 ± 0.659	1.848	0.167
Stylistic Tension	5.450 ± 0.750	5.670 ± 0.680	5.570 ± 0.728	0.930	0.400
Perceived Cultural Correspondence	5.280 ± 0.767	5.500 ± 0.694	5.899 ± 0.725	6.543	0.003
Visual Comfort	5.700 ± 0.667	5.930 ± 0.621	5.879 ± 0.679	1.431	0.248

Table 32. Games–Howell post hoc comparisons.

Pairwise Comparison	Mean Difference	95% CI	Adjusted *p*
Design–General	0.220	[−0.184, 0.624]	0.394
Cultural/Regional–General	0.619	[0.209, 1.029]	0.002
Cultural/Regional–Design	0.399	[−0.072, 0.870]	0.111

6. Discussion

Material and Texture received the highest global FAHP priorities, followed by Color. Their prominence may reflect the recurring use of brick, stone, wood, and natural surface qualities in the vernacular dwelling samples, and their applicability across multiple passenger-compartment interfaces. Recent CMF studies also show that color, material, and texture influence style imagery and perceptual responses [6]. The FAHP weights represent expert-assessed design priorities, whereas the CMF parameter choices remain designer-led.

Material Texture received the highest mean score, whereas Perceived Cultural Correspondence received the lowest. All five dimensions remained significantly above the neutral midpoint. The relatively lower cultural-correspondence score may reflect the restrained and abstract translation strategy, which maintained visual coherence but made regional cultural cues less explicit. Recent studies of subway environments have identified differences between intended cultural representation and passenger perception [15]. Because the Liaoning coastal vernacular theme was disclosed in the questionnaire, these scores represent perceived correspondence with a stated theme. The higher Perceived Cultural Correspondence scores in the cultural-tourism/regional-culture group compared with the general-passenger group further suggest that cultural-correspondence judgments may vary with participants' professional or cultural background.

Several methodological limitations should be acknowledged. First, the 12 photographic stimuli were presented using a consistent format and display size, but their original photographic characteristics—including viewpoint, lighting, cropping, weather, background, and vegetation—could not be fully controlled. Participant-level averaging in the EFA emphasized general perceptual patterns across the visual-sample set and reduced image-specific variation. The resulting factors should be interpreted as participant-level perceptual patterns across the stimulus set. Mixed-effects analysis of the original image-level ratings showed greater participant-level than visual-sample-level variation. Visual-sample variance remained non-zero, indicating perceptual differences among the dwelling images.

Second, the three-factor Kansei solution provided an exploratory representation that distinguished material/surface perception from broader stylistic expression. Although parallel analysis favored the more parsimonious two-factor solution, the three-factor solution yielded lower RMSR and RMSEA values and higher TLI and CFI values in the present

sample. The three-factor structure was retained as an exploratory interpretive solution to preserve this distinction. Stylistic Tension showed weaker psychometric support than the other two factors, and should remain provisional until replicated in an independent sample. Third, the cultural-characteristic analysis relied on literature- and image-based synthesis without a formal multi-coder procedure; inter-rater reliability was not assessed. The final user evaluation examined a single digitally rendered CMF scheme. The theory-specified five-component PCA showed that the observed item grouping was broadly consistent with the predefined evaluation structure, but it does not independently establish construct validity [40]. Anonymous data collection also prevented the verification of participant overlap across study stages and possible familiarity effects.

Future research should test the Kansei structure in larger independent samples. Larger participant and stimulus samples could support multilevel factor analysis of perceptual structures at both levels [41]. Controlled studies using standardized photographic or digitally reconstructed stimuli could compare CMF schemes derived from the two-factor and three-factor structures. Such comparisons could examine whether retaining Stylistic Tension produces meaningful differences in design translation and user evaluation while reducing the influence of irrelevant photographic characteristics. The five-dimensional evaluation structure should also be examined through confirmatory analysis in a separate sample. Unprompted cultural-recognition tasks could distinguish spontaneous recognition from judgments made after the disclosure of the regional theme. Validation should also extend beyond static renderings. Recent research on automotive interiors has examined the effects of surface texture and color on the visuo-tactile perception of synthetic leather for automotive seats [42]. VR-based studies in engineering product development have also evaluated immersive systems in relation to software, hardware, and user-related factors [43]. Future rail-interior studies could extend these approaches through immersive passenger-compartment evaluation, physical samples, full-scale mock-ups, and engineering tests for assessing the applicability of candidate materials and surface treatments under relevant rail-vehicle requirements.

7. Conclusions

This study proposed a Cultural–Passenger–Compartment translation framework for applying the cultural characteristics of Liaoning coastal vernacular dwellings to the CMF design of light-rail passenger compartments. Using representative dwelling images as cultural samples, KE and EFA yielded an exploratory participant-level three-factor representation of general perception across the visual-sample set, comprising Spatial Order, Material Texture, and Stylistic Tension. FAHP was then used to determine expert-assessed priorities among the six CMF elements, with Material, Texture, and Color receiving the three highest global priorities. These results, together with the identified cultural characteristics, informed a designer-led conceptual CMF scheme. User evaluation showed that scores across all five predefined evaluation dimensions were significantly above the neutral midpoint. Overall, the proposed framework provides a structured and traceable process linking cultural analysis, expert prioritization, designer interpretation, and user evaluation. Future studies should compare multiple design alternatives, test the framework with independent samples, and further examine the relationships between cultural characteristics and specific CMF parameters.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/buildings16214268/s1, Table S1: Source and provenance registry for the collected visual materials.

Author Contributions: Conceptualization and methodology, J.L. (Jingying Li) and J.L. (Ji Li); investigation, analysis, data curation, visualization, and writing—original draft, J.L. (Jingying Li); validation, all authors; writing—review and editing, J.L. (Ji Li) and B.H.; supervision and project administration, J.L. (Ji Li). All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Basic Research Projects of the Education Department of Liaoning Province in 2025 under the project "Research on the Inheritance and Innovation of Liaoning's Red Heritage in Cultural and Creative Product Design from the Perspective of Artificial Intelligence" (grant number LJ112510150002). This research was also funded by China Association of Higher Education, 2026 Higher Education Scientific Research Planning Project "Research on the Dynamic Dissemination Model and Practical Mechanism of University Spiritual Culture from the Perspective of Cultural and Creative Product Development" Project ID: CA260703006, and received partial financial support from the Liaoyang Poultry and Livestock Machinery Research Institute.

Institutional Review Board Statement: The study procedures were assessed in accordance with the ethics review procedure of Dalian Jiaotong University. Formal ethics committee review was considered unnecessary because the study used anonymous and voluntary questionnaires, involved no intervention, collected no sensitive or personally identifiable information, and included only adult participants. Participants received information about the study before completing the questionnaire, and consent was indicated through their voluntary participation.

Informed Consent Statement: Informed consent was implied by the participants' voluntary decision to proceed with and complete the questionnaire after they had been informed of the study purpose, the anonymous nature of the questionnaire, and the use of the collected data.

Data Availability Statement: Summary data supporting the findings of this study are presented in the article. The anonymized questionnaire data and related analysis results are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CMF	Color, Material, and Finish
KE	Kansei Engineering
FAHP	Fuzzy Analytic Hierarchy Process
SD	Semantic Differential
EFA	Exploratory Factor Analysis
PAF	Principal Axis Factoring
ML-EFA	Maximum-Likelihood Exploratory Factor Analysis
KMO	Kaiser–Meyer–Olkin
VPC	Variance Partition Coefficient
RMSR	Root Mean Square Residual
RMSEA	Root Mean Square Error of Approximation
TLI	Tucker–Lewis Index
CFI	Comparative Fit Index
PCA	Principal Component Analysis
ANOVA	Analysis of Variance
TFN	Triangular Fuzzy Number
CI	Consistency Index
RI	Random Index
CR	Consistency Ratio

Appendix A

Table A1. Initial bipolar Kansei descriptor pool, semantic classification, and final treatment.

Candidate Bipolar Kansei Pair	Semantic Domain	Final Treatment
Enclosed–Open	Spatial Enclosure	Retained
Compact–Spacious	Spatial Scale	Retained
Narrow–Spacious	Spatial Scale	Consolidated into Compact–Spacious
Crowded–Broad	Spatial Scale	Consolidated into Compact–Spacious
Orderly–Chaotic	Spatial Order	Not retained as an independent item
Regular–Free-form	Spatial Organization	Retained
Continuous–Disjointed	Spatial Continuity	Standardized as Continuous–Fragmented; retained
Layered–Flat	Spatial Hierarchy	Not retained as an independent item
Free–Restricted	Spatial Organization	Consolidated into Regular–Free-form
Symmetrical–Asymmetrical	Spatial Composition	Not retained as an independent item
Stable–Dynamic	Stylistic Stability	Retained
Calm–Lively	Stylistic Vitality	Not retained as an independent item
Restrained–Expressive	Stylistic Expression	Retained
Understated–Showy	Stylistic Expression	Consolidated into Restrained–Expressive
Simple–Complex	Formal Complexity	Retained
Plain–Ornate	Decorative Elaboration	Retained
Minimalist–Intricate	Formal Complexity	Consolidated into Simple–Complex
Traditional–Modern	Cultural Style	Not retained as an independent item
Classical–Contemporary	Cultural Style	Not retained as an independent item
Conservative–Progressive	Stylistic Orientation	Not retained as an independent item
Familiar–Novel	Overall Perception	Not retained as an independent item
Authentic–Artificial	Cultural Authenticity	Not retained as an independent item
Natural–Artificial	Material/Cultural Perception	Not retained as an independent item
Regional–Universal	Regional Identity	Not retained as an independent item
Rich–Monotonous	Visual Richness	Not retained as an independent item
Rough–Smooth	Surface Texture	Consolidated into Rough–Delicate
Rough–Delicate	Surface Texture	Retained
Coarse–Delicate	Surface Texture	Consolidated into Rough–Delicate
Unrefined–Refined	Surface Refinement	Consolidated into Rough–Delicate
Heavy–Light	Visual Weight	Retained
Sturdy–Delicate	Material/Structural Perception	Not retained as an independent item
Lightweight–Cumbersome	Visual Weight	Consolidated into Heavy–Light
Hard–Soft	Material Perception	Not retained as an independent item
Warm–Cold	Material/Color Perception	Not retained as an independent item
Matte–Glossy	Surface Gloss	Not retained as an independent item
Bright–Dark	Color/Lightness	Not retained as an independent item
Harmonious–Conflicting	Overall Harmony	Not retained as an independent item
Attractive–Unattractive	Overall Evaluation	Not retained as an independent item
Comfortable–Uncomfortable	Overall Perception	Not retained as an independent item
Unique–Ordinary	Regional/Cultural Identity	Not retained as an independent item

Source ID	Table 1 source category	Geographic coverage	Source title	Author / institution	Publication date	URL / DOI
SRC01	Academic research	160 traditional dwellings across the Liaoning coastal region	Pedigree Characteristics and Formation Mechanism of Traditional Dwellings in the Liaoning Coastal Area, China	Xiaohan Yu; Shifen Li; Jingqiu Li; Yuan Kuang	2026-05-08	https://doi.org/10.3390/buildings16101873
SRC02	Academic research	Traditional dwellings around the Bohai Rim	Research Approach and Method for the Genealogy of Traditional Dwellings around the Bohai Rim	Shifen Li; Yuan Kuang; Jiayi Zhao; Canning Yu	2024-07-15	https://sjzj.cbpt.cnki.net/portal/journal/portal/client/paper/3e74ae6aa28feca72672d23fe257a772 DOI:10.16414/j.wa.2024.07.001
SRC03	Academic research	Methodological reference for vernacular-dwelling feature identification	Identification and Mapping of Architectural Genes of Traditional Dwellings in the Mountainous Area of Southern Hebei	Yuan Kuang; Shifen Li	2023-12-15	https://sjzj.cbpt.cnki.net/portal/journal/portal/client/paper/9b2fd415c1de94835ca5549d95fa02ab DOI:10.16414/j.wa.2023.12.013
SRC04	Academic research	Qingdui Town, Zhuanghe	From Historical Maps to Urban Plan Analysis: Morphological Structure of Qingduizi Ancient Town from a Typo-Morphological Perspective	Bing Li; Li Miao; Chenglong Liu et al.	2018-04-01	https://faculty.dlut.edu.cn/2013011173/zh_CN/lwcg/675098/content/181733.htm
SRC05	Academic research	Qingdui Town, Zhuanghe	Morphological Evolution of an Ancient Town in the Northern Coastal Hilly Region: The Case of Qingduizi Ancient Town,	Bing Li; Qianzheng Geng; Nanhua Du; Li Miao	2018	https://www.sohu.com/a/254883997_697365
SRC06	Academic research	Fuzhou Ancient City	Modular Relationships between Residential Courtyards and Urban Blocks in Ancient Cities: Three Ming-Dynasty Cities in Liaoning	Qianzheng Geng; Kaiyu Zhou	2019-06	https://www.researchgate.net/publication/376713333_Study_on_the_Module_Relationship_between_Ancient_City_Courtyard_and_Street_Form_-
SRC07	Authoritative and local media	Qingdui Old Street, Yushi Alley, Taiping Street, mosque, and	Photo Feature: Encountering Late-Qing Historic Buildings in Qingdui Town, Dalian	China National Radio (CNR); reporter Fangfei Yu; photographer Shihao Wang	2022-06-09	https://dl.cnr.cn/gdlb/20220609/t20220609_525857207.shtml
SRC08	Authoritative and local media	Qingdui Ancient Town, Taiping Street, Puhua Temple, and Huaxingtai Trading House	A 1,400-Year-Old Town in Dalian Moves toward National Historic and Cultural Town Status	China National Radio (CNR); reporter Yunfu Ge; images provided by the Publicity Department of the CPC	2022-05-21	https://dl.cnr.cn/gdlb/20220521/t20220521_525833137.shtml
SRC09	Authoritative and local media	Qingdui aerial views, Taiping Street, Guogao former site, Huaxingtai, etc.	Dalian: Qingdui Town Selected as a Provincial Historic and Cultural Town	China News Service Liaoning; Publicity Department of the CPC Zhuanghe Municipal Committee	2022-06-11	https://www.ln.chinanews.com.cn/news/2022/0611/323747.html
SRC10	Government and heritage	Xutun Village and Dongmatun Village	Fifteen Villages in Liaoning Included in the Sixth Batch of Chinese Traditional Villages	People's Government of Liaoning Province / Liaoning Daily	2023-03-25	https://www.ln.gov.cn/web/ywdt/jrln/wzxx2018/20230325200111876144/index.shtml
SRC11	Authoritative and local media	Dongmatun Village	Built along the Mountains: Enduring Vernacular Character in a Traditional Village	People's Daily reporter Jingyi Hu; selected images by People's Vision	2024-11-14	https://paper.people.com.cn/rmrb/html/2024-11/14/nw.D110000renmrb_20241114_1-15.htm
SRC12	Authoritative and local media	Dongmatun Village	Built along the Mountains: Enduring Vernacular Character in a Traditional Village	People's Government of Liaoning Province, reposting People's Daily	2024-11-18	https://www.ln.gov.cn/web/ywdt/zymtkln/20241118085508381 96/index.shtml
SRC13	Authoritative and local media	Xutun/Dongmatun and modern-era buildings	Dalian in Pictures: Dongmatun and Xutun Villages Listed as Chinese Traditional Villages	China National Radio (CNR); images provided by the Publicity Department of the CPC Wafangdian Municipal Committee / selected photographers	2022-12-22	https://dl.cnr.cn/gstjdl/20221222/t20221222_526101799.shtml
SRC14	Authoritative and local media	Chen Family Courtyard, Xutun Village	Centennial Chen Family Courtyard in Xutun Village, Wafangdian, Dalian / Related 'New Views of an Ancient Village'	Liaoning Daily / Beiguo; page photography credited to Jinhui Zha	2025-07-28	https://liaoning.lnd.com.cn/system/2025/07/28/030522332.shtml
SRC15	Authoritative and local media	Chunman Street, Chengzitan	Dalian in Pictures: The Century-Old Streets of Chengzitan	China National Radio (CNR); reporter Fangfei Yu; images provided by the Publicity Department of the CPC	2023-02-09	https://news.cnr.cn/local/dftj/20230209/t20230209_526149214.shtml
SRC16	Authoritative and local media	Ming–Qing Old Street and historic courtyards, Fuzhou	Fuzhou Town: A Millennium-Old City and Its Century-Old Academy	Beiguo reporter Shihai Wang	2026-01-20	https://liaoning.lnd.com.cn/system/2026/01/20/030543451.shtml
SRC17	Historical and archival	Traditional dwellings in Fuzhou	Systematic Conservation Planned for More Than 1,700 Qing-Dynasty Dwellings in Dalian: Materials on Fuzhou Dwellings	Jun Wang; Fei Wang; Dalian Library reposting Xinhua materials	2009-06-12	https://www.dl-library.net.cn/wenxian/dlnet/content.php?id=110338
SRC18	Reposts and cross-checking	Xutun/Dongmatun	National Public Notice: Two Places in Dalian Included on the List	Dalian Release (reposted by Sohu)	2022-11-19	https://www.sohu.com/a/607965885_121106822
SRC19	Institutional and supplementary records	Hui vernacular dwellings in Fuzhou	Dragon Boat Festival Journey in Liaoning: Dalian, Fuzhou Ancient City, and Qingdui Ancient Town	Salaam; photographer not identified		https://salaamalykum.com/cn/article/1646
SRC20	Academic research	Traditional dwellings on the Liaodong Peninsula	Evolution of Dwelling Morphology on the Liaodong Peninsula from the Perspective of Overlapping Relationships	Jingqiu Li; Shifen Li; Xihan Fan; Jialing Huang	2025-05-15	https://sjzj.cbpt.cnki.net/portal/journal/portal/client/paper/9bf93fc79d7b7eca36c472797f7ef835 https://doi.org/10.16414/j.wa.2025.05.012
SRC21	Academic research	Rural dwellings around the Bohai Rim	Rural Dwelling Morphology around the Bohai Rim from the Perspective of Dialect Zoning	Shifen Li; Jiayi Zhao; Kaixin Du	2022	https://doi.org/10.12069/j.na.202201120
SRC22	Academic research	Jiaodong–Liaodong Peninsula dwellings	Regional Selection of Vernacular Dwelling Architecture: The Case of the Chuang Guandong Migration	Huiruo Xi	2025-07-20	https://jzcs.cbpt.cnki.net/portal/journal/portal/client/paper/b08fccd679c16ca7602a3cdaf0ba60f4 https://doi.org/10.19892/j.cnki.csjz.2025.14.33
SRC23	Academic research	Traditional dwellings in the southern Bohai region	Identification and Mapping of Architectural Genes of Rural Dwellings in the Southern Bohai Region	Shifen Li; Yuan Kuang; Jialin Wang; Jiayi Zhao	2022	https://sjzj.cbpt.cnki.net/portal/journal/portal/client/paper/3e74ae6aa28feca72672d23fe257a772
SRC24	Government and heritage	Xutun Village and Dongmatun Village	Notice on the Sixth Batch of Villages Included in the List of Chinese Traditional Villages	Ministry of Housing and Urban-Rural Development and five other departments	2023-03-19	https://www.ihchina.cn/zhengce_details/26878.html
SRC25	Government and heritage	Chengzitan modern architectural ensemble	Notice of the People's Government of Liaoning Province on the Ninth Batch of Provincial Cultural Heritage Protection Units	People's Government of Liaoning Province	2014-10-17	https://www.ln.gov.cn/web/zwgkx/lnsrmzfgb/2014n/qk/2014n_deseq/szfwj/95D65AE1E4E44B2BBC43B50
SRC26	Government and heritage	Qingdui Town, Zhuanghe	Preserving a Millennium-Old Townscape: Qingdui Town, Zhuanghe, Dalian Designated a Provincial Historic and Cultural Town	Liaoning Provincial Department of Culture and Tourism (source: Beiguo / Liaoning Daily; reporter Rongqi Wang)	2022-06-09	https://whly.ln.gov.cn/whly/mtjj/4843D492D0B5489E99A852D1D8971C5B/index.shtml
SRC27	Authoritative and local media	Qingdui Town, Zhuanghe	Travel to Southern Liaoning and Visit Qingdui: Historic Charm and Coastal Life	Jing Yang (Liaoning Daily)	2025-04-27	https://news.lnd.com.cn/system/2025/04/27/030511226.shtml
SRC28	Authoritative and local media	Qingdui Town, Zhuanghe	An Unusual Hobby: Collecting and Restoring Historic Houses	Hua Yan (text); images provided by the interviewee	2020-10-19	https://dalian.runsky.com/2020-10/19/content_6086585.html
SRC29	Reposts and cross-checking	Qingdui Town, Zhuanghe	A Man in His Sixties Collects Three Historic Residences in Zhuanghe	Ximing Zhang; Yabo Li (Peninsula Morning Post / 39° Video)	2020-09-16	https://finance.sina.cn/2020-09-16/detail-iivhvpwy7065361.d.html?vt=4
SRC30	Authoritative and local media	Dongmatun Village, Xutun Town, Wafangdian	Unexpected Beauty in an Ancient Village Deep in the Mountains	Zhenzhen Lu (text); Qiang Gao (images)	2023-06-30	https://dalian.runsky.com/202604/15/c6226053.html
SRC31	Authoritative and local media	Dongmatun Village	Drums, Mugwort, and Zongzi: Enduring Cultural Traditions (Cultural China)	People's Daily integrated report (reposted by China Daily website)	2024-06-10	https://cn.chinadaily.com.cn/a/202406/10/WS666649e4a3109f7860de13b2.html
SRC32	Institutional and supplementary records	Dongmatun Village	Youth in Action for Rural Revitalization: Visit to Dongmatun Village by the School of Music	School of Music, Dalian Art College	2025-08-25	https://yyxy.dac.edu.cn/detail/2033_0246d0a5fee2cd7affcd6df24a744f1c.html
SRC33	Authoritative and local media	Xutun Village and Dongmatun Village	Fifteen Villages in Liaoning Included in the Sixth Batch of Chinese Traditional Villages	Jing Yang (originally published in Liaoning Daily; reposted by CRI Online)	2023-03-29	https://ln.cri.cn/2023-03-29/7cbd4284-b20d-69d0-8bc4-3abb83007d6a.html
SRC34	Academic research	Fuzhou, Wafangdian	Climate-Responsive Strategies of Traditional Dwellings in Southern Liaoning	Quan Zhou	2015	https://ygx.sxu.edu.cn/db/%E6%9C%9F%E5%88%8A/dwjzjs/dwjz2015/1509pdf/150914.pdf
SRC35	Authoritative and local media	Fuzhou Ancient City	Fuzhou Ancient City Is Gaining Attention	Donghao Lü (People's Political Consultative Conference Daily)	2024-06-03	https://news.qq.com/rain/a/20240603A02XTU00
SRC36	Historical and archival	Fuzhou Ancient City	Memories of Twelve Elderly Residents Reconstruct an Ancient City	Zhonghe Zhu (text and photographs)	2025-11-20	https://epaper.lnd.com.cn/lnrbepaper/pad/con/202511/20/content_307458.html
SRC37	Historical and archival	Fuzhou Ancient City	The Vanished Fuzhou	Deyun Hou	2009-09-07	https://www.gmw.cn/02blqs/2009-
SRC38	Authoritative and local	Fuzhou Ancient City	Fuzhou Ancient City: Tracing Historic Sites and Memories	Dalian Runsky (photographer not	2020-10-27	https://dalian.runsky.com/2020-
SRC39	Authoritative and local media	Hengshan Academy, Fuzhou	Chinese Nostalgia: Hengshan Academy in Wafangdian, Liaoning—the Only Surviving Ancient Academy in Southern Liaoning	Xuexi Qiangguo (reposted by Dalian Runsky)	2020-07-24	https://dalian.runsky.com/2020-07/24/content_6064310.html
SRC40	Reposts and cross-checking	Hengshan Academy, Fuzhou	Hengshan Academy: The Only Surviving Ancient Academy in Southern Liaoning	Jun Guan (text/images; originally published in Dalian Daily)	2015-01-22	https://www.chinanews.com.cn/cul/2015/01-22/6994548.shtml
SRC41	Reposts and cross-checking	Fuzhou mosque, Hengshan Academy, and Yongfeng Pagoda	Notable Historic Architecture in Dalian and the Inheritance of Ethnic Culture	Related report from Dalian Daily (reposted by Huanqiu.com)	2015-02-03	https://finance.huanqiu.com/article/9CaKrnJHs1v
SRC42	Authoritative and local media	Chunman Street, Chengzitan, Pulandian District	First Cultural Festival Held on Century-Old Chunman Street, Pulandian District	Yaohui Wu (text); images provided by the interviewed organization	2023-06-15	https://dalian.runsky.com/2023-06/15/content_6225346.html
SRC43	Authoritative and local media	Chunman Street, Chengzitan	Experiencing the Old Streets of Chengzitan through the TV Drama Our Days	Yu Zhang (text and photographs)	2023-02-18	https://epaper.lnd.com.cn/lswbepaper/pad/con/202302/18/content_182099.html
SRC44	Authoritative and local media	Chunman Street, Chengzitan	The Popular TV Drama Our Days Brings Attention to Chengzitan Old Street	Shunzhao Han (text); Bing Ge (images)	2023-02-09	https://wenti.runsky.com/content/2023-02/09/content_6218944.html
SRC45	Authoritative and local media	Chengzitan	Old-Street Cultural Festival in Pulandian Opens a New Chapter of Culture–Tourism Integration	Yining Tao; Meng Su; Jiajia Shi	2024-06-08	https://dalian.runsky.com/2024-06/08/content_6241984.html
SRC46	Authoritative and local media	Chunman Street, Chengzitan	A Millennium-Old Town: Strolling the Old Street and Experiencing Coastal Life	Jing Yang (Liaoning Daily)	2025-08-20	https://epaper.lnd.com.cn/lnrbepaper/pad/con/202508/20/content_296547.html
SRC47	Government and heritage	Chengzitan modern architectural ensemble	Introduction to Cultural Heritage Protection Units in Pulandian District VIII: The Chengzitan Modern Architectural Ensemble	Publishing body to be confirmed	2025-12-09	https://view.inews.qq.com/a/20251209A02KJ100

Figure A1. Overview of the literature-source registry used for cultural-sample identification and architectural-characteristic analysis [5,18–20].

Image ID	Building/Sample Name	Object Category	Source Year	URL/Reference
IMG001	Front Elevation of an Individual Building; Gray Stone/Brick Walls, Arched Windows, and Central Door	Front Elevation of an Individual Building; Gray Stone/Brick Walls, Arched Windows, and Central Door	—	https\://link.cnki.net/urlid/11.1930.TU.20260313.1345.004
IMG002	Two Villages in Dalian, Liaoning, Shortlisted as Traditional	Site Photograph of Historic/Vernacular Architecture;	2022	https\://dbzx.cctv.com/2022/11/27/ARTIrxscn8S2XFWwN2JIiH7Q221127.shtml
IMG003	Aerial View of Qingdui Historic Street	Aerial View; Traditional Settlement / Historic Street	2022	https\://dl.cnr.cn/gdlb/20220609/t20220609_525857207.shtml
IMG004	Pedigree Characteristics and Formation Mechanism of Traditional Dwellings in the Liaoning Coastal Area, China	Composite Figure from Literature	2026	https\://doi.org/10.3390/buildings16101873
IMG005	Pedigree Characteristics and Formation Mechanism of Traditional Dwellings in the Liaoning Coastal Area, China	Composite Figure from Literature	2026	https\://doi.org/10.3390/buildings16101873
IMG006	Gable Wall of an Individual Dwelling; Stone Base, Plastered Wall, and Gray Tiles	Gable Wall of an Individual Dwelling; Stone Base, Plastered Wall, and Gray Tiles	—	https\://link.cnki.net/urlid/11.1930.TU.20260313.1345.004
IMG007	Architectural Characteristics of Vernacular Dwellings in	Aerial View of a Settlement/Street	2023	https\://news.cnr.cn/local/dftj/20230209/t20230209_526149214.shtml
IMG008	Stone-Walled Vernacular Dwelling; Distinctive Roof Form	Stone-Walled Vernacular Dwelling; Distinctive Roof Form	—	
IMG009	Xujiatun Stone Shelter	Stone Shelter / Prehistoric Remains	2022	https\://www\.sohu.com/a/607965885_121106822
IMG010	Vernacular Courtyard; Stone Walls and Timber Windows	Vernacular Courtyard; Stone Walls and Timber Windows	—	https\://dl.cnr.cn/gstjdl/20221222/t20221222_526101799.shtml
IMG011	Vernacular Courtyard Gate; Red Door and Gray Wall	Vernacular Courtyard Gate; Red Door and Gray Wall	—	https\://liaoning.lnd.com.cn/system/2026/01/20/030543451.shtml Original streetscape image: https\://liaoning.lnd.com.cn/pic/003/008/489/00300848908_02b9fd44.p Original courtyard-dwelling image: https\://liaoning.lnd.com.cn/pic/003/008/489/00300848909_0b8d0ae3.png
IMG012	Pedigree Characteristics and Formation Mechanism of Traditional Dwellings in the Liaoning Coastal Area, China	Composite Figure from Literature	2026	https\://doi.org/10.3390/buildings16101873
IMG013	Pedigree Characteristics and Formation Mechanism of Traditional Dwellings in the Liaoning Coastal Area, China	Composite Figure from Literature	2026	https\://doi.org/10.3390/buildings16101873
IMG014	Historic Street View	Historic Street / Continuous Building Group	2023	https\://news.cnr.cn/local/dftj/20230209/t20230209_526149214.shtml
IMG015	Close View of an Individual Dwelling; Stone Base, Brick Walls, and Timber Structure	Close View of an Individual Dwelling; Stone Base, Brick Walls, and Timber Structure	—	https\://doi.org/10.19892/j.cnki.csjz.2019.17.002
IMG016	Two Dalian Sites Included in the National Public List	Night View of a Historic Streetscape / Building Cluster	2022	https\://www\.sohu.com/a/607965885_121106822
IMG017	Front Elevation of a Courtyard/Historic Building	Front Elevation of a Courtyard/Historic Building	—	https\://www\.sohu.com/a/847158089_121123756 https\://www\.dl-library.net.cn/wenxian/dlnet/content.php?id=232376
IMG018	Pedigree Characteristics and Formation Mechanism of Traditional Dwellings in the Liaoning Coastal Area, China	Composite Figure / Cropped Image from Literature	2026	https\://doi.org/10.3390/buildings16101873
IMG019	Historical Black-and-White Image; Courtyard/Settlement	Historical Black-and-White Image; Courtyard/Settlement	—	https\://www\.dl-library.net.cn/wenxian/dlnet/content.php?id=110338 https\://www\.chinanews.com.cn/cul/2011/03-03/2881171.shtml
IMG020	Historic Railway Water-Supply Tower	Historic Railway Water-Supply Tower	2022	https\://www\.sohu.com/a/607965885_121106822
IMG021	Village View of Dongmatun	Mountainous Traditional-Village Landscape	2022	https\://dl.cnr.cn/gstjdl/20221222/t20221222_526101799.shtml
IMG022	Russian-Style Building	Russian-Style Modern-Historic Building	2022	https\://dl.cnr.cn/gstjdl/20221222/t20221222_526101799.shtml
IMG023	Continuous Façade of Low-Rise Vernacular Dwellings	Continuous Façade of Low-Rise Vernacular Dwellings	—	https\://salaamalykum.com/cn/article/1646
IMG024	Mountain Courtyard / Stone Vernacular Dwelling	Mountain Courtyard / Stone Vernacular Dwelling	—	. https\://link.cnki.net/urlid/11.1930.TU.20260313.1345.004
IMG025	Former Site of Yushi Hutong, Qingdui	Historic Street/Lane	2022	https\://dl.cnr.cn/gdlb/20220609/t20220609_525857207.shtml
IMG026	Puhua Temple	Religious Building (Puhua Temple)	2022	https\://dl.cnr.cn/gdlb/20220609/t20220609_525857207.shtml
IMG027	Chastity and Filial-Piety Commemorative Stele	Stone Stele / Cultural Heritage Remains	2022	https\://dl.cnr.cn/gstjdl/20221222/t20221222_526101799.shtml
IMG028	Front Elevation / Courtyard Gate of a Vernacular Dwelling	Front Elevation / Courtyard Gate of a Vernacular	—	. https\://link.cnki.net/urlid/11.1930.TU.20260313.1345.004
IMG029	Restored/Reconstructed Courtyard	Restored/Reconstructed Courtyard	—	https\://www\.sohu.com/a/847158089_121123756 https\://www\.dl-library.net.cn/wenxian/dlnet/content.php?id=232376
IMG030	Settlement Environment; Road and Mountainous Terrain	Settlement Environment; Road and Mountainous Terrain	—	. https\://link.cnki.net/urlid/11.1930.TU.20260313.1345.004
IMG031	Zhang Family Chastity and Filial-Piety Archway	Archway / Commemorative Structure	2022	https\://dl.cnr.cn/gstjdl/20221222/t20221222_526101799.shtml
IMG032	Courtyard; Grape Arbor/Tree Shade, Stone Walls, and Timber Windows	Courtyard; Grape Arbor/Tree Shade, Stone Walls, and Timber Windows	—	https\://link.cnki.net/urlid/11.1930.TU.20260313.1345.004
IMG033	Two Dalian Sites Included in the National Public List	Continuous Stone Wall / Vernacular Building Frontage	2022	https\://www\.sohu.com/a/607965885_121106822
IMG034	Watchtower of Chengshan Ancient City	Ancient-City Wall and Watchtower; Defensive/Historic Architecture (Non-Residential)	2020	https\://www\.toutiao.com/article/6906064273982620168/ Repost used for cross-checking: https\://www\.sohu.com/a/438427554_120164081
IMG035	Historic-Street Residential–Commercial Frontage / Shopfront	Historic-Street Residential–Commercial Frontage /	—	https\://dl.cnr.cn/gdlb/20220521/t20220521_525833137.shtml
IMG036	Front Elevation of a Vernacular Courtyard Dwelling (Specific Object Unconfirmed)	Vernacular Courtyard / Dwelling Front Elevation; Gray Brick, Gray Tile, and Timber Lattice Windows	—	No reliable source matching this image one-to-one was identified; visually similar images were not used as substitutes for the original source
IMG037	Courtyard Dwelling; Stone-and-Brick Walls, Lanterns, and	Courtyard Dwelling; Stone-and-Brick Walls, Lanterns,	—	https\://link.cnki.net/urlid/11.1930.TU.20260313.1345.004
IMG038	Vernacular Courtyard Gate; Red Door and Gray Wall	Vernacular Courtyard Gate; Red Door and Gray Wall	—	https\://liaoning.lnd.com.cn/system/2026/01/20/030543451.shtml
IMG039	Simplified Vernacular Dwelling / Gray Brick	Simplified Vernacular Dwelling / Gray Brick	—	https\://news.cnr.cn/local/dftj/20230209/t20230209_526149214.shtml
IMG040	Fuzhou Street-Area Mural / Building Frontage	Fuzhou Street-Area Mural / Building Frontage	—	https\://liaoning.lnd.com.cn/system/2026/01/20/030543451.shtml
IMG041	Mosque	Religious Building (Mosque)	2022	https\://dl.cnr.cn/gdlb/20220609/t20220609_525857207.shtml
IMG042	Aerial View of a Building Cluster/Settlement	Aerial View of a Building Cluster/Settlement		https\://dl.cnr.cn/gstjdl/20221222/t20221222_526101799.shtml
IMG043	Night View of a Century-Old Stone Dwelling	Night View of a Century-Old Stone Dwelling	2022	https\://dl.cnr.cn/gstjdl/20221222/t20221222_526101799.shtml
IMG044	Japanese-Style Building	Japanese-Style Modern-Historic Building	2022	https\://dl.cnr.cn/gstjdl/20221222/t20221222_526101799.shtml
IMG045	Close View of a Vernacular Dwelling; Rubble Stone/Gray Brick Walls and Timber Windows	Close View of a Vernacular Dwelling; Rubble Stone/Gray Brick Walls and Timber Windows	—	https\://link.cnki.net/urlid/11.1930.TU.20260313.1345.004
IMG046	Century-Old Chen Family Courtyard Residence in Xutun Village, Wafangdian, Dalian	Chen Family Courtyard; Timber Structure / Eaves Details	2025	https\://liaoning.lnd.com.cn/system/2025/07/28/030522332.shtml
IMG047	Front Elevation of a Vernacular Dwelling; Stone Base, Plastered/Earth Wall, and Timber Windows	Front Elevation of a Vernacular Dwelling; Stone Base, Plastered/Earth Wall, and Timber Windows	—	https\://link.cnki.net/urlid/11.1930.TU.20260313.1345.004
IMG048	Detail of Stone Wall / Brick–Stone Junction and Courtyard Gate	Detail of Stone Wall / Brick–Stone Junction and Courtyard Gate	—	https\://doi.org/10.19892/j.cnki.csjz.2019.17.002
IMG049	Former Site of Taiping Street, Qingdui	Historic-Street Entrance / Stone Archway and Street-Front Buildings	2022	https\://www\.sohu.com/a/546977026_121106822 Matching-image location: https\://p9.itc.cn/q_70/images03/20220514/f129cb8ec08649fe868c802705f6e51c.jpeg
IMG050	Historical Black-and-White Image; Courtyard/Settlement	Historical Black-and-White Image; Courtyard/Settlement	—	https\://www\.dl-library.net.cn/wenxian/dlnet/content.php?id=110338 https\://www\.chinanews.com.cn/cul/2011/03-03/2881171.shtml
IMG051	Stone Path and Mountain-Woodland Setting in Dongmatun	Village Environmental Landscape; Low Stone Walls and Mountain-Woodland Path	2015	https\://dl.wenming.cn/08/003/201504/t20150401_4406583.htm
IMG052	Flat-Roofed (Tunding) Vernacular Dwelling in Western Liaoning (Specific Courtyard/Image Location to Be Verified)	Flat-Roofed (Tunding) Vernacular Dwelling; Gray Brick, Gray Tiles, and Red Timber Doors/Windows	2017; 2019	https\://lnhld.wenming.cn/gdtp/201704/t20170410_3214264.shtml https\://epaper.lnd.com.cn/lnrbepaper/pc/con/201906/28/content_34138.html
IMG053	Century-Old Chen Family Courtyard Residence at Qigandi, Xutun Village	Site Photograph; Timber Structure / Eaves / Material Details	2025	https\://epaper.lnd.com.cn/lnrbepaper/pc/att/202507/28/a9e5cc54-549a-4bf4-8747-9ff4e380eb11.pdf
IMG054	Yin Family Residence on Fuzhou East Street	Measured Drawing / Literature Figure; Courtyard Plan	2019	https\://doi.org/10.19892/j.cnki.csjz.2019.17.002 https\://www\.researchgate.net/publication/376713333_Study_on_the_Module_Relationship_between_Ancient_City_Courtyard_and_Street_Form_-_Taking_Three_Ancient_Cities_in_Ming_Dynasty_Liaoning_as_Examples

(**a**)

Figure A2. *Cont.*

Image ID	Building/Sample Name	Object Category	Source Year	URL/Reference
IMG055	Ming–Qing Vernacular Dwellings in Fuzhoucheng—East Street / Ming–Qing Historic Street	Site Photograph; Historic Street + Vernacular Courtyard Dwelling	2026	https\://liaoning.lnd.com.cn/system/2026/01/20/030543451.shtml https\://liaoning.lnd.com.cn/pic/003/008/489/00300848908_02b9fd44.png https\://liaoning.lnd.com.cn/pic/003/008/489/00300848909_0b8d0ae3.png
IMG056	Hui Vernacular Dwelling in Fuzhoucheng	Site Photograph; Hui Vernacular Dwelling	—	https\://salaamalykum.com/cn/article/1646
IMG057	Traditional Quadrangle-Courtyard Group in Fuzhoucheng (Ma, Gao, and Han Family Courtyards)	Traditional Quadrangle Courtyards; Photographs to Be Reviewed by Individual Courtyard	2009; 2011	https\://www\.dl-library.net.cn/wenxian/dlnet/content.php?id=110338 https\://www\.chinanews.com.cn/cul/2011/03-03/2881171.shtml
IMG058	Reconstructed Vernacular Courtyard at the Former Wafangdian Site	Site Photograph; Reconstructed Vernacular Courtyard	2025	https\://www\.sohu.com/a/847158089_121123756 https\://www\.dl-library.net.cn/wenxian/dlnet/content.php?id=232376
IMG059	Former Site of Yushi Hutong, Qingdui	Site Photograph; Yushi Hutong Streetscape	2022	https\://dl.cnr.cn/gdlb/20220609/t20220609_525857207.shtml https\://p7.itc.cn/q_70/images03/20220609/9c8cec3d54cf44c2a51b3487ee01af65.jpeg
IMG060	Vernacular Buildings along Taiping Street, Qingdui	Site Photograph; Main Street of Taiping Street	2022	https\://dl.cnr.cn/gdlb/20220609/t20220609_525857207.shtml https\://p0.itc.cn/q_70/images03/20220609/4df40ef4c7574f59a2c0f0e420c0626d.jpeg
IMG061	Aerial View of Qingdui Historic Street	Site Photograph; Aerial View of a Historic Street	2022	https\://dl.cnr.cn/gdlb/20220609/t20220609_525857207.shtml https\://p9.itc.cn/q_70/images03/20220609/9b9c936d366644b8ab690cbc9a6e2af3.png
IMG062	Historic Residence in Taiyanggou, Lüshun ①	Site Photograph; Modern-Historic Red-Brick Residence	2023	https\://www\.sohu.com/picture/716892146 https\://p2.itc.cn/images01/20230901/861242f1dccf48eab477e6b0a62d5989.png
IMG063	Historic Residence in Taiyanggou, Lüshun ②	Site Photograph; Group of Modern-Historic Residences	2023	https\://www\.sohu.com/picture/716892146https\://p2.itc.cn/images01/20230901/49e71b7efce0463e9ada274408df504e.png
IMG064	MDPI Field-Survey Sample A-J-8	Field-Survey Photograph of a Vernacular Dwelling (Source-Paper Sample)	2023–2025	https\://doi.org/10.3390/buildings16101873
IMG065	MDPI Field-Survey Sample A-J-7	Field-Survey Photograph of a Vernacular Dwelling (Source-Paper Sample)	2023–2025	https\://doi.org/10.3390/buildings16101873
IMG066	MDPI Field-Survey Sample A-L-5	Field-Survey Photograph of a Vernacular Dwelling (Source-Paper Sample)	2023–2025	https\://doi.org/10.3390/buildings16101873
IMG067	MDPI Field-Survey Sample A-W-9	Field-Survey Photograph of a Vernacular Dwelling (Source-Paper Sample)	2023–2025	https\://doi.org/10.3390/buildings16101873
IMG068	Flat-Roofed (Tunding) Vernacular Dwelling in Xingcheng Ancient City (Specific Courtyard Unconfirmed)	Western Liaoning Vernacular Dwelling; Flat-Roofed (Tunding) Dwelling / Courtyard Gate	2017	https\://lnhld.wenming.cn/gdtp/201704/t20170410_3214264.shtml
IMG069	Zhou Residence (Zhou Yongji Residence)	Republican-Era Flat-Roofed (Tunding) Vernacular Dwelling in Western Liaoning; Quadrangle Courtyard	2017	https\://lnhld.wenming.cn/gdtp/201704/t20170410_3214264.shtml https\://www\.ln.gov.cn/web/zwgkx/zfxxgk1/zc/xzgfxwj/szf/szfwj/2023010509333699289/index.shtml
IMG070	Vernacular Dwelling Courtyard in Xigou Village	Vernacular Dwelling Courtyard; Stone-and-Timber Gate Structure / Courtyard Wall	2025	https\://liaoning.lnd.com.cn/system/2025/07/28/030522332.shtml
IMG071	Vernacular Dwelling in Hekou Village	Vernacular Dwelling; Stone Walls, Roof, and Courtyard Setting	2025	https\://liaoning.lnd.com.cn/system/2025/07/28/030522332.shtml https\://www\.ln.gov.cn/web/ywdt/jrln/wzxx2018/20230325200118761 44/index.shtml
IMG072	Tizigou Village	Traditional Village / Historic and Cultural Village Environmental Landscape	2024	https\://www\.ln.gov.cn/web/ywdt/tpxx/2024120409304534354/index.shtml
IMG073	Aerial View of Xingcheng Ancient City	Overall/Aerial View of an Ancient-City Settlement; Ming-Dynasty Fortified City	2024	https\://www\.xinhuanet.com/local/20240606/ef7bb3e967aa40208138c9b94671df8c/c.html
IMG074	Historic Courtyard Dwelling along the Ming–Qing Historic Street	Vernacular Dwelling / Courtyard Site Photograph	2026	https\://liaoning.lnd.com.cn/system/2026/01/20/030543451.shtml https\://liaoning.lnd.com.cn/pic/003/008/489/00300848909_0b8d0ae3.png
IMG075	Zhang Family Chastity and Filial-Piety Archway	Traditional Stone Archway; Historic Village Structure (Non-Residential)	2022	https\://dl.cnr.cn/gstjdl/20221222/t20221222_526101799.shtml
IMG076	Architectural Characteristics of Vernacular Dwellings in Southern	Vernacular Dwellings / Aerial View of Streets and Lanes	2023	https\://news.cnr.cn/local/dftj/20230209/t20230209_526149214.shtml
IMG077	Relatively Well-Preserved Historic Streetscape	Aerial View of a Historic Street District / Settlement	2023	https\://news.cnr.cn/local/dftj/20230209/t20230209_526149214.shtml
IMG078	Close View of the Historic Street	Vernacular Dwelling / Close View of a Continuous Historic Streetscape	2023	https\://news.cnr.cn/local/dftj/20230209/t20230209_526149214.shtml
IMG079	Historic-Style Building in Dongmatun Village (Matched to Page	Vernacular Building / Stone Courtyard Entrance	2015	https\://dl.wenming.cn/08/003/201504/t20150401_4406583.htm
IMG080	Dwelling Built in the 1970s (Matched to Page Caption)	1970s Rural Dwelling; Stone-Walled Residence	2015	https\://dl.wenming.cn/08/003/201504/t20150401_4406583.htm
IMG081	Entrance to Dongmatun Village (Stone Marker of Villager Group	Village Entrance / Environmental Landscape	2015	https\://dl.wenming.cn/08/003/201504/t20150401_4406583.htm
IMG082	Flat-Roofed (Tunding) Vernacular Dwelling in Yong'anbao Township, Suizhong County	Western Liaoning Vernacular Dwelling; Flat-Roofed (Tunding) Dwelling	2019	https\://epaper.lnd.com.cn/lnrbepaper/pc/con/201906/28/content_34138.html Print-edition PDF: https\://epaper.lnd.com.cn/lnrbepaper/pc/att/201906/28/552c6d67-fce5-46b9-9adc-9df81719ca79.pdf
IMG083	Entrance and Gray-Brick Façade of a Restored Historic Dwelling (Partially Obscured by People)	Restored Historic Dwelling; Entrance / Gray-Brick Façade	2020	https://dalian.runsky.com/2020-10/19/content_6086585.html
IMG084	View through a Dark Doorway toward a Courtyard Lane and Courtyard Gate	Historic Dwelling; Courtyard Lane / Courtyard Gate / Doorway View	2020	https://dalian.runsky.com/2020-10/19/content_6086585.html
IMG085	Interior Wooden Furniture, Table, and Dark Timber Elements in a Restored Historic Dwelling	Restored Historic Dwelling Interior; Timber Furniture / Interior Woodwork	2020	https://dalian.runsky.com/2020-10/19/content_6086585.html
IMG086	Blue-Green Timber Doors, Windows, and Interior Woodwork	Historic Dwelling Interior; Timber Doors / Windows / Interior Woodwork	2020	https://dalian.runsky.com/2020-10/19/content_6086585.html
IMG087	Long Table and Display Furnishings inside a Renovated Historic Dwelling	Renovated Historic Dwelling Interior; Furniture / Display Furnishings	2020	https://dalian.runsky.com/2020-10/19/content_6086585.html
IMG088	Front Façade of the Former Guogao Site with European-Style Architectural Features	Historic Building; European-Style Façade	2025	https://news.lnd.com.cn/system/2025/04/27/030511226.shtml
IMG089	Granite Courtyard Wall and Front Façade of a Stone Dwelling	Stone Vernacular Dwelling; Granite Courtyard Wall / Front Façade	2023	https://dalian.runsky.com/202604/15/c6226053.html
IMG090	Aerial View of the Valley Settlement in Dongmatun Village	Traditional Village / Valley Settlement; Aerial View	2022	https://www.sohu.com/a/607769205_349247
IMG091	Xujiatun Stone Shelter	Stone Shelter / Prehistoric Remains	2022	https://www.sohu.com/a/607769205_349247
IMG092	Lead Image from a University Social-Practice Webpage; Original Image Not Successfully Retrieved	Unretrieved Webpage Image; Subject Not Verifiable	2025	https://yyxy.dac.edu.cn/detail/2033_0246d0a5fee2cd7affcd6df24a744f1c.html
IMG093	Tencent Webpage/Account Icon; Not an Architectural Image of	Webpage / Account Icon; Non-Architectural Asset	2024	https://news.qq.com/rain/a/20240603A02XTU00
IMG094	Courtyard and Main Hall of Hengshan Academy	Historic Academy Architecture; Courtyard / Main Hall	2020	https://dalian.runsky.com/2020-10/27/content_6088456.html
IMG095	Front Façade of a Traditional Brick-and-Stone Tiled House on Ming–Qing Street	Traditional Street-Front Dwelling; Brick-and-Stone Façade / Tiled Roof	2020	https://dalian.runsky.com/2020-10/27/content_6088456.html
IMG096	Façade and Timber Doors and Windows of an Intangible-Cultural-Heritage Leather Shop	Historic Street-Front Building; Timber Doors / Windows / Shop Façade	2020	https://dalian.runsky.com/2020-10/27/content_6088456.html
IMG097	Mountain Gate and Axial View of Hengshan Academy	Historic Academy Architecture; Mountain Gate / Axial Courtyard View	2020	https://dalian.runsky.com/2020-07/24/content_6064310.html
IMG098	First Courtyard and Front Façade of the Lecture Hall	Historic Academy Architecture; Courtyard / Lecture-Hall Façade	2020	https://dalian.runsky.com/2020-07/24/content_6064310.html
IMG099	Plaque, Bracket Elements, and Timber-Structure Details of the Lecture Hall	Historic Academy Architectural Detail; Plaque / Brackets / Timber Structure	2020	https://dalian.runsky.com/2020-07/24/content_6064310.html
IMG100	Second Courtyard and Former Residential Area for Teachers and Students	Historic Academy Architecture; Courtyard / Former Residential Area	2020	https://dalian.runsky.com/2020-07/24/content_6064310.html
IMG101	Oblique Aerial View of Chunman Street and Its Continuous Roofscape	Historic Streetscape / Settlement; Oblique Aerial View / Continuous Roofscape	2023	https://dalian.runsky.com/2023-06/15/content_6225346.html
IMG102	Aerial View of Chunman Street from an Alternative Direction	Historic Streetscape / Settlement; Aerial View	2023	https://dalian.runsky.com/2023-06/15/content_6225346.html
IMG103	Interior Domestic Living Scene	Residential Interior / Domestic Living Scene	2023	https://epaper.lnd.com.cn/lswbepaper/pad/con/202302/18/content_182099.html
IMG104	Continuous Street Houses with Festival/Film-Production	Historic Street Houses / Continuous Street Frontage	2023	https://wenti.runsky.com/content/2023-02/09/content_6218944.html
IMG105	Aerial View of Chunman Street and the Riverside Settlement	Historic Streetscape / Riverside Settlement; Aerial View	2025	https://epaper.lnd.com.cn/lnrbepaper/pad/con/202508/20/content_296547.html
IMG106	Floral-and-Fruit Patterned Ceramic-Tile Mosaic on the Wall of a Century-Old Building	Architectural Surface Decoration; Ceramic-Tile Mosaic / Wall Detail	2025	https://epaper.lnd.com.cn/lnrbepaper/pad/con/202508/20/content_296547.html

(**b**)

Figure A2. Overview of the visual-sample collection and provenance registry used for candidate-image screening. (**a**) IMG 1–54. (**b**) IMG 55–106 [5,21].

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