

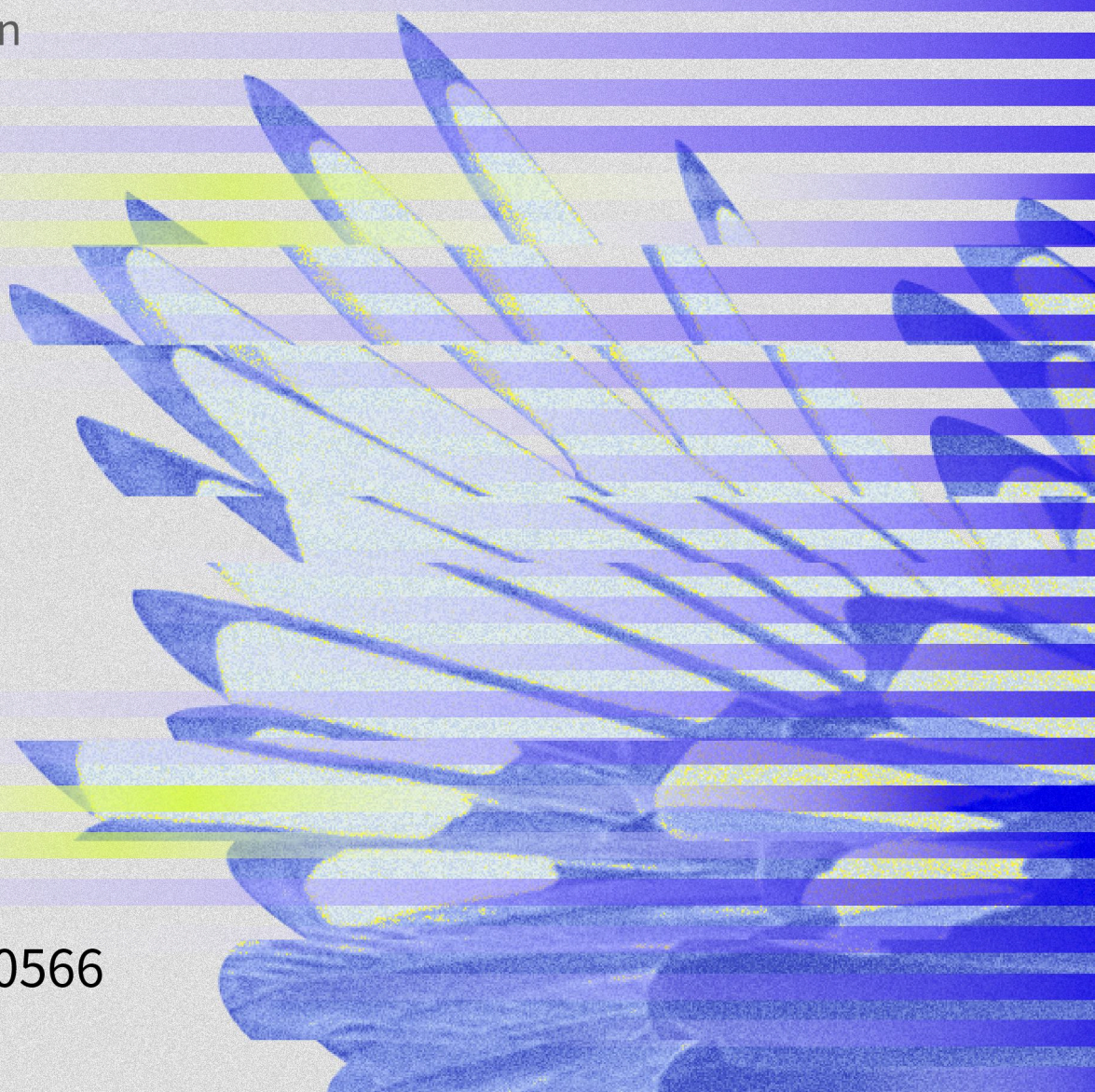
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Aims & Scope

The journal aims to build a high-level international academic platform to integrate the ancient and the modern, and to communicate with the East and the West. The journal focuses on two main objectives: firstly, to explore how to draw inspiration from cultural narratives, traditional knowledge and chronological contexts to enlighten contemporary design; secondly, to focus on interdisciplinary and cross-cultural academic dialogues and ideological collisions, and to reshape the theories, methods and practices of design innovation.

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FOREWORD

It is a great pleasure to contribute this foreword for this new academic journal dedicated to design practice and research from a truly international perspective. The mission and goals of the journal are ambitious and forwardthinking, as they aim to transcend longstanding boundaries between disciplines and professions, overcome geographical distance, bridge political differences, and connect diverse cultural traditions with rapidly developing emerging technologies. This journal is highly relevant to our times and carries enormous potential to deliver meaningful and lasting contributions to both well-established design disciplines and newly emerging fields of design research and professional practice. I would like to offer my warmest and most sincere congratulations to the journal's leadership, editorial board, and all members of the editorial team.

As explained in the invitation to write this introduction, the journal will “explore how cultural narratives, traditional knowledge and historical contexts inform contemporary design across various domains, while also examining the role of design in reinterpreting, preserving and transforming cultural identities in the modern world”. These objectives are exceptionally timely, comprehensive, and deeply meaningful to the global design community. My strong support for these goals and my high expectations for the journal's future influence are rooted in my fifty years of teaching experience, combined with extensive community service and professional landscape architecture practice in the United States and other countries, including Italy and China.

Crosscultural exchange, international collaboration, and interdisciplinary scholarship are profoundly valuable for any academic design program that seeks to build a dynamic, inclusive, and globally connected environment for design dialogue. These efforts help challenge narrow and limited cultural perspectives, promote innovative interdisciplinary and international education, outreach, and research, and inspire careful and reflective thinking about the role and significance of cultural traditions in a fastchanging modern world.

The launch of the International Journal of Cultural Design builds precisely on this spirit. It creates similar valuable opportunities while carefully addressing the distinctive contexts of Chinese villages and local communities. This journal serves as an important collaborative platform that brings together students and faculty from around the world to explore rich and diverse cultural narratives, and to demonstrate through realworld practice how design can transform and renew cultural identity while remaining firmly rooted in cherished traditions.

Once again, I offer my wholehearted congratulations on the launch and official initiation of this outstanding journal. I am confident that it will grow into an influential voice in international design scholarship and make enduring contributions to crosscultural understanding and creative design

Stephen Richard Drown FASLA
Professor and Chair Emeritus, Faculty of Landscape Architecture
University of Idaho
April 28, 2026

PREFACE

Between the global and the local tension, design has long transcended the boundaries of creation and function, becoming a core practice that carries, translates, and even reinvents cultural meaning. The launch of the International Journal of Cultural Design is precisely an academic response to this historical shift.

We recognize that cultural design is by no means merely adorning traditional symbols on the surface; rather, it is about deeply weaving cultural heritage, social context, and design thinking together, activating the interpretive and creative power of traditional knowledge within contemporary problem domains. This journal especially values inquiries arising from the intersection of anthropology, sociology, history, and design, questioning how cultural narratives crystallize into design strategies, how historical contexts shape material and immaterial forms, and how design reflexively reshapes collective memory and cultural identity.

To this end, at its inception, we have specially established several pioneering sections aimed at breakthroughs: "Cultural Narratives and Design Translation," focusing on the creative translation of intangible heritage such as oral history, rituals, and myths into products, spaces, and experiences; "Heritage Activation and Social Innovation," concentrating on community-centered design actions that restore endangered crafts and historical sites to public life; "Traditional Craft and the Digital Future," exploring new knowledge and possibilities for craft systems within artificial intelligence and parametric design; and "Design Criticism and Cultural Identity," providing a critical platform for examining the power relations and identity politics behind design practice. These sections serve not only as anchors for cutting-edge topics but also aim to bridge the gaps between theory and practice, history and the present.

Looking ahead, the International Journal of Cultural Design aspires to become a source of discourse for multicultural design. In today's design-narrative-driven world, we pay particular attention to indigenous design knowledge from various ethnic groups, advocating for a polyphonic writing of global design history. The journal will actively embrace open research, promote the indepth application of practice-based action research, speculative design, and other methods, and build long tables for researchers, designers, and craft practitioners to deliberate together. We look forward to, in rigorous yet warm engagements, paving a path worthy of entrusting to the future for the continuity of human culture and design innovation.

Rong Ha, Professor

April 28, 2026

CONTENTS

Assessing the Aesthetic Quality of Waterfront Spaces in Tourist-Oriented Villages Using Scenic Beauty Estimation	1-14
Yakun Chang, Zipeng Song, Dangqing Mo, Tao Liu, Antonio Pietro Latini, Yingnan Li	
Interpretation and Regeneration of Ming Dynasty Blue-and-White Porcelain Patterns from a Peircean Semiotic Perspective	15-37
Jiaxuan Jiang, Rong Han, Stephen Richard Drown	
Art Complete: a New Framework in Industrial Design	38-55
Raul Guliyev	
A Study on the Landscape Formation and Cultural Characteristics of Daerim-dong Chinatown	56-66
Hyunjin Chun	
Effective Comfort in Vernacular Courtyard Housing: A Socio-Environmental Comparison of Hausa Compounds in Kano and Siheyuan Houses in Beijing.	67-88
Jiddah Joy Demai, Junjie Zuo, Nzoko Kakese Jeremie	
Experimental Investigation of Gender-Based Preferences for Skeuomorphic Flat Icons via Eye-Tracking: Evidence from 18-28-year-old Participants	89-102
Qingli Liu, Chuhan Xu, Haojing Guo	
Listening and Design as Cultural Infrastructure: Rethinking Innovation Through a Relational and Situated Approach	103-114
Leandro Pisano	
The Impact of Heritage Brand Storytelling on Young Consumers' Attitudes: An Empirical Study Based on DEMATEL-ANP and the ABC Attitude Model — A Case of Hengshun	115-131
Zhe Zhu, Yanying Shi, Jinhuan Lu	

Assessing the Aesthetic Quality of Waterfront Spaces in Tourist-Oriented Villages Using Scenic Beauty Estimation

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Abstract: Scenic Beauty Estimation (SBE) is a widely applied psychophysical method for quantifying landscape aesthetic quality based on public visual preferences. Rural waterfront landscapes serve important ecological, social, and economic functions, and their visual quality plays a critical role in shaping visitor experience and community well-being. This study evaluates the aesthetic quality of waterfront spaces in Jiangxin Island, Zhenjiang, using a combination of field surveys and photographic documentation. Different respondent groups were invited to assess landscape scenes, and key influencing factors were identified through expert-based screening. Correlation and multiple regression analyses were conducted to develop a quantitative evaluation model. The results show that scenic beauty scores are significantly higher in well-developed areas, such as Orange Island, and lower in relatively undeveloped agricultural zones. Five factors were identified as having significant effects on scenic beauty: plant species diversity, waterfront morphology, rationality of vegetation configuration, landscape coordination, and types of spatial elements. The developed regression model provides a robust tool for evaluating and optimizing waterfront landscape quality, offering practical support for planning, management, and tourism-oriented development of rural waterfront environments.

Keywords: Rural Waterfront; Landscape Evaluation; SBE; Jiangxin Island, Zhenjiang City

1. Introduction

Rural waterfront spaces are important components of rural landscapes, contributing significantly to daily life, agricultural production, and cultural identity in rural communities (Dragan et al., 2024; Wang et al., 2022). With rapid urbanization and increasing public expectations for living environments, aesthetic quality has become a key concern in environmental planning (Tu et al., 2024; Meitner, 2004). High-quality landscapes extend beyond visual appeal, providing economic, social, and ecological benefits. They support regional economic development, promote sustainable tourism, and improve residents' quality of life. These functions are particularly evident in rural landscapes, especially in suburban areas, where they deliver diverse ecosystem services and help alleviate the pressures associated with urbanization (Tu et al., 2024; Zheng et al., 2021). As Shen et al. demonstrated in Zhenjiang, plant species diversity provides measurable ecosystem services beyond aesthetic value (Shen et al., 2023).

In China, the implementation of the national Rural Revitalization Strategy has promoted substantial improvements in rural economic development, environmental conditions, and infrastructure (Ma et al., 2023).

However, environmental governance capacity in many rural areas remains insufficient, and the aesthetic quality of rural landscapes has received relatively limited research attention (Ma et al., 2023; Zheng et al., 2021). This research gap highlights the need for systematic evaluation of rural waterfront spaces, which inherently involve multiple dimensions, including rural industry, economic development, ecological processes, and social well-being (Dragan et al., 2024; Di Fazio & Modica, 2018). Recent studies on Jiangxin Island and riverside greenways have assessed landscape performance and user perception differences, yet neither quantified scenic beauty drivers in rural waterfronts using a predictive mode (Li et al., 2025; Li et al., 2026).

The Scenic Beauty Estimation (SBE) method, developed by Daniel and Boster (1976), is a widely recognized psychophysical approach for quantifying public preferences for scenic beauty (Daniel, 2001; Hull, 1986). It has been extensively applied in various contexts, including landscape assessment, public preference evaluation, and environmental planning (Arthur et al., 1977). In a typical SBE study, respondents evaluate visual representations of landscapes, enabling researchers to quantify perceived scenic beauty. The reliability and validity of the SBE method are grounded in its foundation on public perception, which has been consistently demonstrated to provide a robust and objective measure of aesthetic quality (Daniel et al., 1977).

The SBE method has been widely applied to a variety of landscape types, with evaluation factors adapted to specific environmental contexts. For example, studies on forest landscapes have identified tree density, understory openness, and visibility as key determinants of scenic beauty (Chen et al., 2015; Deng et al., 2013; Ribe, 2005). In agricultural settings, factors such as architectural characteristics, water quality, and farmland texture have been shown to influence visual preferences (Yao et al., 2017; Yi-nan et al., 2016). In addition, the method has been successfully applied to agroforestry systems (Franco et al., 2003), roadside vegetation (Akbar et al., 2003), and rural landscapes more broadly (Wen & Burley, 2020; Tahvanainen et al., 2002). These studies indicate that while the SBE method provides a robust and flexible framework, the selection of evaluation factors should be tailored to the specific characteristics of different landscape types.

In waterfront contexts, SBE-based research has progressed along two main directions. Methodologically, studies have integrated SBE with techniques such as eye-tracking to explore observers' cognitive processes and aesthetic responses (L. Sun et al., 2025). From an application perspective, researchers have developed conceptual frameworks incorporating ecological, structural, and visual indicators for waterfront landscape assessment (Badach & Raszeja, 2019). In addition, studies have examined the relationship between visual quality and landscape character in waterfront linear parks (D. Sun et al., 2013), analyzed the influence of river scale on aesthetic quality (X. Li et al., 2022), and investigated the coupling of spatial, psychological, and behavioral dimensions in landscape evaluation (Liu et al., 2023). However, several critical gaps remain. First, existing studies often lack a systematic typological framework that captures the diversity of waterfront spaces (e.g., rivers, ponds, canals, and wetlands) in rural contexts, resulting in findings with limited specificity and applicability. Second, more targeted analyses are needed to isolate and quantify the influence of key natural and biophysical factors, moving beyond general aesthetic evaluations to identify specific attributes that drive scenic beauty.

Addressing these gaps is of considerable practical significance. Developing a tailored evaluation model for diverse rural waterfront spaces can provide a scientific basis for targeted planning and management interventions, thereby enhancing rural tourism attractiveness, supporting local economic development, and promoting environmental improvement. To achieve this, the present study aims to: (1) identify and characterize the key natural and biophysical factors influencing scenic beauty in rural waterfront environments; (2) evaluate the aesthetic quality of different types of rural waterfront spaces and develop a quantitative evaluation model; and (3) propose evidence-based optimization strategies to support landscape planning and management.

2. Materials and methods

2.1 Study area

The study area, Jiangxin Island, is a river island located in the Yangtze River within Dantu District, Zhenjiang, China (**Figure 1**). The island is situated approximately 1–3 km from the riverbanks and is characterized by predominantly flat terrain with a dense network of waterways. A “Y”-shaped river system, together with numerous ponds and wetlands, forms diverse waterfront spaces that define the island’s rural landscape. These water resources play an important role in supporting local livelihoods, including agriculture, daily activities, and tourism. The area has developed agro-tourism based on its agricultural production, integrating activities such as fruit picking, sightseeing, and recreation. The combination of rural landscape features and accessible waterfront environments makes Jiangxin Island a representative case for studying rural waterfront spaces.

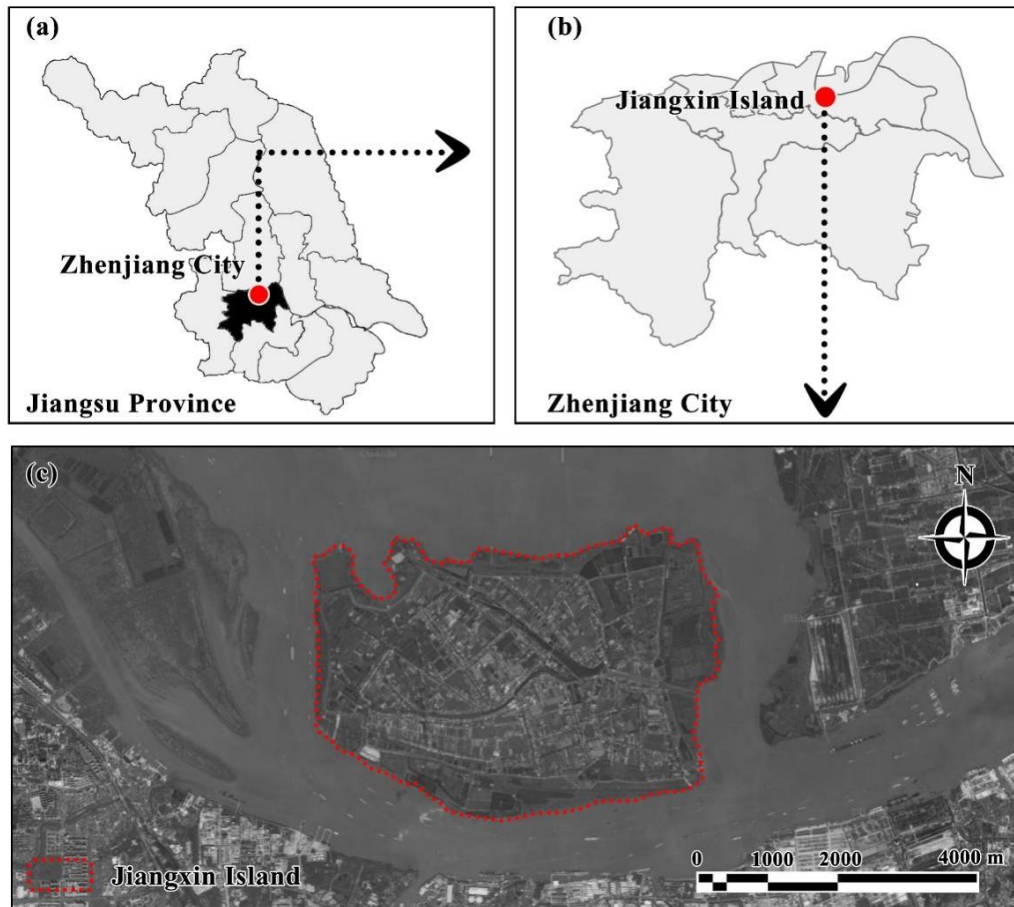


Figure 1 Study area of Jiangxin Island

2.2 Methodology

This study follows a structured framework consisting of four sequential phases: classification of waterfront space types, aesthetic evaluation using the SBE method, analysis of influencing factors based on the Semantic Differential (SD) method, and model development through statistical analysis. Specifically, waterfront spaces were first classified into distinct typologies according to their functional and morphological characteristics. The aesthetic quality of each type was then quantitatively evaluated using SBE based on public perception. Subsequently, the key influencing factors were analyzed using the SD method. Finally, correlation and multiple regression analyses were conducted to identify significant predictors and to develop an evaluation model for scenic beauty.

The overall research workflow is illustrated in **Figure 2**, and the detailed procedures for each phase are

described in the following subsections.

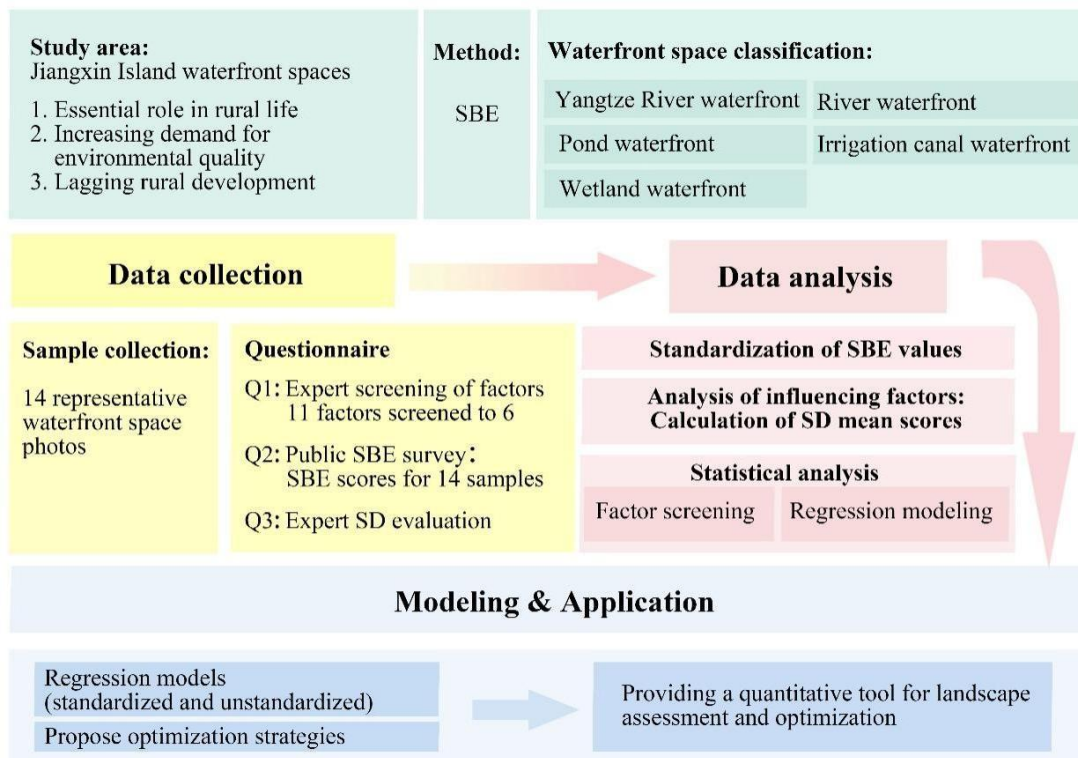


Figure 2 Research framework and methodological workflow of the study

2.2.1 Questionnaire design and distribution

This study employed three structured questionnaires to collect data from different respondent groups, incorporating both expert knowledge and public perception. This multi-group approach leverages the complementary strengths of each group: experts provide analytical evaluations of landscape attributes, while the public reflects holistic aesthetic preferences. The integration of these perspectives enables the development of a comprehensive and reliable evaluation system. Our distinction between resident and tourist perceptions follows Li et al., who reported significant evaluation gaps between these two user groups (Y. Li et al., 2025).

Questionnaire 1 (Expert screening of factors): This questionnaire was distributed to 50 experts in environmental design, landscape architecture, and urban planning. Its purpose was to identify and screen the key visual evaluation factors for waterfront spaces, ensuring a scientifically grounded selection of variables. Experts were asked to assess the relative importance of pre-defined factors.

Questionnaire 2 (Public Scenic Beauty Assessment using SBE): This questionnaire was designed to evaluate the scenic beauty of waterfront spaces on Jiangxin Island using the SBE method. It was distributed to 152 respondents, including both professionals and non-professionals, to capture diverse perceptions. Respondents were asked to rate the overall perceived scenic beauty of each landscape photograph. After removing 16 invalid responses, 136 valid questionnaires were retained, resulting in an effective response rate of 89%.

Questionnaire 3 (Expert SD evaluation of factors): This questionnaire was administered to another group of 50 experts. Using the SD method, respondents evaluated the presence and degree of the selected factors in each landscape sample. This provided quantitative assessments of landscape attributes (independent variables), which were later correlated with public scenic beauty scores.

2.2.2 Waterfront space classification

Waterfront spaces in Jiangxin Island were classified to facilitate a comprehensive understanding of the study area and to provide a basis for targeted landscape optimization. The classification was based on two key criteria: the socio-functional role of the water body and its physical spatial scale. Accordingly, five types were identified:

the Yangtze River waterfront, river waterfront, pond waterfront, irrigation canal waterfront, and wetland waterfront (**Figure 3**).

The first criterion, socio-functional role, refers to the primary functions of the water body within the rural community, including both domestic and productive uses. Domestic functions involve daily activities and leisure, such as washing, recreation, and visual enjoyment, while productive functions relate to agricultural and economic activities, including irrigation, aquaculture, and transportation. These functional differences influence patterns of human activity, infrastructure, and management practices, thereby shaping the visual characteristics of waterfront spaces.

The second criterion, physical spatial scale, considers the size and form of the water body, such as large rivers, linear canals, and small ponds. Spatial scale influences visual openness, ecological processes, and the ways in which people interact with the landscape.

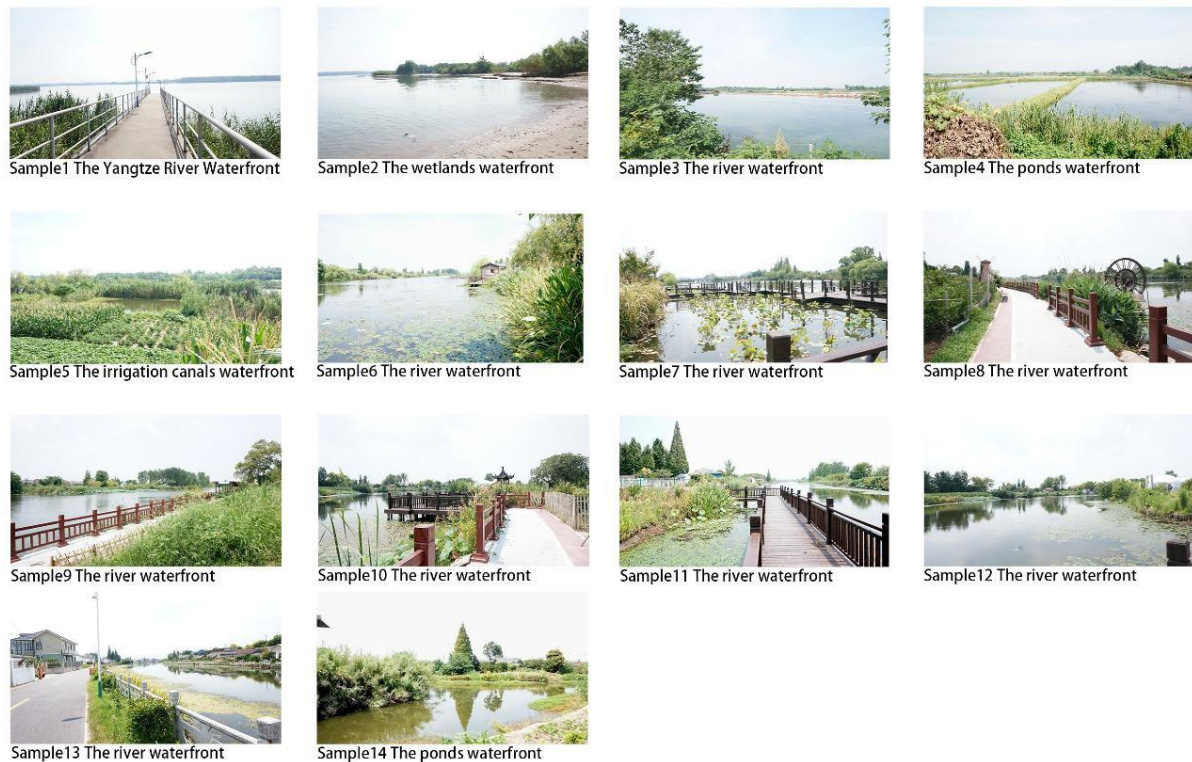


Figure 3 The 14 landscape samples of Jiangxin Island used for evaluation

Applying this dual-criteria framework to Jiangxin Island resulted in the identification of five distinct waterfront types. The Yangtze River waterfront represents a large-scale space characterized by composite ecological, transport, and scenic functions. River waterfronts (tributaries) are typically medium-scale corridors with mixed domestic and productive roles. Pond waterfronts are small-scale, intimate spaces that integrate daily activities with aquaculture. Irrigation canal waterfronts are characterized by their linear form and primary agricultural function. Wetland waterfronts vary in scale and are dominated by ecological and aesthetic functions.

This classification system establishes a structured framework for subsequent scenic beauty evaluation. By linking physical landscape characteristics with patterns of human use, it enables a more systematic analysis of aesthetic preferences and supports the development of differentiated optimization strategies for different waterfront types.

2.2.3 Image acquisition and factor quantification

To ensure that the photographs accurately represented on-site conditions and to minimize the influence of environmental variability (e.g., weather and lighting), a standardized image acquisition protocol was implemented.

All landscape samples were photographed in August under consistent natural lighting conditions between 9:00 and 16:30, without the use of flash. Photographs were taken at a height of 1.5 m, corresponding to the average human eye level. A consistent horizontal shooting angle was maintained across all samples, and non-landscape elements (e.g., people, vehicles, and animals) were excluded from the frame. All images were captured using the same camera and by the same photographer (**Figure 3**).

Based on the aesthetic characteristics and natural attributes of rural waterfront spaces, an initial set of 11 potential factors influencing scenic beauty was identified for subsequent screening. These included vegetation-related factors (plant species diversity, color richness, and vertical layering), water-related attributes (water surface cleanliness and waterfront morphology), and spatial characteristics such as hydrophilicity, rationality of vegetation configuration, residential architecture, spatial rhythm, landscape coordination, and types of spatial elements.

Following the screening process, six key factors were retained for quantitative analysis. The SD method was employed to assess the presence and intensity of these factors within each landscape sample. A total of 50 undergraduate and graduate students from relevant disciplines participated as evaluators. They rated each factor for all 14 landscape samples using a Likert scale. The mean score for each factor across all evaluators was calculated for each sample. These values, referred to as SD scores, represent the quantified landscape attributes and were used as independent variables in subsequent correlation and regression analyses.

2.2.4 Expert-based factor screening

Following the identification of the preliminary evaluation factors, a questionnaire survey was conducted among 50 experts in environmental design and landscape architecture. The experts were asked to assess the influence of each factor based on their professional judgment. Ratings were collected using a 5-point Likert scale, where 1 indicated “very low impact” and 5 indicated “very high impact.”

The mean score of each factor (M_j) was computed to evaluate the level of agreement among experts. Factors with higher mean scores and lower variance values were considered more important and consistent, and were therefore retained for further analysis:

$$M_j = \frac{\sum_{i=1}^n x_{ij}}{n} \quad (1)$$

The variance reflects the degree of agreement among experts regarding each evaluation factor.

$$\sigma_j^2 = \frac{\sum_{i=1}^n (x_{ij} - M_j)^2}{n} \quad (2)$$

x_{ij} is the influence of the j th factor, σ_j^2 is the variance of the j th factor score. x_{ij} is the rating of the j th factor by the i th expert, n is a number of experts.

Factors with a variance greater than 1 were considered indicative of substantial disagreement among experts and were excluded. Factors with a mean score greater than 3 (the midpoint of the 5-point scale) were regarded as having a significant influence on scenic beauty and were retained. This two-step screening ensured that the selected factors were both influential and consistent.

To mitigate variability in scoring caused by differences in rater stringency (i.e., some evaluators being more critical and others more lenient), the raw scenic beauty scores from Questionnaire 2 were standardized. This transformation converts subjective ratings into normalized values, enabling meaningful comparison and aggregation. The standardization was performed as follows:

$$Z_{ij} = \frac{R_{ij} - R_j}{S_j} \quad (3)$$

where Z_{ij} is the standardized score given by the i -th respondent to the j -th landscape sample, X_{ij} is the original rating, $\bar{X}_j$ is the mean rating of the j -th respondent across all samples, and S_j is the standard deviation of that respondent's ratings.

The standardized scores were then averaged across all respondents to obtain the scenic beauty score (SBE value, Z_i) for each landscape sample:

$$Z_i = \frac{\sum Z_{ij}}{N_j} \quad (4)$$

where N_j denotes the total number of respondents. This transformation removes individual rating biases and produces comparable scenic beauty scores for subsequent statistical analysis.

3. Results

3.1 Selection of impact factors

The results of expert scoring for the influencing factors of scenic beauty are presented in **Table 1**. The variance of each factor reflects the level of consensus among experts. As shown in Table 1, the variance values range from 0.596 to 1.173.

Factors such as “plant color richness,” “water surface cleanliness,” “waterfront hydrophilicity,” “waterfront residential architecture,” and “spatial rhythm” exhibited variance values greater than 1, indicating substantial disagreement among experts regarding their influence. These factors were therefore excluded to improve the reliability and consistency of the selected variables. For the remaining factors, the relatively low variance values indicate a high level of agreement among experts, supporting their inclusion in subsequent analysis.

In addition, based on the 5-point Likert scale used in this study, factors with a mean score greater than 3 were considered to have a significant influence on scenic beauty. This threshold is commonly used to distinguish between factors with limited influence (≤ 3) and those with substantial influence (> 3).

Based on these two criteria—high consensus (low variance) and a mean score above 3—six key factors were identified: plant species diversity, plant layer richness, waterfront morphology, rationality of waterfront vegetation configuration, landscape coordination, and types of spatial elements.

Table 1 Expert scoring results for impact factor screening

No.	Aesthetics Evaluation Factor	degree of influence	Variance ²
1	Plant species diversity	3.970	0.734
2	Plant color richness	3.680	1.160
3	Plant layer richness	3.970	0.911
4	Water surface cleanliness	4.320	1.101
5	Waterfront morphology	3.740	0.665
6	Waterfront space hydrophilicity	3.940	1.173
7	Rationality of vegetation configuration	4.290	0.678
8	Waterfront residential architecture	3.150	1.243
9	Spatial rhythm	3.650	1.228
10	Landscape coordination	4.000	0.882
11	Types of spatial elements	3.850	0.596

3.2 Evaluation results of scenic beauty

A total of 152 questionnaires were distributed, of which 136 were considered valid after excluding 16 invalid responses, resulting in an effective response rate of 89%.

As presented in **Table 2**, the SBE values of the 14 waterfront landscape samples are evenly distributed, with seven samples having positive values and seven having negative values. The samples, ranked in descending order of SBE values, are as follows: Sample 7 > Sample 8 > Sample 10 > Sample 9 > Sample 11 > Sample 6 > Sample 3 > Sample 12 > Sample 1 > Sample 14 > Sample 13 > Sample 4 > Sample 2 > Sample 5.

A clear distinction can be observed between samples with positive and negative SBE values. Samples with higher SBE scores generally indicate a higher level of aesthetic preference, whereas samples with lower or negative values indicate relatively lower aesthetic evaluations.

Table 2 SBE values of the 14 waterfront landscape samples

No.	SBE value	Waterfront type	No.	SBE value	Waterfront type
1	-0.280	Yangtze River waterfront	8	0.620	River waterfront
2	-0.590	Wetland waterfront	9	0.400	River waterfront
3	0.120	Pond waterfront	10	0.450	River waterfront
4	-0.380	Pond waterfront	11	0.320	River waterfront
5	-0.660	Irrigation canal waterfront	12	-0.230	River waterfront
6	0.290	River waterfront	13	-0.350	River waterfront
7	0.630	River waterfront	14	-0.340	Pond waterfront

To explore potential perceptual differences among respondent groups, a preliminary analysis was conducted based on available demographic variables. Using the raw beauty scores (1–5 scale) from Questionnaire 2, ratings from local residents (living or studying in Zhenjiang, $n = 61$) and non-local visitors ($n = 91$) were compared. Residents rated the irrigation canal waterfront (Sample 5) slightly higher (mean = 2.07) than visitors (mean = 1.92), whereas visitors assigned higher scores to the developed Orange Island area (Sample 7) (mean = 3.21) compared to residents (mean = 3.02). Similar differences were observed across other landscape types. In contrast, comparisons between professionals ($n = 51$) and non-professionals ($n = 101$) showed no substantial differences (e.g., Sample 7: 3.18 vs. 3.12). Given the limited sample size for subgroup analysis, these findings should be considered preliminary.

Table 3 Mean raw scenic beauty scores of selected samples by respondent group

Sample type	Sample No.	Residents ($n = 61$)	Visitors ($n = 91$)
Irrigation canal waterfront	5	2.070	1.920
Wetland waterfront	2	2.300	2.180
River (developed, Orange Island)	7	3.020	3.210
River (typical)	10	2.980	3.110

3.3 Analysis of the Influence of Evaluation Factors

The SD scores of all factors for each sample are presented in **Table 4**. The influencing factors were coded as follows: X1: plant species diversity, X2: plant layer richness, X3: waterfront morphology, X4: rationality of vegetation configuration, X5: landscape coordination, and X6: types of spatial elements. To examine the relationship between SD scores and scenic beauty, the samples were grouped based on their SBE rankings (Section 3.2). Differences in SD scores were observed between high-ranking samples (e.g., Nos. 7, 8, and 10) and low-

ranking samples (e.g., Nos. 2, 4, and 5).

Higher-ranked samples generally exhibited SD scores above the overall mean in key factors such as waterfront morphology (X3), rationality of vegetation configuration (X4), landscape coordination (X5), and types of spatial elements (X6). In contrast, lower-ranked samples tended to show SD scores below the overall mean in factors including plant species diversity (X1), vegetation configuration (X4), landscape coordination (X5), and types of spatial elements (X6). These results indicate that variations in these factors are associated with differences in scenic beauty evaluations.

Table 4 Mean SD scores of evaluation factors for each sample

No.	X1	X2	X3	X4	X5	X6
1	2.660	2.660	2.940	2.710	2.890	2.860
2	2.830	2.970	3.260	2.800	2.660	2.540
3	3.140	3.200	2.940	3.000	3.260	3.000
4	3.230	2.970	3.140	3.110	2.830	3.030
5	3.400	3.600	3.030	2.970	3.030	2.770
6	3.800	3.740	3.430	3.510	3.600	3.490
7	3.690	3.430	3.600	3.430	3.340	3.510
8	3.630	3.510	3.290	3.310	3.600	3.400
9	3.630	3.510	3.090	3.510	3.260	3.260
10	3.600	3.630	3.430	3.710	3.690	3.800
11	3.740	3.660	3.340	3.600	3.630	3.490
12	3.490	3.230	3.260	3.260	3.290	3.280
13	2.860	2.890	2.970	2.970	3.110	3.090
14	3.910	3.690	3.310	3.460	3.600	3.200
average value	3.400	3.340	3.220	3.240	3.270	3.190

4. Discussion

4.1 Correlation between scenic beauty and landscape factors

Prior to developing the evaluation model, a correlation analysis was conducted between the SBE values and the six influencing factors to identify variables for subsequent regression analysis. The results are presented in **Table 5**. A factor was considered significantly correlated with scenic beauty when the p-value was less than 0.05.

As shown in Table 5, plant layer richness (X2) was the only factor with a p-value greater than 0.05, indicating that it was not significantly correlated with scenic beauty. In contrast, the remaining five factors—plant species diversity (X1), waterfront morphology (X3), rationality of vegetation configuration (X4), landscape coordination (X5), and types of spatial elements (X6)—all exhibited statistically significant positive correlations with SBE values, as indicated by p-values below 0.05 and positive Pearson correlation coefficients. The significance of plant diversity (X₁) and waterfront morphology (X₃) in our model aligns with the ecosystem service findings of Shen et al. and the spatial comfort study of Song et al., both conducted in Zhenjiang (Shen et al., 2023; Song et al., 2024).

Table 5 Pearson correlation results SBE and evaluation factors

Impact factor	r	p-value (two-tailed)	Significance
X1 Plant species diversity	0.562	0.036	Significant
X2 Plant layer richness	0.492	0.074	Not significant

X3 Waterfront morphology	0.543	0.045	Significant
X4 Rationality of vegetation configuration	0.706	0.005	Significant
X5 Landscape coordination	0.707	0.005	Significant
X6 Types of spatial elements	0.816	0.000	Significant

4.2 Correlation between scenic beauty and landscape factors

This section aims to quantify the influence of evaluation factors on scenic beauty and to develop a predictive model using regression analysis. The modeling process was conducted in two steps. First, univariate linear regression analyses were performed to evaluate the relationship between each individual factor (X_1 – X_6) and the SBE values. Subsequently, the significant factors were incorporated into a multiple linear regression model to construct a comprehensive predictive framework. The results of the univariate regression analyses are presented in Table 6.

Table 6 Results of univariate linear regression analyses for SBE values

Independent Variable	B	Std. Error	Beta	t	p	R ²
X_1	0.641	0.272	0.562	2.356	0.036*	0.316
X_3	1.199	0.535	0.543	2.238	0.045*	0.295
X_4	1.013	0.294	0.706	3.449	0.005**	0.498
X_5	0.960	0.277	0.707	3.461	0.005**	0.499
X_6	1.086	0.222	0.816	4.887	0.000**	0.666

**Note: X_1 = plant species diversity; X_3 = waterfront morphology; X_4 = rationality of vegetation configuration; X_5 = landscape coordination; X_6 = types of spatial elements.*

** $p < 0.05$, ** $p < 0.01$.*

The analysis indicated that five factors (X_1 , X_3 , X_4 , X_5 , and X_6), excluding X_2 due to its non-significant correlation, were significantly associated with scenic beauty ($p < 0.05$). Among these, X_6 (types of spatial elements) exhibited the strongest explanatory power ($R^2 = 0.666$).

Scenic beauty is typically influenced by the combined effects of multiple factors. Therefore, a multiple linear regression analysis was conducted using the five significant variables (X_1 , X_3 , X_4 , X_5 , and X_6) as independent variables and the SBE value as the dependent variable, in order to develop a comprehensive predictive model and evaluate the relative contribution of each factor.

The results show that the overall regression model is highly significant ($F(5, 8) = 17.215$, $p < 0.001$). The adjusted R^2 value is 0.874, indicating that the model explains 87.4% of the variance in scenic beauty and demonstrates a high level of goodness of fit. The variance inflation factor (VIF) values for all variables are below 3, suggesting that multicollinearity is not a concern. The detailed regression coefficients are presented in Table 7.

Table 7 Results of multiple linear regression analysis for SBE values

Variable	B	Std. Error	Beta	t	p	VIF
Constant	-3.726	0.698		-5.338	0.001**	
X_1	0.192	0.184	0.168	1.044	0.327	1.892
X_3	0.450	0.321	0.204	1.403	0.199	1.543
X_4	0.359	0.264	0.250	1.361	0.211	2.135
X_5	0.273	0.237	0.201	1.152	0.283	1.985

Variable	B	Std. Error	Beta	t	p	VIF
X ₆	0.707	0.241	0.531	2.934	0.018*	1.732

Note: *p < 0.05, **p < 0.01. Dependent variable: SBE value. R² = 0.915, Adjusted R² = 0.874.

When controlling for other variables, X₆ (types of spatial elements) emerged as the most influential factor, as it was the only variable that remained statistically significant (p = 0.018) in the multivariate model and exhibited the largest standardized coefficient (Beta = 0.531). This indicates that variation in spatial element diversity is strongly associated with differences in scenic beauty under multivariate conditions.

The p-values for the other four factors (X₁, X₃, X₄, and X₅) were greater than 0.05, suggesting that their independent effects were not statistically significant when controlling for other variables. This may reflect overlapping influences among predictors or potential interactions between variables. Despite their lack of statistical significance in the multivariate model, these factors were retained based on their theoretical relevance and their significance in univariate analyses, thereby contributing to a more comprehensive evaluation framework.

4.3 Model Establishment, Validation and Discussion

The scenic beauty evaluation model for waterfront spaces in Jiangxin Island was developed based on the results of the regression analysis. To reflect the data processing workflow and provide a quantitative reference for prediction, the model is presented in two equivalent forms.

4.3.1 The Multiple Regression Model

Based on the multiple regression results, the final predictive model for the scenic beauty of Jiangxin Island's waterfront spaces is established using the unstandardized coefficients. The model is expressed as:

$$Y_{SBE} = -3.726 + 0.192X_1 + 0.450X_3 + 0.359X_4 + 0.273X_5 + 0.707X_6 \quad (5)$$

Where Y_{SBE} represents the predicted scenic beauty estimation value, and X₁, X₃, X₄, X₅, and X₆ denote the mean scores (on a 1–5 scale) of the corresponding evaluation factors.

This model provides a quantitative approach for estimating scenic beauty. By inputting the mean scores of the relevant factors for a given waterfront space, the corresponding SBE value can be calculated.

4.3.2 Model validation

To evaluate the generalizability of the model and reduce the risk of overfitting, a leave-one-out cross-validation (LOOCV) approach was applied. This method is particularly suitable for small sample sizes (n = 14), as it maximizes the use of available data by training the model on n – 1 samples and testing it on the remaining sample.

The procedure generated 14 models. In each iteration, one sample was excluded, the model was calibrated using the remaining 13 samples, and the excluded sample was predicted. This process resulted in 14 predicted SBE values, each obtained from a model that did not include the corresponding observation during training.

The predicted values showed a strong and statistically significant correlation with the observed SBE values (r = 0.927, p < 0.001). The root mean square error (RMSE) was 0.152, indicating a relatively high level of predictive accuracy given that SBE values are standardized scores.

These results suggest that the model has good predictive performance within the study context, although further validation with larger datasets is needed to confirm its broader applicability.

4.3.3 Implications for landscape design and cultural interpretation

The model results suggest that the scenic beauty of rural waterfront spaces is shaped by the combined influence of multiple landscape characteristics. Among these, types of spatial elements (X₆) appear to be the most influential factor, as indicated by its significance in the multivariate model. This finding implies that introducing diverse spatial elements—such as viewing platforms, walkways, and resting areas—may enhance the perceived

attractiveness of waterfront spaces. In addition, waterfront morphology (X_3) and the rationality of vegetation configuration (X_4) show relatively strong associations with scenic beauty, indicating their potential importance in shaping overall landscape quality. Although plant species diversity (X_1) and landscape coordination (X_5) were not statistically significant in the multivariate model, they remain important components of landscape aesthetics and may contribute to scenic beauty through combined or context-dependent effects.

While this study quantitatively identifies key biophysical factors influencing scenic beauty, aesthetic perception is also shaped by cultural context. The higher SBE scores observed in developed areas, such as Orange Island, may reflect not only the quality of landscape design but also visitors' expectations of an accessible and curated rural environment. In contrast, lower scores in undeveloped agricultural areas may indicate a perceptual gap between functional landscapes and aesthetic expectations.

These findings suggest that the interpretation of landscape features may vary depending on users' cultural backgrounds and experiential contexts. Future research incorporating qualitative approaches could further explore how local traditions, visitor perceptions, and landscape use patterns interact with the biophysical factors identified in this study.

5. Conclusion

This study applied the SBE method to evaluate the aesthetic quality of rural waterfront spaces in Jiangxin Island. By integrating expert screening, SD-based factor assessment, and regression modeling, a quantitative framework was established to analyze the relationship between landscape characteristics and scenic beauty.

The results indicate that scenic beauty is associated with multiple landscape factors, including types of spatial elements (X_6), rationality of vegetation configuration (X_4), landscape coordination (X_5), waterfront morphology (X_3), and plant species diversity (X_1). Among these, types of spatial elements (X_6) showed the strongest and statistically significant effect in the multivariate model, suggesting its prominent role in shaping perceived aesthetic quality. Other factors, although not statistically significant in the multivariate context, may contribute to scenic beauty through combined or context-dependent effects.

The developed regression model demonstrates good predictive performance within the study context (Adjusted $R^2 = 0.874$; LOOCV $r = 0.927$), indicating its potential as a quantitative reference for evaluating and comparing the scenic quality of similar rural waterfront spaces.

In addition, the findings highlight that scenic beauty is not solely determined by biophysical characteristics but may also be influenced by cultural perceptions and user expectations. This suggests that the interpretation of landscape features can vary depending on experiential and socio-cultural contexts, which should be considered in future research and practice.

Overall, this study contributes a data-driven approach to understanding and evaluating rural waterfront aesthetics, providing a foundation for evidence-based landscape planning and management. By focusing on key influencing factors, the proposed framework may support more informed decision-making in the development and enhancement of rural waterfront environments.

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Y.L.; methodology, Z.S.; resources, T.L.; software, Y.C.; supervision, Y.L.; validation, Y.C. and Z.S.; visualization, Y.C. and D.M.; writing— original draft, Z.S.; writing—review and editing, A.P.L. and Y.L. All authors have read and agreed to the published version of the manuscript.

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Interpretation and Regeneration of Ming Dynasty Blue-and-White Porcelain Patterns from a Peircean Semiotic Perspective

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Abstract: Traditional scholarship typically regards porcelain patterns as decorative imagery affixed to specific vessel forms, overlooking their structural consistency across diverse carriers and contexts. Drawing upon Peircean semiotics, this study examines the layout of Ming Dynasty blue-and-white patterns across multiple porcelain categories. Through comparative imagery and observational experiments, it investigates whether identical images retain recognisability and semantic reference when applied across different vessel types. Findings reveal that while patterns exhibit diverse appearances across ceramics due to form variations, their spatial and compositional similarities enable observers to form consistent interpretations even without explicit cultural cues. Results indicate that this image stability stems from relational visual arrangements. This discovery offers a fresh perspective on understanding the continuity of traditional imagery across media and provides empirical support for the cross-contextual use of symbols in contemporary design.

Keywords: *Peircean semiotics; Ming Dynasty blue-and-white porcelain; patterns; cultural transmission*

1. Introduction

The development of commerce and urbanisation in the early Ming period laid the foundation for the flourishing of porcelain production. In the second year of the Hongwu reign, workshops were established at the foot of Zhushan Hill in the town to produce ceramics for the imperial court, termed 'official kilns' to distinguish them from private kilns" (Lan Pu, 2019). Porcelain production was thus integrated into the imperial system at both ritual and administrative levels. By the mid-Ming period, the expansion of social division of labour, changes in the corvée and tax systems, and the development of a commodity economy created a production landscape where "white smoke obscured the sky by day, while red flames scorched the heavens by night" (Wenlan Fan, 2004). The competitive market between official and private kilns, alongside the practice of official kilns supporting private firing, gradually expanded, presenting new opportunities for the porcelain industry. As the most prolific category of Ming ceramics, blue-and-white porcelain achieved remarkable maturity in materials, techniques, forms, and decoration. Its patterns emerged as core visual symbols within specific social contexts and historical conditions, their meanings continually reconfigured by shifts in cultural conventions among users. Thus, they became both potent historical witnesses and ideal carriers of culture. Through the interplay of patterns and colours, these motifs intertwined with social customs to form multi-layered cultural references, rendering each piece a tangible embodiment of social experience and cultural identity.

Current scholarly discourse on Ming Dynasty blue-and-white patterns primarily unfolds through three perspectives: Firstly, the history of craftsmanship. Scholars such as Hsieh, E. et al., focusing on blue-and-white porcelain from the Jingdezhen kilns of the Ming Dynasty, attribute its distinctive hues primarily to changes in craftsmanship and firing conditions during the transition from imported to domestically produced cobalt pigments

in the Chenghua period (**Hsieh et al., 2023**). Second, stylistic dating. Ferreira, L.F.V. et al. employed the X-ray diffraction technique (XRD) to establish foundational correlations between Iranian blue pigment, mixtures of Iranian and Chinese pigments, or purely Chinese pigments, and the stylistic dating of each sample (**Ferreira et al., 2025**). Secondly, subject identification: Jin, X et al. proposed a reliable acoustic identification method for ancient ceramics and established a digital code for their acoustic characteristics, providing multiple practical applications for audible signal feature recognition in exhibitions, conservation, trade, identification, and security management of ancient ceramics and other cultural relics (**Jin et al., 2023**). Deng, Z et al. addressed the challenges of localised fading in ancient ceramic decorative patterns and image noise by proposing a multi-level watershed segmentation method (**Deng et al., 2025**). Thirdly, decorative styles: Bao, Q et al. employed a grounded theory combined with a KANO-AHP hybrid model to classify and quantify the core aesthetic characteristics of blue-and-white porcelain, thereby establishing a multidimensional aesthetic feature database for its patterns (**Bao et al., 2025**); Wang Aihong et al. explored the compositional methods, patterns, and principles of decorative motifs in Ming Dynasty Zhengde imperial blue-and-white porcelain through formal analysis, interpreting the cultural connotations conveyed by Islamic-style vessels during the Zhengde period within Sino-foreign cultural exchanges (**Wang & Luo, 2021**).

While existing research has achieved a relatively thorough understanding of the temporal characteristics of Ming Dynasty blue-and-white patterns, further exploration is warranted regarding how these patterns function as symbols within their contexts: How did the symbolic meanings of Ming Dynasty blue-and-white patterns emerge through social interaction? How does the social embeddedness of these symbolic meanings shape their historical connotations and influence their application value in contemporary design? These questions render the boundaries of Ming Dynasty blue-and-white patterns as visual symbols somewhat ambiguous, thereby diminishing their potential as a traditional medium for enhancing sociocultural understanding and public awareness.

2. Opportunities

In light of this, discussions surrounding the interpretation and regeneration of Ming Dynasty blue-and-white patterns may be developed along the following lines:

- a. The stability of blue-and-white patterns. Focusing on how Ming Dynasty blue-and-white motifs evolved from specific images into highly recognisable symbols through prolonged usage, laying the groundwork for subsequent interpretation and regeneration.
- b. The generation and convergence of meaning. Re-situating the meaning of patterns within processes of viewing, usage, and dissemination, examining how interpretative responses at different levels gradually accumulate to form a stable social consensus.
- c. Whether symbols can serve as conditions for preserving cultural memory. This explores how historical narratives, visual experiences, and collective memory participate in sustaining a pattern's meaning, enabling certain interpretations to remain activated across generations.
- d. The potential for design experimentation. Directing attention to the contemporary design context, this examines how pattern regeneration can become an observable, comparable semiotic process through the adjustment and validation of symbolic conditions, without presupposing the inevitability of meaning.

This paper proposes to examine, from a Peircean semiotic perspective, the symbolic process by which Ming Dynasty blue-and-white patterns derive cultural symbolic meaning from their foundational forms through social contextualisation. This offers a fresh perspective for subsequent discussions on contemporary expressions of traditional elements.

3. Methodology

3.1 The Hierarchical Classification and Applicability of Peircean Semiotics

Unlike symbolic theories centred on linguistic systems, Peirce regarded symbols as universal cognitive tools, positing that human understanding of the world is invariably achieved through symbolic activity. The meaning of a symbol requires interpretation via another symbol; new symbols may be viewed as fresh metaphors superimposed upon older ones, constituting a universal rhetorical process (Zhang, 2022). The core of Peirce's semiotics rests upon a triadic relational model: "Sign—Object—Explanatory Note" (Peirce & Lisker, 2014). A sign is a perceptible or recognisable form; the object is the thing or concept signified by the sign; the explanatory note transcends individual psychological responses, representing the phased outcome of meaning generated during the sign's comprehension process. These three elements continually unfold through processes of understanding and reinterpretation (Yoshiji Mise, 1981). This dynamic process endows sign meaning with extensibility and generativity (Figure 1).

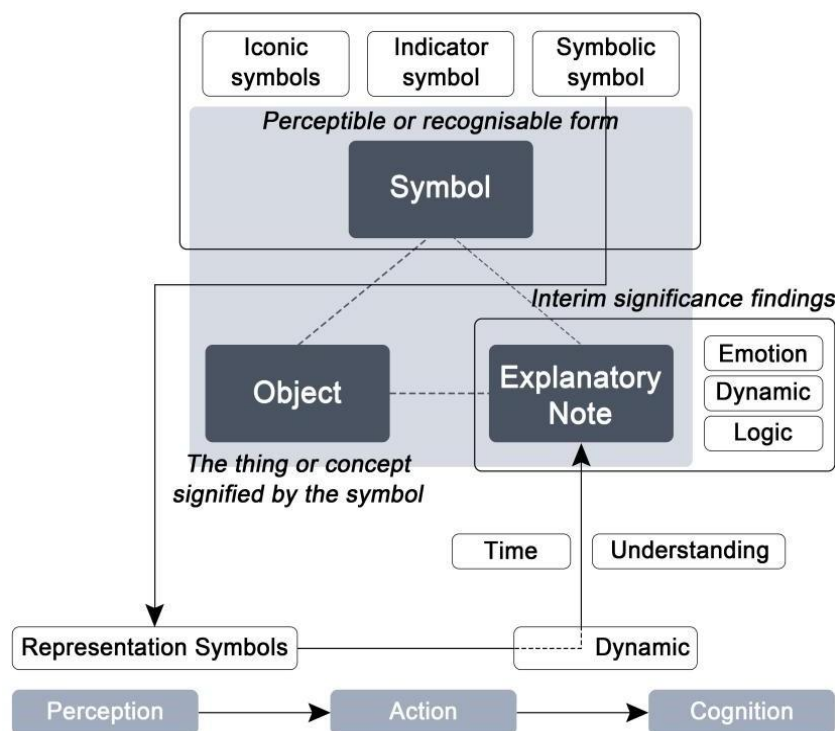


Figure 1 Pierce's Hierarchical Classification Diagram.

To clarify how symbols function, Peirce proposed a hierarchical classification. His most representative categorisation comprises three levels (Peirce & Hoopes, 1991): first, symbols are distinguished by their mode of existence into indexicals, indicials, and symbols. Indexicals establish connections through formal, structural, or qualitative resemblance to objects, relying on perceptual comparability; Indexicals point to objects through actual spatio-temporal or causal connections, focusing on the direct link between the sign and the real-world situation; Conventions are predicated on social conventions and rules of usage, established upon habitual cognition within the internal system of the sign. This foundational classification clarifies the different referential levels of signs, ranging from intuitive perception to social norms. Secondly, based on the internal relationships within the first-level symbolic sign, it distinguishes between the signifier, the object, and the interpretant. The signifier refers to the perceptible form of the symbol; the object is divided into immediate objects and dynamic objects; the interpretant may also manifest as meaning outcomes at different stages. This level of classification can be viewed

as a structural activity unfolding continuously over time and through the process of understanding, where the same symbol may present different types of interpretants at different stages of interpretation. Thirdly, concerning the function of interpretants in meaning generation at the preceding level, Peirce proposed a further distinction in their nature: affective, performative, and logical interpretants. Aesthetic interpretants constitute the immediate sensations evoked by symbols at the perceptual level; dynamic interpretants manifest as behavioural responses and practical inclinations prompted by symbols; logical interpretants emerge as stable understandings and cognitive rules formed through repeated use. These three tiers of interpretants progress sequentially, traversing a journey from perception to action, culminating in the establishment of cognitive structures.

The visual motifs employed in Ming Dynasty blue-and-white porcelain—such as traditional patterns depicting figures, animals, plants, and landscapes—maintain recognisable contours and structural relationships to their real-world counterparts. This likeness establishes an initial perceptual connection between the motif and its subject, forming the intuitive foundation for the pattern's comprehension and acceptance. Through similarity, the viewer is guided to complete an initial recognition of meaning. Yet Ming blue-and-white patterns transcended mere formal reproduction; their elements assumed referential functions within specific contexts. The arrangement of motifs, their precise positioning, and the vessel types to which they were applied often further guided viewers to associate them with particular usage scenarios, thereby establishing more explicit referential relationships. As a particular series of patterns recurs in social usage, its meaning gradually transcends direct associations with specific objects or situations. Through prolonged cognitive accumulation, it solidifies into a universally comprehensible visual symbol. At this stage, the interpretation of patterns increasingly relies on established cultural experience and aesthetic conventions, continually forming and refining itself through the processes of viewing, usage, and dissemination. Viewers from different historical periods and social statuses may generate divergent interpretations of the same pattern, embodying what has been termed "infinite derivations" (Zhao, 2016). The incremental identification of individual pictorial elements gradually diminishes. This transition transforms blue-and-white patterns from concrete figurative representations into a recognisable cultural language, solidified through repeated use and social consensus.

The interconnection of patterns across figurative, indicative, and symbolic dimensions enables their continuous reinterpretation and transformation across historical contexts, provided their concrete forms remain recognisable. This grants them enduring potential for citation. Drawing upon Peirce's hierarchical classification and structural process of symbols, Ming dynasty blue-and-white patterns can be progressively understood not merely as static decorative forms, but as stable symbols possessing an intrinsic structure. It is precisely in this sense that this theoretical framework can more clearly explain the temporal and open characteristics of meaning generation in Ming Dynasty blue-and-white patterns, providing a reliable theoretical premise for their transition from historical to contemporary contexts and enabling their interpretation and regeneration.

3.2 Sample typing sources and processing

The selection of samples for this study was designed to capture the representativeness and diversity of Ming Dynasty blue-and-white patterns, with a view to exploring the stability of symbols and underlying patterns. A total of 24 items were selected, comprising platters (13), bowls (4), cups (4), jugs (2) and vases (1). They are primarily sourced from museums and relevant collections in China, Japan and the United Kingdom. This cross-regional approach to sample acquisition has, to a certain extent, broadened the diversity of material sources and helped to mitigate potential biases arising from differences in collection systems. Furthermore, in the selection of overseas samples, this study has deliberately included representative cases characterised by distinct cultural contexts. Japan, as a key partner in Ming-dynasty maritime trade, maintained close circulation links with Jingdezhen blue-and-white porcelain; its reception largely occurred within the East Asian cultural sphere, where the objects' original

contexts and aesthetic structures were preserved at the level of use; In contrast, Britain served primarily as a key node in modern global trade and museum collection systems. The blue-and-white porcelain in its collections has largely been detached from its original context of use, entering a knowledge-constructing system centred on appreciation, classification and research. During this transition, the symbolic meaning of the patterns has also undergone reinterpretation within a cross-cultural context.

Furthermore, to ensure the validity and comparability of the research analysis, this study has introduced a clear geographical restriction in the sample selection process: all samples are either attributed to, or can be highly reliably identified as, products of the Jingdezhen kiln system in Jiangxi. As the core region for the production of Ming Dynasty blue-and-white porcelain, Jingdezhen possesses a relatively stable production tradition in terms of raw materials, techniques and decorative patterns, providing a basis for comparison between different artefacts in terms of form and meaning.

To ensure comparability and cross-cultural reference, contemporaneous blue-and-white porcelain circulated abroad and relevant historical paintings were consulted, with selections made through museum catalogues. Criteria for sample selection included: clear and recognisable patterns, structural integrity, and maintainable distinctiveness across different vessel forms and layouts. Preliminary observation and formal analysis of Ming Dynasty blue-and-white patterns revealed that landscapes, figures, plants, and animals constituted the most frequently occurring motifs. Other relatively common themes, such as purely decorative geometric patterns, provided limited information in the analysis of pictorial symbols and were less directly identifiable than the aforementioned four categories. Consequently, these were categorised as supplementary patterns within the analytical scope of this study.

During the symbol extraction phase, guided by Peircean semiotics, the principal motifs within patterns were regarded as the core elements of the signifier. The extraction process relied on a multi-layered reference system, combining the inherent morphological characteristics of the patterns with auxiliary motifs to identify key symbols maintaining high recognisability across different vessel types. The objective of this stage was to abstract operational symbolic elements from the complex decorative context, providing a clear foundation for subsequent implementation.

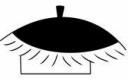
During the analysis and experimentation phase, extracted symbols were first categorised to clarify their semantic origins. Subsequently, representative symbols were selected for derivative combinations, generating diverse design proposals. These were tested under varying compositional conditions to assess symbolic interpretability and semantic directionality. Design proposals were presented to observer groups through experimental sessions, documenting logical interpretations, emotional interpretations, active interpretations, and patterns of interpretative variation. This analysed convergence and deviation trends in symbol interpretation under varying conditions, yielding verifiable data while offering fresh perspectives for the cross-contextual application of ornamentation and contemporary design.

3.3 Symbolic Interpretation

Iconic symbols represent the most fundamental referential form within symbolic systems. Their core lies in visual comparability – the intuitive similarity between the symbol's form and its object is activated through visual perception, enabling viewers to extract the pattern's content at the primary perceptual level without linguistic reliance. Landscape motifs represent the most systematised category within Ming Dynasty blue-and-white patterns, characterised by simple yet distinctive contour lines of peaks, flowing curves of water, silhouettes of trees, and spatial structures created through layered perspective (**Table 1**). Typical mountain compositions establish symbolic rhythms through repeated triangles, arcs, and curves, ensuring high perceptual recognition of the mountain forms. Rivers convey directionality via continuous curves and the interplay of solid and void elements, while tree forms

utilise branching trunks and leaf outlines to provide semantic cues of vegetation. Landscape scenes are often accompanied by auxiliary forms such as vegetation and mist. These supplementary features reinforce object boundaries through contrast, repetition, or rhythmic lines, thereby enhancing intuitive recognition. For instance, the layered brushstrokes along mountain edges create structural cues through variations in thickness and negative space relationships. This renders the image more readily interpretable while maintaining an objective resemblance to natural forms.

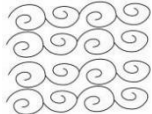
Table 1 Extraction Table of Symbolic Elements in Landscape Patterns

Sample						
Name	Blue-and-White Porcelain Plate with Landscape and Figures			Blue-and-White Porcelain Plate with Sailing Ship Design		
Collector	Tokyo National Museum			The British Museum		
Pattern characteristics	The mountain massif predominantly adopts a segmented block-face construction.			Pavilions with geometric outlines nestle amidst the hills and waters, while vessels dot the surface of the water.		
Subject symbol						
	Mountains	Trees	Cloud	Pavilion	Towers	Small boat
Sample						
Name	Jade Hall Fine Ware Marked Blue-and-White Bowl with Landscape and Figures			Landscape and Figures: Hexagonal Inkstone		
Collector	The Palace Museum			Tokyo National Museum		
Pattern characteristics	The dwelling is situated at the foot of the slope, with selected features presented in isolation to emphasise their contours.			The size of the peaks and the interplay of foreground and background obstructions exhibit variation.		
Subject symbol						
	Houses	Trees	Hillside	Plank bridge	Pavilion	Mountains

The figure motifs on Ming Dynasty blue-and-white porcelain predominantly drew inspiration from literati lifestyles or narrative scenes. Their creative purpose transcended mere pictorial representation, further employing

the lines of human movement to provide recognisable clues for identifying figures (Table 2). Within patterns depicting figures dwelling, standing, or interacting, the connecting lines at key junctures and the simplified contours of garments became pivotal points for discerning character intent and status. The pronounced proportions and dynamic postures of the figures also enabled viewers to swiftly grasp visual units during initial observation, without requiring additional cultural interpretation.

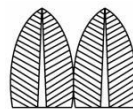
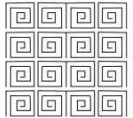
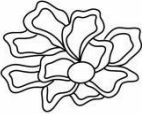
Table 2 Extraction of Symbolic Elements in Figurative Patterns

Sample						
Name	Blue-and-white porcelain plate depicting narrative scenes			Ancient Blue-and-White Dish with Arhat Motifs		
Collector	Sir Butler, United Kingdom			Tokyo National Museum		
Pattern characteristics	The central section depicts the scene of 'climbing over the wall under cover of night', while the surrounding motifs feature geometric patterns and Western floral bouquets.			The figure's fundamental form is constituted by the proportions of its complete torso and limbs, possessing an immediately recognisable human shape.		
Subject symbol						
	Figures	Bouquet 1	Bouquet 2	Figures	Geometric pattern 1	Geometric pattern 2
Sample						
Name	Auspicious Landscape with Swirl Pattern: Sake Cup Inscribed "Fortune" in Blue-and-White Porcelain			Blue-and-White Porcelain Bell with Arhat Design and Animal-Shaped Handle		
Collector	Tokyo National Museum			The Palace Museum		
Pattern characteristics	Geometric patterns serve as background elements, accentuating the central figure on horseback as the focal point.			The ensemble cast distinguishes characters through varied postures, each maintaining distinct physical recognition.		
Subject symbol						
	Figures	Geometric 1	Geometric 2	Figures	Bouquet 1	Bouquet 2

Unlike the narrative representations of landscape spaces or human movement, botanical motifs in Ming

Dynasty blue-and-white patterns predominantly rely on the abstraction of natural forms to achieve highly recognisable linear characteristics (**Table 3**). For instance, the Basket-Carried Flowers establishes a visual focal point through the repetitive layering of petals and stamens, emphasised by the contours of its edges. Similarly, the Peony Pattern employs layered petals to create texture alongside foliage, resulting in a densely patterned whole where the core form remains clearly discernible. The representational quality of botanical motifs further manifests in their dynamic flow and compositional equilibrium. The rhythmic rotation of petals and the extension of foliage lines create movement, while the overall repetitive pattern provides visual stability and predictability. Through processes of extraction, attenuation, and emphasis, these motifs achieve a form that retains recognisable characteristics while possessing decorative appeal.

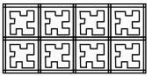
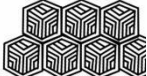
Table 3 Symbolic Elements Extracted from Botanical Motifs

Sample						
Name	Blue-and-White Basket-Handled Plate with Floral Design			Blue-and-White Floral Pattern Pitcher		
Collector	Suzhou Museum			National Palace Museum, Taipei		
Pattern characteristics	The flowers in the basket are arranged in bundles, with stems radiating outward from the same container opening.			Flowers serve as the visual focal point, while leaves provide filler and connect the elements.		
Subject symbol						
	Figures	Bouquet 1	Bouquet 2	Figures	Geometric pattern 1	Geometric pattern 2
Sample						
Name	Blue-and-White Porcelain Bowl with Strange Rock and Peony Design			Blue-and-White Bowl with Floral and Bird Designs		
Collector	The Palace Museum			Tokyo National Museum		
Pattern characteristics	The peony pattern is rendered with a full, double-petaled structure, its petals layered upon one another.			The continuous extension of branches provides the structural foundation for birds to perch.		
Subject symbol						
	Figures	Geometric 1	Geometric 2	Figures	Bouquet 1	Bouquet 2

Animal motifs within the blue-and-white decorative system encompass both real-world creatures and

mythological beings. Image extraction often relies on exaggerated bodily contours and dynamic postures: fish motifs typically employ curved body lines and fin outlines to convey swimming motion; bird motifs convey position and movement through extended wings and feathered lines; while beasts maintain key points for object recognition within exaggerated structural forms (**Table 4**). These clues constitute the object's typical characteristics at the formal level, enabling the immediate schema to serve as a decorative layout while preserving the recognisable bridge between the object and its identifiable form.

Table 4 Extraction of Symbolic Elements in Animal Motifs

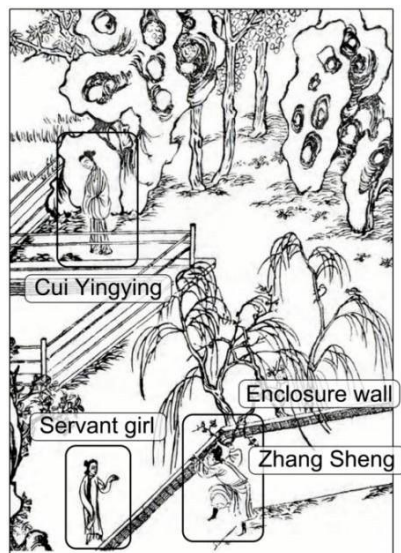
Sample						
Name	Blue-and-White Rabbit Motif Flower- Patterned Dish			Large Blue-and-White Plate with Branching Boughs and Sash-Tied Birds		
Collector	Tokyo National Museum			Tianjin Museum Collection		
Pattern characteristics	characterised primarily by slender ears, with clean, continuous lines and relatively intricate auxiliary patterns.			The positions and postures of the two birds are clearly distinguishable.		
Subject symbol						
	Rabbit	Geometric pattern 1	Geometric pattern 2	Bird	Plants	Cloud pattern
Sample						
Name	Large Blue-and-White Bowl with Fish and Waterweed Design			Blue-and-White Horse-Riding Cup		
Collector	The Palace Museum			The Metropolitan Museum of Art		
Pattern characteristics	The fins and tail are depicted in an outstretched position, forming a harmonious arrangement with the curved surface of the cup			Depicted in a sideways, slightly downward-facing pose, with the limbs rendered in an abstract style that contrasts with the body's central axis		
Subject symbol						
	Fish	Plants 1	Plants 2	Horse	Geometric pattern 1	Geometric pattern 2

Landscape, figure, plant, and animal motifs in Ming blue-and-white porcelain exhibit distinct stylistic characteristics. Landscape patterns convey rhythmic vistas through linear composition and layering; figure motifs achieve vividness through action and posture; plant designs establish visual cadence via floral and foliage contours and arrangement; animal motifs maintain intuitive recognition through characteristic features and movement. Beyond singular representations, Ming blue-and-white patterns frequently combine multiple natural subjects into unified compositions. When patterns carry narrative elements or depict highly complex action sequences, their visual comparability diminishes, requiring cultural context or story knowledge for deeper interpretation. Such combinations often adhere to specific narrative logic.

In interpreting Ming blue-and-white patterns, the fundamental reason viewers can swiftly recognise an image as a specific figure, natural form, or life-form lies not only in the aforementioned 'likeness' but also in these images having been repeatedly incorporated into literature, painting, and everyday narratives. Based on this assessment, we reverse-engineered the earlier samples to identify recurring themes across different media with highly consistent outcomes, thereby elucidating how meaning becomes crystallised.

The prevalence of opera narratives and character-based stories as motifs in Ming Dynasty blue-and-white patterns constitutes a common phenomenon, gradually evolving into a significant decorative category, most notably exemplified by *The Romance of the West Chamber* (Li, 2024). From the mid-Wanli period of the Ming dynasty, the stylistic approach to *The Romance of the West Chamber* illustrations became increasingly refined and intricate. Concurrently, with the development of private printing houses and the popularity of vernacular literature, illustrations across different regions began to influence and borrow from one another, leading to a gradual stabilisation of compositional forms for classic scenes (Teng, 2021). Take the classic composition "Climbing the Wall Under Cover of Night" as an example. The illustration (Figure 2) has formed a cross-media dialogue with blue-and-white porcelain patterns (Figure 3). The image captures the moment just before Zhang Sheng leaps from the wall, the most suspenseful instant before the conflict erupts. The act of scaling the wall itself possesses potent dramatic force. The wall as a spatial boundary and the dynamic instant captured in the figure's leap combine to form a highly recognisable scene. This narrative is conveyed by minimising variations in facial depiction while emphasising the spatial division represented by the "wall" and the act of "crossing the boundary". Upon encountering this composition, the viewer transcends mere observation of nocturnal movement or physical exertion, instead conjuring a narrative pivot long established within literary and theatrical traditions. Moreover, the botanical motifs adorning the plate's rim bear similarities to floral decorations found on contemporary Turkish Iznik ceramics (Figure 4). The central scene depicting "climbing over the wall under cover of night" remains particularly stable, indicating that Ming Dynasty blue-and-white patterns undergo shifts in meaning through segmented transmission during cross-cultural dissemination. Decorative border patterns largely remain at the level of formal resemblance, with meanings adaptable to stylistic and regional variations. In contrast, figurative motifs rooted in literary narratives achieve high stability through prolonged exposure to repeated viewing and interpretation within cultural contexts.

Compared to figurative motifs that rely on narrative actions to achieve representational resemblance, landscape, plant, and animal patterns constitute another, more fundamental symbolic system. Among landscape motifs, the distant-view composition is selected for discussion. In blue-and-white porcelain, this type of landscape often exhibits a highly formulaic structure: foreground trees and rocks, midground water's edge, and background mountain ranges unfold sequentially. The layering of peaks and the flow of waterways create a visual itinerary, transforming the landscape from mere decoration into a symbol of the literati's idealised retreat from worldly life. This compositional approach not only recurs frequently on ceramics but also appears extensively in contemporary landscape paintings (Figure 5). It is precisely this cross-media repetition that gradually transformed the high-distance landscape composition into a widely accepted subjective notion of "how landscapes ought to be presented".



THE WEST CHAMBER: 'CLIMBING OVER THE WALL UNDER COVER OF NIGHT'
Ming Dynasty, Xuexiangju Journal: 'Timeless Splendour'



THE WEST CHAMBER: 'CLIMBING OVER THE WALL UNDER COVER OF NIGHT'
Ming Dynasty, by Min Qiji

Figure 2 Illustration of "Climbing the Wall at Night" from The Romance of the West Chamber

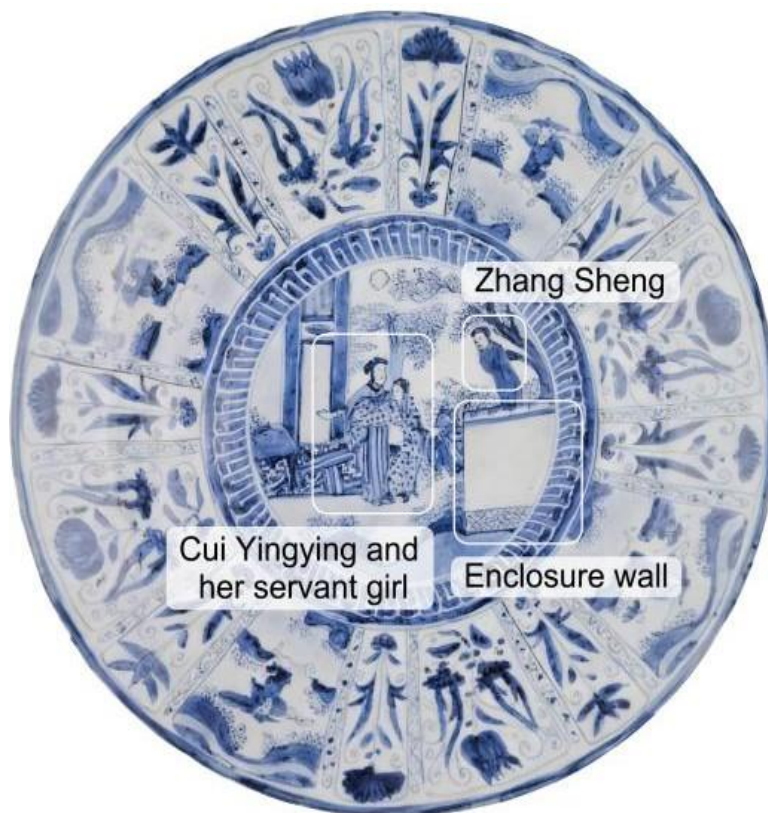


Figure 3 Ming Chongzhen Period Blue-and-White Porcelain Plate with Narrative Motifs



Figure 4 Turkish Iznik Ceramics

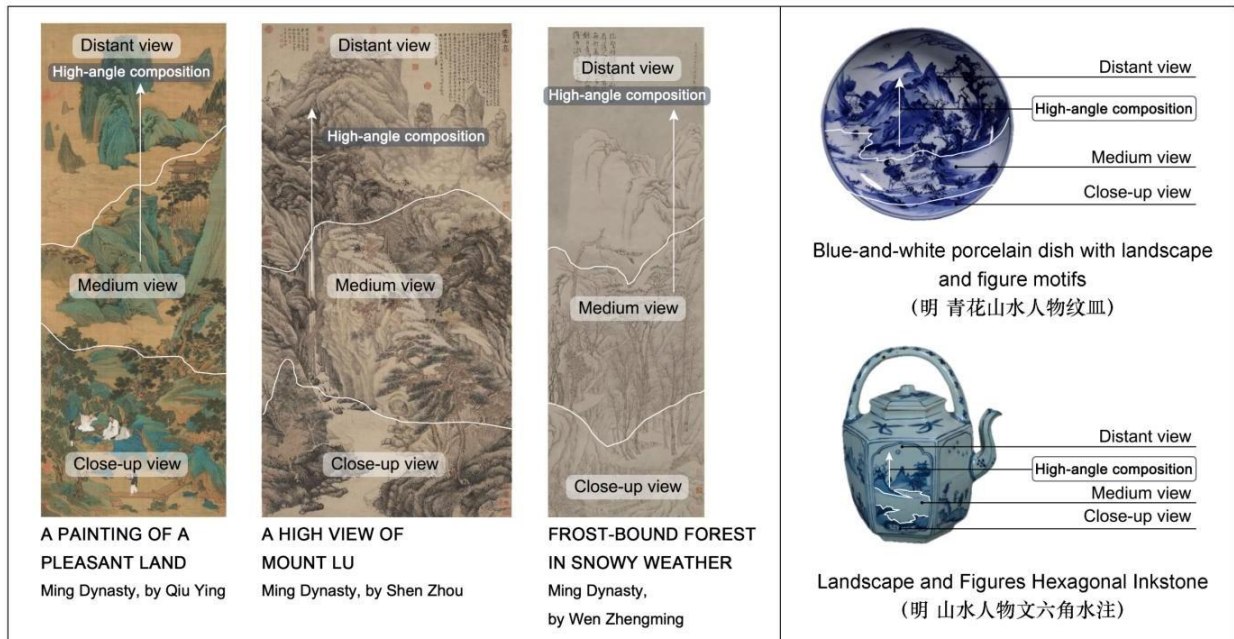


Figure 5 Diagram illustrating the relationship between high-perspective landscape painting and ceramic decoration

Floral motifs exhibit considerable variety. Patterns featuring plum blossoms, peonies, and other plants establish clear rhythms through extended branches and leaves, rotated and repeated petal arrangements (**Figure 6**). Across different vessel forms, the core structural elements of these floral designs remain consistent, while subtle variations enrich their narrative dimensions (**Jing et al., 2024**). Within the viewer's cultural framework, these motifs are both recognisable and capable of conveying deeper meanings. Within botanical motifs, the peony has long held explicit symbolic significance in Chinese painting traditions. Since the Tang and Song dynasties, it has been regarded as the flower of wealth and nobility. This connotation is repeatedly referenced in flower-and-bird paintings, such as Zhu Zhanji's "Wealth Within the Vase," where the peony within the vase displays layered petals and a state of full bloom, its very name carrying cultural allusion. In decorative arts from the Ming dynasty onwards, peony motifs proliferated across paintings and brocades, paralleling the idealised, recurring depictions of peonies

in blue-and-white porcelain (**Figure 7**).

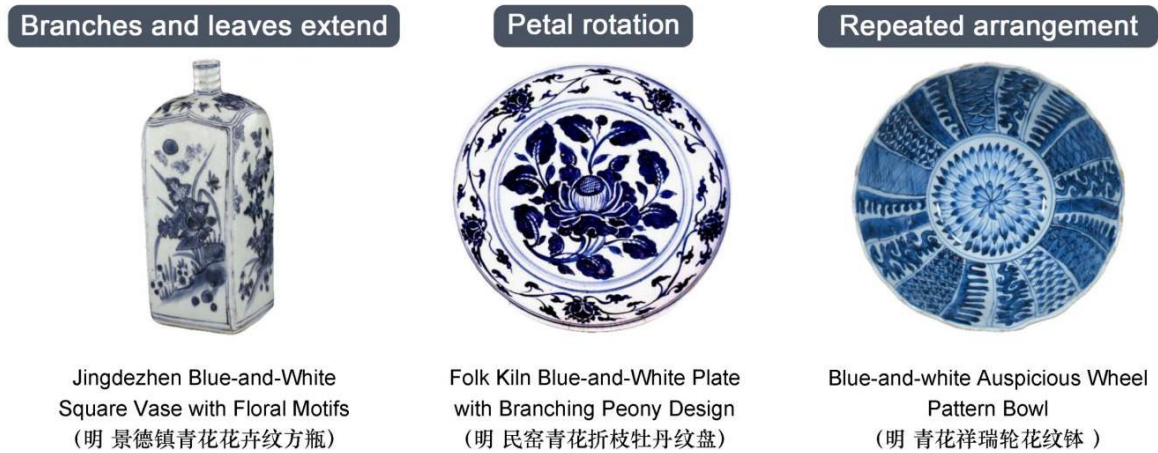


Figure 6 Comparative Layout of Botanical Motifs

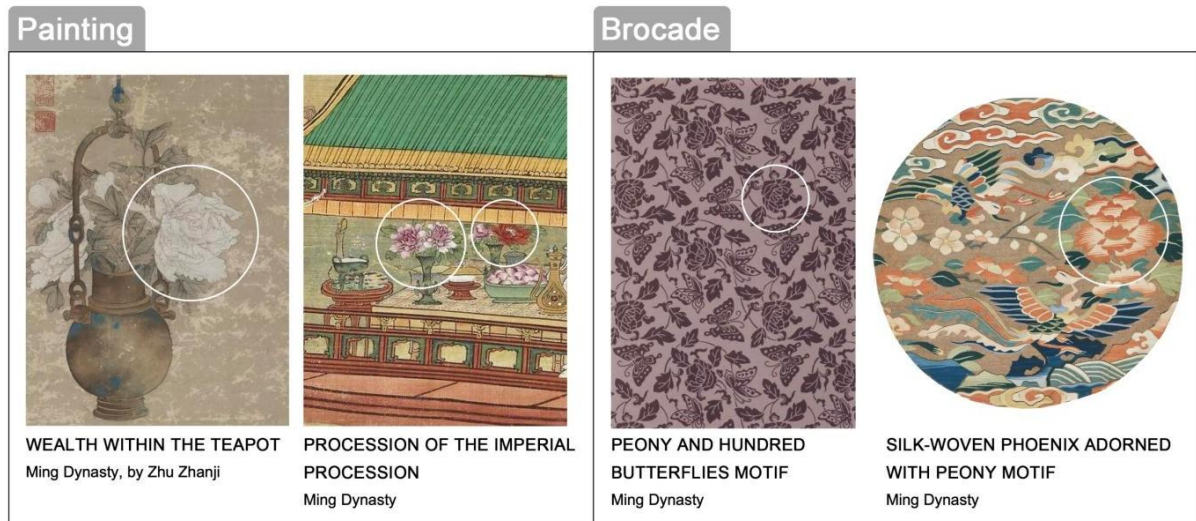


Figure 7 Correspondence of Peony Motif Forms

Animal motifs often employed repetition and standardised depictions. For instance, the fixed rabbit motif complemented surrounding geometric patterns, creating a continuous visual rhythm through arrangement and interaction (**Figure 8**). Their specific social or auspicious connotations could be understood through symbolic pathways. Compared to dragons and phoenixes—images steeped in institutional and mythical significance—rabbit motifs were less prevalent in Ming blue-and-white porcelain. Yet their symbolism demonstrated continuity: in Han dynasty stone carvings, rabbit designs featured simplified lines; in Han relief stones, silk paintings, and bronze ware, rabbit motifs frequently appeared alongside the Queen Mother of the West myth, depicted in scenes of "jade rabbits pounding medicine" to symbolise longevity (**Figure 9**). The Ming-era treatise *Zhezong Zhi* records: "For New Year, the auspicious gourd and ten-thousand-year blessings; for Lantern Festival, the lantern; for Dragon Boat Festival, the Celestial Master; for Mid-Autumn Festival, the moon rabbit. The Ming imperial court observed the custom of changing attire according to the solar terms. During the Mid-Autumn Festival on the fifteenth day of the eighth lunar month, it was customary to worship the moon for blessings. People adorned themselves with rabbit-patterned accessories (**Figure 10**) to seek auspicious omens. These seasonal observances cemented the rabbit motif's propitious symbolism within traditional understanding, reinforcing its established interpretations through prolonged usage.

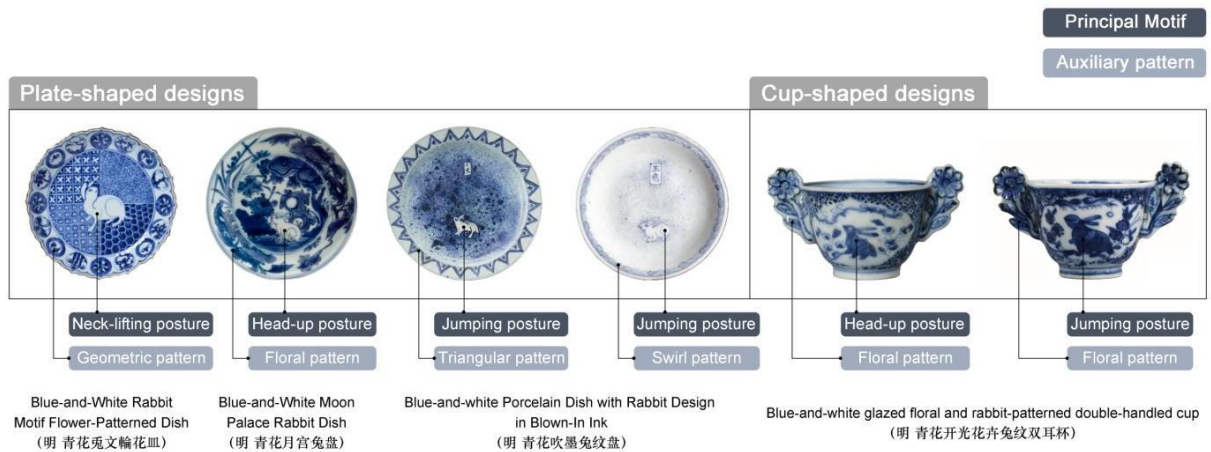


Figure 8 Arrangement of rabbit motifs on similar vessel types

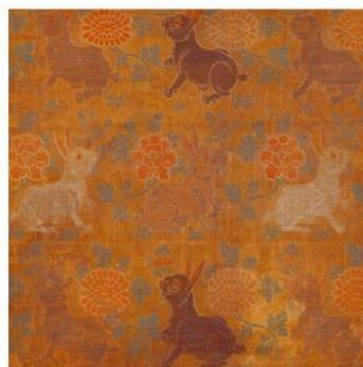


JADE RABBIT POUNDING MEDICINAL HERBS

PICTORIAL BRICK

Han Dynasty

Figure 9 Han Dynasty rabbit-patterned portrait bricks



YELLOW GROUND WITH
OSMANTHUS AND RABBIT MOTIF
EMBROIDERED BROCADE
Ming Dynasty



KESI MID-AUTUMN FESTIVAL
EMBROIDERED BADGE FEATURING
JADE RABBIT MOTIF
Ming Dynasty

Figure 10 Ming Dynasty rabbit-pattern brocade

The perception of Ming Dynasty blue-and-white patterns initially arose from a certain comparability in form

and subject matter, with similarity facilitating recognition. However, the ultimate social sharing of symbolic meaning and confirmation within cultural memory depended on the continuous development of interpretative frameworks. This development manifested as a differentiated yet serialised process across different pattern categories, establishing stable referential relationships with specific cultural meanings (**Table 5**).

Table 5 Symbolic Feature Translation Matrix for Four Thematic Categories

Theme	Representative Motif	Solidified Interpretive Elements	Translatable Symbolic Characteristics
Landscape	Lofty-style landscape	Ordered natural world	The hierarchical relationship between waterfronts, mountain ranges, and foreground, middle ground, and background
Figures	Excerpt from The Romance of the West Chamber	Specific Narratives	Character Movement Patterns
Plants	Peony motif	Wealth and Nobility	Layered petals, clustered at the centre
Animals	Rabbit motif	Auspicious, gentle	Long ears, crouching posture

4. Design Innovation

The preceding analysis, grounded in Peircean semiotics, conducted a layered examination of the symbolic structures within landscape, figure, plant, and animal motifs in Ming Dynasty blue-and-white porcelain patterns. It elucidated the progressive solidification of these motifs from their formal resemblance and contextual referents to socially codified conventions, sustained through reproducibility. However, merely describing the historical evolution and theoretical interpretation of these symbolic structures fails to address a fundamental question: when these highly stable symbols are detached from their original material medium and social context, do their symbolic relationships remain valid? If so, what core elements sustain them? If shifts occur, at which level do these relationships begin to unravel? Therefore, a research methodology capable of reactivating symbolic relationships must be introduced. Accordingly, design innovation is incorporated into the research framework. Representative patterns previously demonstrated to possess high symbolic stability are selected and treated as an operational process of deconstruction, extraction, and reconfiguration of existing symbols. This approach tests the elasticity and continuity of symbols during cross-contextual translation.

Through the deliberate extraction and reconfiguration of core symbolic elements, we observe whether they continue to trigger relatively consistent interpretative outcomes within new visual systems. This approach responds to Peirce's semiotic theory regarding the open-ended, progressive, and infinitely extensible nature of meaning generation.

Blue-and-white patterns exhibit significant advantages in visual adaptability and symbolic clarity. These concise, recognisable visual elements facilitate symbol reuse and modern design regeneration (**Zhao et al., 2025**). Design innovation adopts a reverse approach from analysis to operation. Starting from established, validated stable relationships, it progressively transforms these into adjustable design elements corresponding to key variables at the symbolic level. These include: whether the symbol remains recognisable, whether meaning orientation shifts, and whether interpretative outcomes diverge. This transforms the design process into an experimental field for controlling and comparing symbolic conditions (**Figure 11**).

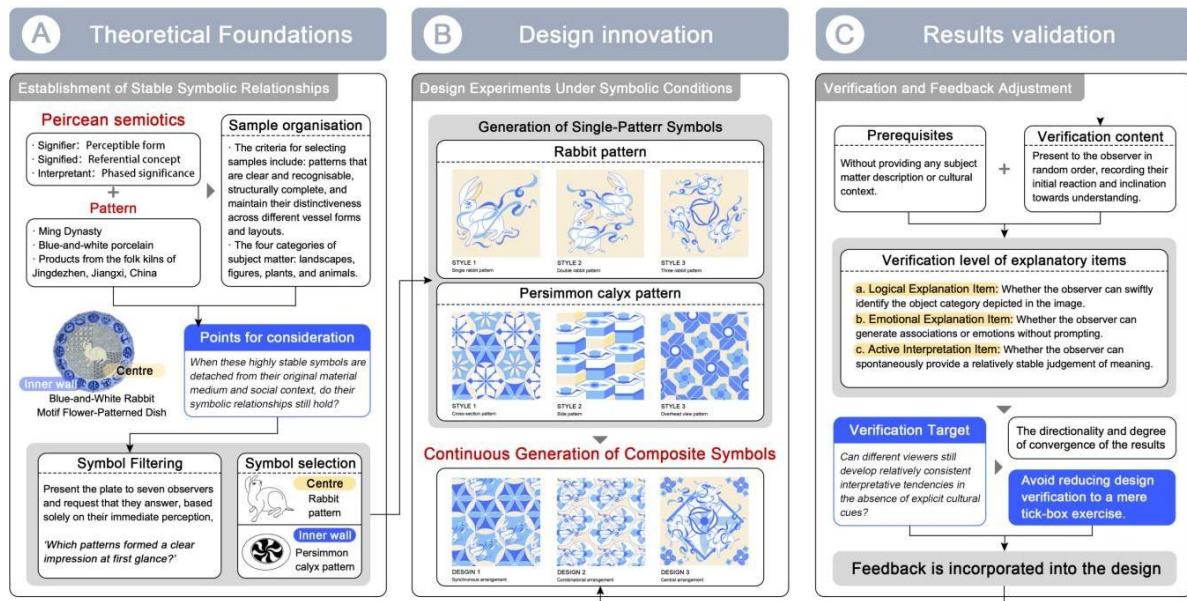


Figure 11 Design Experiment Flowchart

Building upon the preceding symbolic analysis, a selection of pattern groups rich in symbolism was chosen as experimental samples. From these, imagery underpinning the symbols' validity was extracted, with particular emphasis on identifying formative elements capable of maintaining high recognisability and semantic directionality across different vessel types and layouts. Subsequently, these extracted symbols were established as fundamental units for design operations. Experimental applications involving retention, attenuation, or reconfiguration were conducted to observe shifts in symbol recognition and semantic comprehension, thereby pre-forming a series of design proposals sharing similar conditions yet differing in relationships. This process enabled comparability between proposals of diverse themes while revealing under which conditions symbols remain stable and when interpretative shifts occur. Thus, design innovation was transformed into an experiment observing symbolic relationships.

Upon design completion, user observation verifies whether symbolic elements trigger original or analogous cognition, focusing on the directionality and convergence of outcomes. This assesses whether diverse observers, lacking explicit cultural cues, still develop relatively consistent interpretative tendencies. This approach avoids reducing design validation to mere symbol comparison. Experimental findings are then fed back into the design process to refine the innovation workflow, establishing a reusable framework for cross-contextual symbol translation and stability verification.

4.1 Deconstruction: From Blue-and-White Patterns to Symbolic Recognition

The experiment selected a blue-and-white rabbit-patterned wheel-decorated dish from the Chenghua period of the Ming dynasty as the initial observation object. A clear compositional structure exists between the centre of the dish and its inner rim (**Figure 12**). The centre features rabbit motifs as the primary decoration, with geometric patterns forming an intermediary field in the background. The inner rim is adorned with a continuous arrangement of encircling patterns. The juxtaposition of diverse motifs on a single vessel facilitates comparative analysis of immediate recognisability across different symbols.

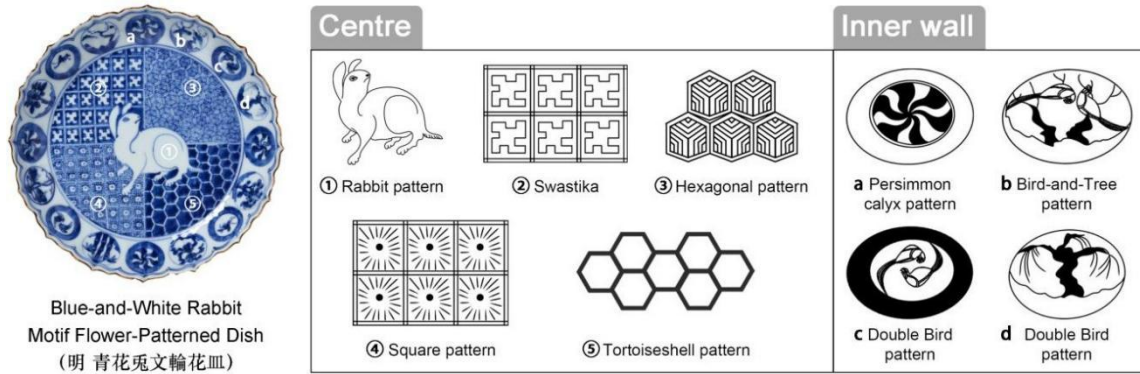


Figure 12 Symbolic Analysis of Patterns on Blue-and-White Rabbit-Motif Floral-Rimmed Dish

The first phase of the experiment involved guiding observers to autonomously identify patterns on the dish surface without prompting. The vessel was presented to seven observers without providing pattern names. The observer group required no specialist background but was instructed to answer solely based on intuitive perception: "Which patterns formed a clear impression at first glance?" Observational findings (**Table 6**) revealed that despite the coexistence of animal motifs, geometric patterns, and continuous border decorations, observers' attention was not evenly distributed across all elements. All seven observers clearly identified the rabbit motif, three actively described the persimmon calyx motif, and one prioritised the persimmon calyx motif as their primary recognition, demonstrating high consistency. In contrast, the geometric patterns serving as background elements, while perceived, were more frequently described using terms such as "filler" or "accent", and were less often acknowledged as distinct, independently recognisable symbols. Other patterns around the rim, such as bamboo and bird motifs, were scarcely singled out individually and did not enter the realm of explicit symbolic recognition.

Table 6 Symbolic Feature Translation Matrix for Four Thematic Categories

Observer Number	Primary Identified Pattern	Secondary Identified Motif	Observation Description Keywords
O1	Rabbit motif (①)	Tortoiseshell Pattern (⑤)	At first glance, one sees a rabbit, surrounded by decorative elements
O2	Rabbit Pattern (①)	Persimmon Peduncle Pattern (a)	First the rabbit catches the eye, then one discerns the flower-like ornamentation
O3	Swastika Pattern (②)	Rabbit motif (①)	The central geometric pattern is quite distinct, then notice the rabbit
O4	Persimmon calyx pattern (a)	Rabbit motif (①)	The pattern directly above is rather interesting; it catches the eye immediately.
O5	Rabbit motif (①)	Other unidentified	Primarily notice the rabbit in the centre; the rest are not readily discernible.
O6	Rabbit motif (①)	Square Pattern (④)	The rabbit is particularly distinct, with the background geometric patterns clearly delineated
O7	Persimmon calyx pattern (a)	Rabbit motif (①)	The persimmon calyx pattern is clearly defined, with the rabbit motif only discernible at its centre

Based on observational experimental findings, the rabbit motif and persimmon calyx motif were selected as core symbolic objects for subsequent design experiments. All subsequent design experiments and validations centred on these two ornamental categories, prioritising symbols already effectively recognised and consensus-formed at the perceptual level. By adjusting their combinations and visual conditions, we further examined how

their interpretative elements varied under different conditions.

4.2 Regeneration: From Symbol Recognition to Combination Translation

When the persimmon calyx-like pattern and the central rabbit motif enter into a combinatorial relationship, a disparity exists in their symbolic hierarchies. The archetypal persimmon calyx pattern radiates outward from its central point, exhibiting a symmetrical, radial structural characteristic. The peripheral persimmon calyx-like elements establish an indirect similarity to natural forms by extracting the growth nodes of the fruit, while the outward-projecting angular units suggest growth, continuity, and fruition. As an animal motif, the rabbit pattern possesses explicit referential meaning. In contrast, the persimmon calyx-like pattern contributes to meaning formation through its spatial positioning. Extracted rabbit and persimmon calyx patterns serve as fundamental units for design translation. While preserving the recognisability of core elements, experiments with four-directional continuous planar arrangements generate new pattern compositions. This process observes whether recognisability and semantic directionality remain stable.

4.2.1 Step 01: Symbolic Generation Experiment with Single Patterns.

The rabbit motif, the most recognisable core pattern on the plate surface, demonstrated highly consistent identification results in observational experiments. Using the rabbit motif as the template, its form was deconstructed while preserving symbolic integrity. Key features—such as the direction of the head, the curvature of limbs, and the overall dynamic posture—were extracted and symbolically rendered (**Figure 13**). The persimmon calyx motif recurs as a rim decoration. Its fundamental composition was analysed, with emphasis on extracting pattern details under varying scales to form a stable, balanced decorative structure on the plane (**Figure 14**).



Figure 13 Schematic of rabbit motif symbol design



Figure 14 Persimmon calyx motif symbolic design schematic

4.2.2 Step 02: Experimental generation of composite symbols.

Building upon the continuous units derived from prior experiments, this phase reorganises the rabbit and persimmon calyx motifs within a unified visual system (**Figure 15**). Each motif group employs a consistent 1:1

square composition as its canvas, ensuring comparability among derived symbol outcomes. Three arrangement strategies were devised: First, synchronous arrangement. Rabbit and persimmon peduncle motifs repeat at equal intervals horizontally or vertically, maintaining consistent orientation. Observe whether merged symbols retain recognisability. Second, composite arrangement. Motifs combine into a single symbol, which is then repeated. Observe whether the new composition elicits emotional responses akin to the original symbols. Third, central arrangement. Positioning the rabbit pattern as the core element at the centre, with persimmon calyx patterns radiating around it to form a radial layout. Observing the interpretative hierarchy of symbols after spatial weight adjustments. All three arrangement experiments are presented devoid of narrative context, ensuring the symbols' form and arrangement itself become the primary identification cues. By adjusting symbol styles, rotation angles, spacing, and repetition counts, multiple comparable design proposals are generated, providing clear foundations for subsequent experimental validation.



Figure 15 Schematic of combined symbol design

4.3 Results: From Combined Translation to Valid Verification

In Peircean semiotics, interpretants unfold as theoretical premises during use. Consequently, the design feedback process was structured as an iterative adjustment of symbolic conditions, documenting shifts in interpretive responses.

First, without providing any contextual explanation, three sets of pattern samples with different arrangement forms were presented to seven observers in random order. Their initial reactions and interpretative tendencies were recorded. The experiment documented three categories of response information, corresponding to different levels of interpretative items in Peirce's semiotics:

- a. Logical Explanation Item: Whether the observer could rapidly identify the object category signified by the image.
- b. Emotional Explanation Item: Whether the observer generates associations or emotional responses without prompting.
- c. Active Interpretation Item: Whether the observer spontaneously provided a relatively stable judgement of meaning.

The key observation and comparison focused on how adjustments to different variables influenced the pathways of explanation item generation. The validation process employed a longitudinal comparison approach, starting from the same symbolic prototype to observe changes in interpretative responses under varying design conditions (**Figure 16**).

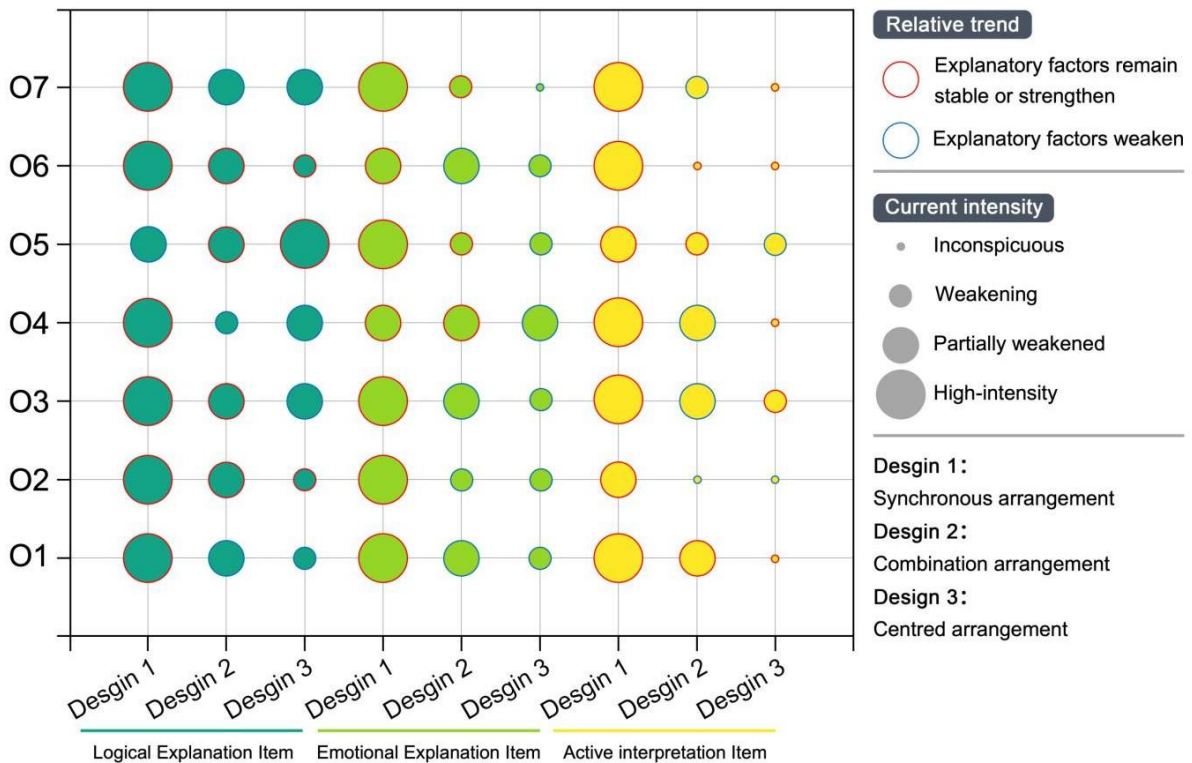


Figure 16 Relative states and changes of explanation items under different arrangement patterns

4.3.1 a. Logical Interpretation Items

Across all arrangements, the core rabbit motif maintains highly stable recognisability. In the synchronous arrangement, six out of seven observers swiftly identified the rabbit motif prototype as "rabbit" and the persimmon calyx motif prototype as "persimmon". The sole hesitant observer indicates that when repetitive units become excessive and visual density increases, logical interpretation items are slightly affected. In the combination arrangement, 5 out of 7 observers recognised the rabbit motif, while 4 recognised the persimmon calyx motif. When the rabbit and persimmon calyx motifs combined to form a new symbol, the core shape of the rabbit motif retained dominance. The persimmon calyx motif, positioned peripherally in a supporting role, exhibited weaker logical recognition. In the centred arrangement, all seven observers recognised the central rabbit motif, demonstrating highly stable logical recognition of the core symbol. Most observers identified the peripheral persimmon-stem motif, though two regarded it as supplementary decoration rather than an independent symbol.

4.3.2 b. Emotional Interpretation Component

Emotional responses exhibited heightened sensitivity to symbol variations. In the synchronous arrangement, all observers retained associations of "lively," "gentle," and "auspicious" emotions even after removing contextual narratives, indicating the rabbit motif's emotive flexibility persists through rhythmic transformations. In the combined arrangement, all observers similarly triggered "lively" and "gentle" emotional responses to the rabbit motif, while the persimmon calyx pattern elicited "abundant" and "auspicious" emotions, albeit with relatively weaker intensity. This indicates that the emotional interpretation of the persimmon calyx pattern is influenced by its position and combination method. In the central arrangement, observers generally responded to the central rabbit motif with "gentleness," while emotional responses to the surrounding persimmon calyx motifs were markedly lower than those to the rabbit motif. Nevertheless, the overall association with "blessing" was maintained.

4.3.3 c. Active interpretive items

Active interpretive items exhibited marked variation across symbol arrangements. In synchronous arrangements, five observers spontaneously interpreted symbols as conveying social meanings of "auspiciousness"

and "blessing," while two remained primarily at the emotional level. In the combined arrangement, three observers interpreted the composite pattern as conveying an overall "auspicious" meaning, while four remained anchored to emotional associations with individual symbols. This indicates reduced stability in active interpretation when symbols combine to form novel configurations. In the central arrangement, all five observers assessed the social meaning of the entire composite symbol, though two primarily focused on the emotional dimension of the rabbit motif, failing to fully integrate the persimmon calyx motif into their social interpretation.

The arrangement of three categories reveals distinct interpretative dynamics. Logical interpretations remain highly stable on rabbit-patterned items, while peripheral persimmon-stalk patterns show slight declines influenced by arrangement and positioning. Emotional interpretations consistently remain strong on rabbit-patterned items, with auxiliary symbols triggering slightly reduced responses. Agency interpretations prove most susceptible to variations in arrangement and combination; when symbols depart from their original context or form new combinations, the formation of social meaning tends to diverge. The meaning of symbols is not immediately conferred upon completion of the design, but is continually generated, confirmed, or diminished within specific symbolic contexts. Preserving the key form of the core pictogram is the prerequisite for ensuring the stability of logical and emotional interpretation. Any formal changes must be made without compromising this core form. Auxiliary symbols may undergo minor visual positioning adjustments, but their supporting role to the core symbol must be considered. They are primarily employed to enhance design expressiveness, while the core pictogram remains the primary bearer of meaning.

5. Discussion

Within contemporary design discourse, the semiotic significance of Ming blue-and-white patterns extends beyond visual interpretation and can be rearticulated as a set of generative mechanisms. Drawing on Peirce's triadic framework, this study reorganizes its findings into three interrelated pathways that inform design practice at different levels.

At the iconic level, the internal structural logic of blue-and-white ornament—exemplified by the rhythmic continuity of scroll motifs and the radial organisation of medallion patterns—provides a basis for morphological abstraction. Rather than remaining confined to surface decoration, these elements may be reconfigured as modular units and incorporated into contemporary ceramic design through geometric or parametric strategies. In this process, the pattern no longer merely embellishes the object but actively participates in shaping it, influencing vessel contours, opening proportions, and modes of assembly. What emerges is a shift from two-dimensional ornamentation to three-dimensional form generation.

At the indexical level, the cultural and historical contexts embedded in such patterns—ranging from literati aesthetics to maritime imaginaries—operate as latent references that can be activated through design. Instead of direct visual quotation, these associations are mediated through use scenarios, narrative frameworks, or interaction logics. For instance, in interactive product design, carefully structured user pathways and situational cues allow cultural meanings to surface gradually within the experience, fostering a perceptual link between past contexts and present engagement.

At the symbolic level, the established meanings carried by traditional motifs—such as auspiciousness, harmony, and cyclical order—undergo selective reinterpretation. Detached from fixed historical readings, these symbolic values can be recoded within contemporary communication systems. In branding and information design, such transformations enable traditional signification to evolve into a visual language aligned with current cultural narratives, while retaining its conceptual depth.

Building on these layers, the study further explores the adaptability of this semiotic framework across media. In ceramic practice, pattern logic informs both form generation and glaze articulation; in digital interfaces, it

translates into iconographic systems and dynamic visual structures; and in interaction design, it contributes to the construction of user engagement and cultural cognition. Through these applications, blue-and-white patterns shift from passive decorative resources to active semiotic infrastructures, capable of generating meaning across diverse design contexts.

6. Conclusion

Centred on Peirce's semiotic theory and analysing Ming Dynasty blue-and-white patterns to explore design innovation, this study attempts to address a long-assumed yet rarely verified question: where does the stability of traditional patterns originate, and can it be systematically preserved or regenerated in contemporary expression? Through hierarchical analysis of pattern symbol structures, symbolic translation of design operations, and experimental validation of interpretant generation processes, this study endeavours to transform the question from empirical judgement into a methodological issue amenable to analysis and verification.

First, we move beyond static approaches that treat pattern meaning as symbolic outcomes or collections of cultural allusions. By introducing Peircean semiotics—specifically the framework of indexical signs, indexical relations, and interpretants—we deconstruct and reanalyse Ming Dynasty blue-and-white patterns. The findings reveal that the symbolic efficacy of patterns rests upon multiple relational layers: the signifier level underpins intuitive object recognition; the relationship between sign and object is continually activated through context; and the ultimate stabilisation of meaning depends upon the accumulation and consolidation of interpretive items through prolonged, repeated usage. Through reverse comparative analysis of extensive samples, this study confirms the highly structured characteristics exhibited by four thematic categories—landscapes, figures, plants, and animals—within Ming Dynasty blue-and-white patterns. These four themes exhibit distinct yet comparable levels of symbolic stability across the representational, relational, and interpretative dimensions, thereby avoiding the pitfall of substituting thematic categorisation for theoretical analysis.

By establishing historically validated stable symbolic relationships as the starting point, this research introduces design innovation into semiotic studies, transforming it into an experimental basis for verifying theoretical judgements. The design process is defined as the deconstruction and reconstruction of symbolic conditions, centred on critical variables such as whether symbols remain recognisable, whether semantic orientation shifts occur, and whether interpretative outcomes diverge. This approach positions design as a means to observe how symbols develop stably. Experimental validation further demonstrates that object recognition does not equate to meaning establishment. Within experimental samples, even when iconic-symbolic recognition remains stable, interpretative elements may weaken or fragment due to shifts in symbolic weighting, visual hierarchy, or compositional relationships. The allegorical meanings taken for granted in traditional patterns rely on repeated confirmation through long-term use under specific symbolic conditions, exhibiting characteristics of intergenerational accumulation and open extension. Interpretative elements represent phased stable outcomes whose stability depends on historical usage, yet may be readjusted under new symbolic contexts.

Future research may broaden its scope to encompass additional subjects and samples, conducting cross-object and cross-period comparisons to explore the recognisability and semantic orientation of diverse semiotic symbols. Participation from varied audiences—including cross-cultural observers of differing ages and professional backgrounds—will enhance understanding of symbolic diversity. Furthermore, more complex symbolic combinations could be employed to observe interactions within multifaceted visual relationships, thereby enriching the expressive forms of symbolic regeneration. The integration of Peircean semiotics with design innovation proposes a research methodology for understanding how traditional patterns generate meaning, achieve stability, and undergo regeneration. This approach avoids the distortion of meaning inherent in experiential or stylistic translation. It also offers methodological insights for translating broader traditional visual symbols within

contemporary contexts.

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Art Complete: a New Framework in Industrial Design

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Abstract: This article introduces and examines the concept of Art Complete as an industrial design methodology aimed at harmonizing technological development, cultural identity and human psychophysiological perception. Design is seen as a mediator between the human technology and the environment in the context of globalization. The "factor ecosystem" model which incorporates global, local and individual factors that influence an era's visual languages and serves as the theoretical foundation. Art Complete is a method of arranging the physical space or object that produces a gradient between functionalism and the richness of the form's symbolic meaning. The visual language includes three levels: the inanimate external environment (geometry, ergonomics), the living external environment (biophilic elements) and the user's inner world (associations and personalization). Their combination influences rational and subconscious perception, reduces stress and strengthens the emotional connection with the object. The concept is supported by examples from the history and practice of design—from the Bauhaus to contemporary interfaces—as well as promising areas: adaptive materials, biomaterials and the circular economy. The proposed language of Art Complete considers both functional (ergonomic and technological) and emotional (symbolic) aspects, striving to achieve a balanced design for sustainable and human-centered environments. The paper clarifies the methodological basis of the approach, introduces a practical framework for its application, and discusses potential contradictions in the economic, cultural, and ethical realms.

Keywords: *Art Complete; industrial design; visual language; factor ecosystem; cultural identity; biophilic design; ergonomics; personalization; inclusivity; sustainable development; circular economy; emotional design; interface and interaction; architectural environment; human-centered design*

1. Introduction

Modern industrial design is entering a phase of qualitative sophistication, where form and aesthetics are increasingly inseparable from social and environmental contexts. These processes are accompanied not only by the growth of scientific and technological capabilities, but also by a number of sociocultural tensions, the weakening of cultural identity, increasing social divide and escalating conflicts in the global space. Under these conditions, design ceases to be solely a tool for form-making and is becoming a mediator between human, technology and the environment (Saravia-Pinilla et al. 2016). Consequently the need arises for a holistic visual language capable of not only reflecting change but also structuring the human experience of interaction with the new reality.

In this context, the Art Complete concept is proposed as a method for an integrated approach to the design of the subject-spatial environment. By "Art Complete," we mean a method of form-generation in which the visual language of a product is constructed simultaneously from functional requirements and symbolic values, reducing cognitive load and strengthening the emotional connection between a person and the object. It is assumed that through purposeful environmental design, positive feedback can be generated: aesthetically and psychologically aligned objects stimulate more responsible user behavior which in turn influences the development of technologies and social practices. This idea can be correlated with a factor ecosystem (see Section 2.1), which proposes

consideration of global, local, and personal factors in design.

Art Complete is based on the assumption that art, design and technology are interdependent as systems that simultaneously reflect and shape cultural reality. Accordingly, the goal of this visual language is not simply the decorative complexity of form but rather the communication of complex semantic structures through functional objects. Efficiency, cultural variability and psychological comfort are viewed as complementary characteristics rather than competing design parameters (**Krippendorff, 2007**).

The goal of this work is to formalize the Art Complete approach and clarify its methodological framework for industrial applications. We ask how, from the initial concept to the stages of use and disposal, an object is created that possesses both technological perfection and "soul. In this context, design is seen as a means to maintain harmony both internally and externally and thus sustain the preservation of cultural heritage or the interconnection with nature in the context of the progress of science and technology (**Kostiuk, 2024**).

The argument of this paper is that Art Complete is a methodological framework to enable the incorporation of functional, cultural and psychological elements in industrial design (**Schoenholz & Kolko, 2009**).

2. Understanding the Concept

2.1 Theoretical Framework and Methodology

The history of the formation of artistic and design practices reveals consistent patterns that allow us to view the development of visual languages as a consistent process of human understanding of the surrounding world (**Abramson, 1990**). Beginning in prehistoric times, visual forms served as a means of capturing observable reality: natural phenomena, mythological stories and social rituals. Early religious images which arose as a reaction to a lack of better understanding of natural processes, gradually transformed from polytheistic interpretations of natural forces to monotheistic models and further to a scientific explanation of the world. At each stage, art and object culture served as a visual register of this evolution of worldview reflecting the level of cognition and the nature of human relationships with reality.

Despite the growth of scientific knowledge a significant portion of human behavior continues to be determined by cognitive and subconscious mechanisms (**Conway, 1968**). In various disciplines this phenomenon is described by similar concepts: *Zeitgeist* ("spirit of the age") in philosophy, herd behavior in sociology and the collective unconscious in the analytical psychology of C. G. Jung. To clarify the mechanism of their action, this paper introduces an analogy with the concept of *terroir* used in agronomy, to denote the totality of natural conditions (climate, soil, microflora etc.) that shape the characteristics of a product (cheese, wine etc.) (**Vaudour et al., 2015**). In a broader sense *terroir* can be understood as the totality of objective and cultural circumstances that determine the content of human thought and the forms of its expression.

In this context *Zeitgeist* is interpreted as the mental manifestation of such an "era's *terroir*" the result of the interaction of natural, technological and sociocultural parameters (**Fernandes & Ferreira, 2018**). Global factors include fundamental laws of nature, astronomical processes, the level of scientific knowledge and its limitations. Local factors are formed on these foundations: geography, climate, biosphere, language, social and cultural norms and many more. These parameters interact with each other, creating a dynamic system, in which cultural phenomena emerge synchronously in different regions. Thus, similar ideas may emerge independently by different authors under the influence of common historical circumstances (e.g. wars, pandemics, industrialization or global exhibitions).

As depicted in **Figure 1** this model views human thinking as the result of a three-level structure of factors:

1). **Global (objective) factors** natural and universal laws that determine the basic conditions for the existence of life.

2). **Local factors** including:

Local factors primarily determined by the objective factors (geography climate resources);

Local factors primarily determined by the subjective factors (socio-cultural environment traditions norms collective representations).

3). **Personal (subjective) factors** individual interpretations and experiences shaped by local factors.

It is the combination of these factors that shapes a person's individual "terroir" and consequently the nature of their creative activity. As Glenn Alexander Magee notes "...no man can surpass his time since the spirit of his time is also his spirit. ["*Zeitgeist*" p.262] Any work is historically relevant because it expresses a specific configuration of factors within this moment.

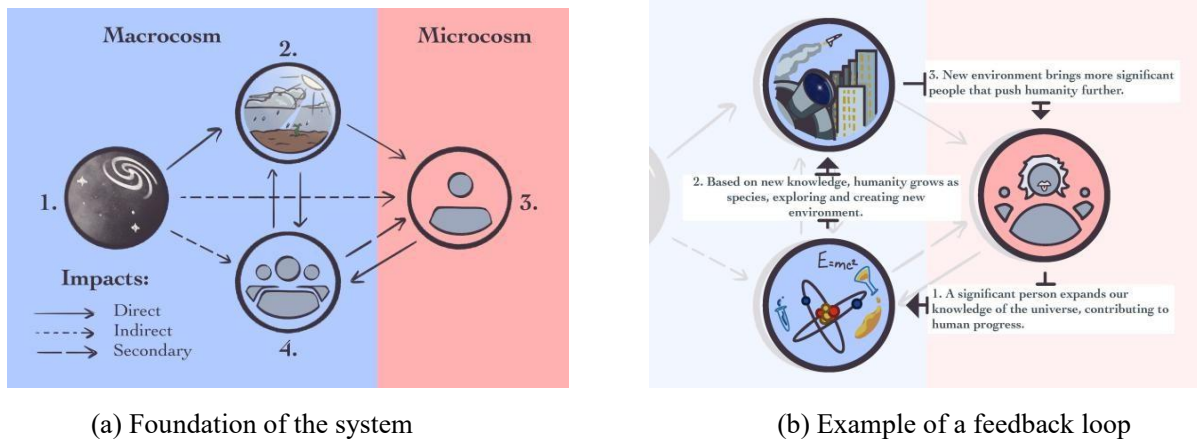


Figure 1 Design of the Factor Ecosystem.

Figure 1 illustrates, how creative output emerges from the interaction of global, local and personal factors, rather than from individual intention alone. The feedback loop emphasizes that designed objects are not passive results, but active agents that reshape cultural and environmental conditions.

Creative activity in this system illustrated in **Figure 1(b)** forms a cyclical process. Individual discoveries, scientific, artistic or technological change, social practices; society in turn transforms the environment through new design principles; the resulting environment influences subsequent generations. A closed feedback loop emerges, in which each new factor generates the next (**Kerne, 2002**). This work proposes to designate this dynamic interdependence as a factor ecosystem, a model that explains the emergence of new discoveries and serves as the theoretical basis for the concept of Art Complete.

The symbols and structural elements of the visual language in the concept of Art Complete serve more than just decoration: they are carriers of meaning that profoundly impact a person's mental state. They convey cultural, historical and biological codes, evoking an emotional response and associative connection with the surrounding environment. Even ancient architects and designers recognized this connection: Eastern treatises on feng shui described the "art of competently constructing houses and selecting interior furnishings," as a continuous flow of knowledge about the influence of object placement and color combinations on the harmony and health of residents. Modern research confirms that the harmony of color, form and texture in an interior fundamentally changes a person's mental state and health, meaning that the language of images in space proves to be a powerful tool for influencing not only the individual user, but also the public consciousness (**McGee & Park, 2022**). Repeated daily in architecture and interior design, such symbols create the "terroir" of an era, a combination of local conditions and ideological factors that sets the backdrop for perception and drives thought patterns.

Art Complete emphasizes the close connection between the "microcosm" and "macrocosm" of perception: each decorative or functional element simultaneously resonates with the user's personal experience and with a broader cultural or natural context. This can be achieved through repeating motifs and fractal structures that

connect small details with larger images. Experiments have shown that abstract non-fractal images increase stress by 13% while natural scenes with complex fractal patterns reduce it by 44% emphasizing the profound connection between people and their environment (Hollander et al., 2021; Taylor, 2006). Consequently Art Complete's visual compositions employ similar principles: by combining colors and repeating patterns, they form a holistic language that operates simultaneously on personal and archetypal levels. For example, an object can be roughly "deconstructed" into an external shell, surface animations, like movement and color transitions and an internal layer of human perception.

Once visualized the structure of Art complete could resemble a concentric circle consisting of three layers which are displayed in **Figure 2**:

- 1).The inanimate outer world;
- 2).The animate outer world;
- 3).The internal world.

Structure of Art Complete

- First layer, cold, Universe, symmetry, macrocosmos;
- Second layer, warmth, Earth, asymmetry, life;
- Third layer, mind, microsomos



Figure 2 The Layer System of Art Complete. Color choices are symbolically selected to depict the inanimate cold, animate warmth and infinite mind. Yet selection is subjective and is a subject to change.

By incorporating the factor ecosystem into its structure, Art Complete allows a designer to perceive a product or space as a whole new realm of its own, with a general shape, natural comfort and personalized attributes.

The first (external) level includes the inanimate outer world: sections of architecture and urban space, industrial design objects and interiors that have the least interaction with nature. Here the form and composition of elements influence the sense of order or disorder. It defines the shape and geometry of the body—this is the actual "shell" of an inanimate object. Classic examples: the strict rationality of constructivist and minimalist interiors, where the home was called a "machine for living", create a clear structure of perception. But in an overly "dry" cold design it's easy to lose the emotional connection with the space. Research shows that angular sharp shapes evoke subconscious tension and even fear (increased amygdala activity) while rounded lines are perceived as friendlier and calming (Papanek, 1972). Designers can incorporate this knowledge into external volumes: for example the use of smooth curves or rounded edges in facades and furniture weakens formal rigidity and creates

a sense of protection while clear verticals and geometric structures impart status and rationality. Thus on an inanimate level the structure of Art Complete balances between utilitarian clarity and soft ergonomics.

The second animate outer world relies on natural and organic elements: the use of plants, natural materials and forms reminiscent of flora and fauna. Contemporary biophilic design aims to bring nature back into cities and living areas. As experts note the integration of green spaces and natural textures is not only aesthetically pleasing but also genuinely improves human well-being: a biophilic approach reduces stress improves productivity and air quality and the plant species themselves have a beneficial effect on the indoor microclimate and our well-being (Joye, 2007). Historical and contemporary examples are compelling: from soaring cathedral domes inspired by the curvature of natural forms to "green" facades and living walls in modern buildings. Gaudí in Catalonia, as it can be seen in **Figure 3(a)**, immortalized tree and leaf motifs in the columns and ornamentation of his buildings, and landmark examples like the Bosco Verticale towers in Milan from **Figure 3(b)** demonstrate a commitment to biophilic ideas. In industrial design this is reflected in objects with rounded "organic" shapes and in interiors in the use of natural stone wood and plant-covered surfaces to create a sense of unity with nature. In industrial design it's about dynamic and tactile aspects: it is born at the moment of interaction (buttons, touch indicators, changing surfaces).



(a) The ceiling of La Sagrada Família by Gaudí

(b) Bosco Verticale

Figure 3 (a)Source: Flickr (SBA73, 2011), CC-BY-SA 2.0; (b)Source: Thomas Ledl (2016), CC-BY-SA 4.0.

The third (inner) level is a person's internal world: the experiences, memories and subconscious associations that each person brings to their perception of space. This level is emotional and cultural: how the user interprets visible symbols (patterns, color accents, ornaments) against the backdrop of their culture and experience. In particular, the choice of specific colors, patterns and symbols often reflects a personal history. Some collect objects in their interiors that remind them of their native culture or childhood while others prefer shades and textures that evoke a sense of calm or inspiration. Feng shui takes this subjectivity into account: the selection of each interior element is strictly personal and aimed at balancing the energy-informational field of the residents. On a neurological level our brain "filters" visual information through the prism of personal experience, invisible archetypes and symbolic connections. That's why, regardless of stylistic preferences, space must be filled with meaningful images: a small symbol or detail can trigger a chain of associations, inaccessible to rational analysis, yet profoundly impacting the unconscious (Barrett & Barrett, 2010). Spaces or products at this layer must have a broad choice of customization to allow the individual to form their personal space or object, according to their taste.

As a result, the methodology of Art Complete serves as an important tool, not only for the personal, but also for the social transformation of consciousness through the environment. Researches have shown that architectural spaces literally shape people's thinking: the beauty and harmony of the external environment evoke associative

admiration and inspire creativity, while thoughtful urban planning and the "expanded consciousness" of the urban environment change the social behavior of citizens (**Bonenberg, 2020**). In this paradigm, Art Complete should be viewed not as a single style or a set of decorative techniques, but rather as a language for combining existing elements. It builds a "grammar" of visual signs, where each line color and shape complements one another and can influence the unconscious. Thus, the repetition of motifs and the fractal organization of space pierces the subconscious, while conscious perception "reads" the embedded narrative from the space. Research on biourbanism emphasizes that a consistent spatial structure (symmetry, repetition, fractality) nourishes our physiology, reduces stress and induces positive emotions (**Joye, 2007**). This way, Art Complete offers a design system in which visual language becomes a metaphor for the reality around us: aesthetics is formed as a "meaning machine" and influences the user's subconscious and thinking.

2.2 What is Art Complete?

The historical development of art and design has been accompanied by the formation of a system of stylistic classifications, reflecting the worldview of the respective eras. Style serves as a tool for organizing artistic experience: it allows for the recording of dynamic principles of form-making, their reproduction and transmission within professional practice. Since the spatial environment is anthropogenic, it is a subject to conscious regulation and can influence human behavior and emotional state. The psychology of perception and environmental studies show that spatial parameters, color proportions and the plasticity of form directly influence the user's cognitive and emotional reactions (**Tuszyńska-Bogucka et al., 2020; Shemesh et al., 2021**). Consequently, the design of a visual language can be considered a tool for creating a comfortable and sustainable experience of interaction with the environment.

This paper proposes the concept of "Art Complete" not as a new style, but as a methodological approach to design, based on the idea of "complete harmony" between form, function and context. Its principle lies in the consistent integration of various stylistic systems creating a continuous transition between them. The goal is not to create a fundamentally new aesthetic, but to establish a "gradient" between existing artistic approaches: from functionally oriented contemporary solutions, to historically rich forms imbued with cultural semantics. Thus, Art Complete strives to establish a balance between the utilitarian and symbolic richness of form (**Pylypchuk & Krivenko, 2020**).

The emergence of this methodology stems from the contradictions of contemporary design practice. On one hand, demands for efficiency, mass production and resource conservation have led to the proliferation of minimalist and standardized solutions. On the other hand, globalization has increased the need for local and individual identity. As a result, many everyday objects acquire a neutral and impersonal character, losing their cultural and emotional expressiveness. Art Complete in this case is an attempt to bridge this gap by integrating technological rationality and cultural richness.

The methodology envisions a harmonious compromise between modern production, technologies and traditional methods of form creation. It focuses on incorporating craft practices, ornamental systems and historical motifs into industrial and household design, without sacrificing functional effectiveness (**Conway, 1968**). This preserves the ability to adapt cultural heritage to modern conditions while the physical environment gains an additional semantic layer.

Regarding the historical value, Art Complete's primary goal is not to fully return to those forms, but rather a restoration of the semantic richness of designed objects. Within this approach, design practice is viewed as a means of maintaining cultural memory and fostering emotionally meaningful human interaction with the environment. This method assumes that the designer consciously works at the intersection of the artistic and utilitarian, using visual codes that convey not only functional information, but also an emotional subtext. The term "Art Complete"

itself reflects a desire for integrity and completeness of the image. Within this concept, the synthesis of the explicit and the implicit becomes central: the outer aesthetic layer of a product (graphics, colors, silhouettes) interacts with the inner content (the user's psycho-physiological response).

2.3 Situating Art Complete Within Contemporary Design Discourse

Themes, raised in this methodology, aren't novel: Art Complete is often built upon existing models and solutions, using a new framework to bring them together for a general elevation of design, as an influential tool. We need to compare and distinguish, which aspects make Art Complete a unique system within the discourse of design.

PEST analysis, developed by Francis Aguilar, with all of its alternative versions, is another tool to consider external macro-environmental factors (**Aguilar, 1967**). Despite the similarities, those PEST is only for scanning the environment that affects business, while factor ecosystem is aimed at grasping factors of multiple layers and types, including individual, giving us a wider range of things to consider, while designing a product. Another major difference is that with PEST model, users didn't initially consider understanding the cause-and-effect relationship between these factors, while factor ecosystem carries that as a priority to utilize in design (**Collins et al., 2021**). It facilitates the recognition of constraints and opportunities on different levels: global, local and individual, which in turn guides design decisions that are sensitive to contexts, cultures and psychology. By using this framework, designers will be able to breakdown and categorize the existing designs into similar layers according to the symbolism behind each. It might yet be a subject to many tests and reviews, and extreme need for transparency and control is required. It needs to be stressed that if a future iteration of such framework will indeed cause the intended feedback loop, it requires ethical regulations, as it might be considered as a manipulation of population. Things, like public access to regular reports, transparent development and breakdown must be provided to keep the clear image of intentions behind the design. Such knowledge should be fully and easily accessible to prevent any potential control by people for selfish or even dangerous reasons.

The concept of "affordance", initially coined by James J. Gibson in the field of psychology, was referring to what an environment provides to an animal, defining how an animal lives in this environment. Later, the term was appropriated by Donald Norman, as a concept within the context of Human-Computer Interaction (**Norman et al., 1988**), alluding to the perceivable "action possibilities" of a design, narrowing down the original definition of the term. In 2013, Norman extended the concept, adding "signifiers" that "... communicate where the action should take place. While this concept, either original or adapted definition of it, is close to the factors within the ecosystem, it cannot quite envelop the entire meaning behind it: affordances and signifiers are one-sided and do not consider how actor's development within the environment will affect the environment itself.

The points of view of Victor Papanek and Klaus Krippendorff towards industrial design almost entirely align with Art Complete's principles. Victor Papanek in his works criticized commercial approach of designers: how they were not in touch with the society, for which they are designing the products, contributing to consumerism and harming the environment (**Papanek, 1972**). He developed comprehensive frameworks to change the approach of designers, and while his contributions brought many programs in design for social need, it never formed a fully theorized "social model" as an alternative to "business model" (**Margolin & Margolin, 2002**).

Unlike Papanek, Krippendorff was concerned about what artifacts are, what semantic value they carry for the user. He was arguing that "a strong commitment to normative submission excludes human agency" (**Krippendorff, 2007**). Krippendorff intended to ground design in meaning that, instead of being fixed, would shift depending on users, context and cultures.

While Art Complete also intends to work for the society and be considerate of their unique traits, it is an attempt to unify and push the theoretic development of older concepts further, by providing a new universal tool that goes beyond semantic, social and ecological value. Factor ecosystem, in combination with the three-layered

structure, are meant to be flexible tools that can apply to other fields of design in order to break any products, visuals and spaces, down to a symbolic triad, that allows us to enhance each aspect of a design in a more thoughtful way. Art Complete uses its framework to bridge the gap of product semantics of Krippendorff and social model of Papanek, with a wider range of aspects that should be considered, to fully shift the business model of modern design, by bringing together the theory of all other factors and their interactions.

3. Analysis of Art Complete

3.1 Cultural Adaptability and Inclusivity

The Art Complete's visual methodology proposes considering design as a an adaptive cultural translation. Since perception is highly dependent on personal and cultural factors, it is important that visual metaphors be as universal as possible and encompass a wide range of perceptions. This entails two important principles: (1) using neutral or meaningful symbols that are appropriate for different cultural groups; (2) taking user feedback into account, allowing the visual environment to be customized to their needs.

The first principal is well exemplified by the history of the Bauhaus movement. A school of art, founded in 1919 in Weimar, aimed at harmoniously integrating craftsmanship with technical skill, as well as the notion of mass production and making "art for everyone" functional and accessible. After the Bauhaus closed in 1933, many of its graduates emigrated, including to the United States, where they continued to teach and design in the American context – laying the foundations for the "International Style" and modernist architecture of the mid-20th century. In the USSR in the early 1920s, interest in Bauhaus principles was also strong: Soviet architects and propagandists noted "a particular interest on the part of the USSR in the Bauhaus's focus on the mass production of household items and the rational organization of living space" considering this consonant with the goals of industrialization and mass housing. Similarly in Japan, Western-inspired minimalism was interpreted through the prism of the local aesthetics of Zen and wabi-sabi. Zen Buddhism and Shintoism influence Japanese design with the idea of giving value to "emptiness and pure simplicity of shape or form" ("ku", "ma") and wabi-sabi teaches one to "appreciate imperfection and natural materials. Hence, Japanese designers added symbols of their nation in a minimalist shape, such as branches of cherry blossoms, waves or bamboo in an organic and natural manner, giving it profound meaning. Ultimately, even the overall form, despite all the need in globality, requires a local warmth and associative content emphasizing the idea of cultural adaptability (**Kostelnick, 1995**).

This principle can also be found in the interior design of the Azerbaijani guest room designed for the CICA International Center, in which national patterns become an organic part of contemporary aesthetics. It's highlighted through inserts, containing images of oriental carpets, carved elements and ethnic motifs that contrast with the minimalist-style furniture and interior elements. Such an approach acknowledges the material of the carpet's pattern which is one of the major symbols of culture, thus providing the interior space with a unique character of being "homely. Another relevant case is that of the brand named CHELEBI, operating from Baku, which reinterprets Azerbaijani visual culture through contemporary furniture. For instance, Khudafarin series are directly inspired by ancient Khudafarin bridges, transforming traditional structures into contemporary design totems. While many designs within the brand were made authentic to the original inspiration, in some cases, constrained by minimalism, they convey only an abstract feeling of the original source material, losing the reference for international audience, unaware of the history behind the product. CHELEBI refers to their collection as "... draws inspiration from the structural elegance of the historic Khudafarin Bridge. Crafted from solid oak, the set reflects the bridge's strength and balance, reinterpreting its engineering grace through clean lines and thoughtful proportions. This shows the smart reimagination of this ancient structure, but the visual representation of the original was not conveyed, ultimately losing the cultural significance. In section 3.3, we will explore this specific

case through the prism of Art Complete and a possible middle ground for this dilemma. The sociocultural impact of such integration is confirmed by research: the combination of cultural elements and modern designs increases the value and recognition of a product in the global market **(Reinecke & Bernstein 2013)**. Art Complete as a methodology strives to create such hybrids, making industrial products culturally significant and recognizable. With it, designers can integrate local ornaments symbols and craft techniques into a modern industrial product without losing its authenticity.

It is also important to mention the risk of cultural appropriation, while designing products and spaces for audience of a specific background. For avoiding such incidents, it is recommended to involve the members of these cultures, doing deep research, crediting and collaborating with them. This way, communities will become an integral part of the process, creating their product with designers.

The second principle is another significant factor that is a complement of cultural adaptability. Art Complete's focus is on inclusivity in the sense that it considers the characteristics of its users regarding age, physical, and cognitive traits. In most designs, the assumption is that the average user of a particular object will be right-handed; however, this creates a problem for all other users of the population. For example, the typical scissor, pen or kitchen utensil is designed in such a manner that only right-handed persons can utilize them. To overcome this ergonomic bias, modern UX methodologies recommend avoiding rigid assumptions about handedness and allowing users to configure the interface as they see fit **(Herring, 2010)**. In urban environments inclusivity is demonstrated through special adaptive elements: tactile paving on sidewalks, audible traffic lights and voice navigation at pedestrian crossings ensure safe navigation for visually impaired and blind people. Similarly, clear spatial zoning and standardized routes (uniform sidewalks, ramps signs) reduce confusion and the expenditure of physical and cognitive effort, especially for the elderly and disabled. In all these cases, Art Complete's design takes into account the diverse experiences of users, ensuring that cultural context and ergonomic adaptations are integrated into a unified whole.



(a)Khudafarin Bridge



(b)Khudafarin Dining Set

Figure 4 (a)Source: The official website of the President of Azerbaijan, CC BY 4.0; (b)Source: CHELEBI.

Finally, adaptability and inclusiveness are also important in digital interfaces. Modern graphics programs and games increasingly offer flexible settings for left-handed users and those with different needs: toolbars and keyboard shortcuts can be rearranged to suit the user's preferences. For example Sony patented a touchscreen gaming controller, surface of which itself allows players to adjust the placement of buttons and thumbsticks to suit their personal preferences and hand sizes. The patent description explicitly states that the traditional rigid layout of elements can be uncomfortable for different players and therefore there is a need to "allow for different configurations" without releasing new models for different hands. Thus, the trend is for interfaces and devices to

go beyond the "right-handed" standard and adapt to the user. Researches in UX come to same results: design shouldn't assume a dominant hand, but rather allow for user customization of elements, becoming ambidextrous by default (**Gajos et al., 2008**). This reflects the overall idea of the Art Complete methodology: universal design forms are combined with consideration of cultural diversity and physical characteristics creating products that are equally organically perceived in different societies and by different people. Within it, inclusivity is treated not as a secondary requirement, but as a design parameter embedded at every stage of form development, interaction design and customization.

3.2 Synthesis of Aesthetics and Ergonomics

In many ways the idea of the unity of form and function dates back to the Bauhaus, which advocated the motto "form follows function", a product's appearance should reflect its purpose, prioritizing comfort and efficiency. Scandinavian design of the mid-20th century (Aalto, Jacobsen and others) aimed for the "harmony of form and function", combining minimalism with the warmth of natural materials and a focus on the user. Aalto brought organic lines and natural materials to functionalism, while Jacobsen brought unusual forms with impeccable proportions and strict ergonomics. In the mid-century Dieter Rams at Braun formulated the "less, but better" approach; his technique was distinguished by "disciplined simplification", emphasizing the maximum utility and durability of the product. Rams believed that good design is not so much the object itself as the experience of using it: useful, understandable and unobtrusive. All these examples demonstrate how aesthetics and ergonomics went hand in hand in classical design, a clean laconic form emphasizes the convenience and clarity of the device without distracting with embellishments.



(a)Scandinavian house by Aalto



(b) Dieter Rams: Braun SK4 (1956) and SK55 (1963)

Figure 5 (a)Source: Flickr (Filipe Brandão, 2005), CC BY-NC-SA 2.0;

(b)Source: Flickr (Markus Spiering, 2011), CC BY-NC-ND 2.0.

Figure 5 gives clear examples, of how Alvar Aalto and Dieter Rams envisioned their designs. They were working on contrasts of natural materials like wood and angular shapes, to create a space where comfort of nature, luxury and modernity coexist.



(a) OP-1 by Teenage Engineering

(b) Nothing Phone 1 by Nothing Technology Ltd

Figure 6 (a)Source: Flickr (Rasmus Andersson, 2013), CC BY-NC 2.0;

(b)Source: Wikimedia Commons (2023), CC BY-SA 4.0

Today, the legacy of such principles can be seen in the design of leading brands. Apple under Jony Ive emphasized minimalism and extreme intuitiveness: according to Steve Jobs, the most important thing in our design is to make everything intuitively obvious and technology should be "beautiful and white like Braun", packaged simply. Similar techniques have been carried over to electronic interfaces: the clear interfaces of the iPhone and Mac with clean typography have become benchmarks for ease of perception. Teenage Engineering electronics (a synthesis of retro aesthetics and modern capabilities as in the OP-1 and TP-7), with an example, provided in **Figure 6(a)**, continue the tradition of minimalism and tactility: their instruments symbolize a modern interpretation of nostalgia, combining aesthetic simplicity with advanced functionality, engaging the user in the creative process. The Nothing Phone from **Figure 6(b)** emphasizes transparency as a style and an idea. Its unadorned body with minimalist design and transparent elements, transforms technology into a philosophical object. The principles of Apple, Teenage Engineering and Nothing can be considered to correspond to different "levels" of a general design framework: the former emphasize pure form and convenience (lower levels of form and ergonomics), while the latter emphasize depth of meaning and symbolism (higher levels of context and individualization). Art Complete proposes to develop this idea by adding a third element—the symbolic "soul" of the product. The geometric shell provides the foundation (whether eco-friendly or technological), the ergonomic layer ensures comfort, and visual metaphors convey cultural and emotional meaning. As a result, the product becomes understandable "without words" and simultaneously personalized. Usage scenarios are described not through instructions, but by matching the user's intuition.

3.3 Operationalization of the Framework

It needs to be pointed out that Art Complete is presenting a new framework for designers to work with, that won't simply give a new solution to some issues we face, but push forward the need to apply new developments from different fields, to enhance the process of designing. Let's dive deeper into the practical examples behind the application of Art Complete in design.

For the example of how an object can be created from layers of Art Complete's structure, we will give an example of a custom smartphone in **Figure 7**. Its "inanimate" outer layer, the body and shape is designed to fit securely in the hand and reflect its intended purpose (e.g. smooth curves for one-handed use, clearly defined edges for connectors) while the symmetrical button allocation would allow to customize their purpose, making them not only versatile, but inclusive to people with different physical characteristics. The "living" layer, the on-screen

interface is constructed according to simple geometry: large icons, clear pictograms and touch zones. The software is meant to be highly reactive, giving smooth and efficient actions followed by haptic response. The “inner” layer in the phone would be represented by symmetrical customisable buttons on the sides and apps within the software, imbuing itself across all other layers, bringing everything together into a personal experience. Due to the contracts between geometry and ergonomics these elements are distributed as intuitively as possible: the phone's physical profile allows the user to choose how to handle it and the layout of buttons and icons on the screen corresponds to natural gestures. As a result, even without extensive training, the user easily understands how to launch an app or how to begin using the device. By using this methodology we divided the object into form (material, dimensions), interaction (function placement and sensors) and semantic shell (interface and symbols) to make the smartphone both ergonomic and intuitive. This layered analysis demonstrates how Art Complete can function as a diagnostic and generative tool, allowing designers to evaluate existing products and guide future development.

Nevertheless, we must consider complications that may come with such alterations, deviating from traditional phone designs. Modern smartphones have developed a highly optimized form, that all brands slowly follow, gaining similar designs. However, as we already mentioned, those tend to assume some details for customers, forcing them to adapt to the product. Now, with new a design, new innovations must be made to optimize it for better performance and convenience. In terms of hardware, the camera bump must be reduced, along with the weight distribution, to avoid discomfort while handling the phone. With the right telephoto module such issue can be removed and give greater performance, but this might also increase the price of the product. Fluid and reactive software is easy to make in the vacuum of phone-native apps, however it becomes trickier with alternative apps that a user can download. Every app will need to create a new version that fits the functionality of such software. Its performance also might become a problem of hardware: a good customization needs to have a wide range of possibilities, satisfying even extreme requests. This hints at the need of generative capabilities within the software, capable of adapting to the needs, which can be solved with a high quality chip. With the current shortage on chips, this will further increase the price, making it even less accessible to the populations. The second option is to have a less expensive chip, that will produce more heat while working, which requires a greater cooling system. Some brands are slowly moving in this direction by outsourcing this customization: Nothing is developing Essential Apps, where users can prompt an idea of an app to AI, which will code and design it for them, ready to deploy it into their device. It is still in early stage and faces many bugs and inconsistencies, needing some regulations. But it already shows the future of personal devices: every phone and its software will become custom, fitting the vision of Art Complete.

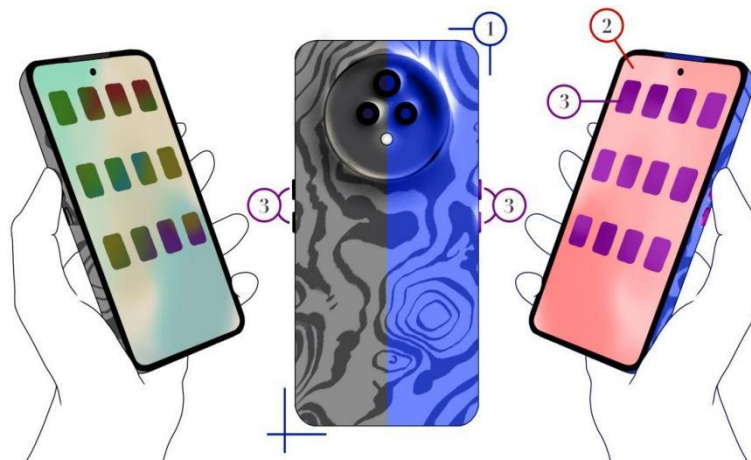


Figure 7 Concept of the phone. 1: Symmetrical, ambidextrous body;

2: Fluid, organic and reactive software; 3: Highly customisable buttons and applications.

Art Complete proposes developing these ideas into "emotionally intelligent" products, objects that are

subjectively beautiful, comfortable and connected to the user's senses. Firstly adaptive "smart" materials could allow products to adapt to the user: prototypes of coatings and fabrics that change color or texture, based on user or environmental cues, have already emerged. Secondly products should "age" gracefully: for instance by incorporating the developed concept of patina into design we consider traces of use not as defects, but as a piece's history. As one author wrote, patina "extends product longevity, by fostering an emotional connection between the user and the object, transforming it from a disposable item into a cherished artifact". This approach encourages owners to repair and preserve their items. Finally, a deep emotional connection is created through customization and symbolism: the ability to tailor a product's appearance and behavior to your individual needs makes it "entirely yours" which deepens attachment (**Mugge et al., 2009**). Thus, Art Complete's "levels" can include adaptability, durability and personalization, something that makes people not just use an item, but develop a deep connection with it.

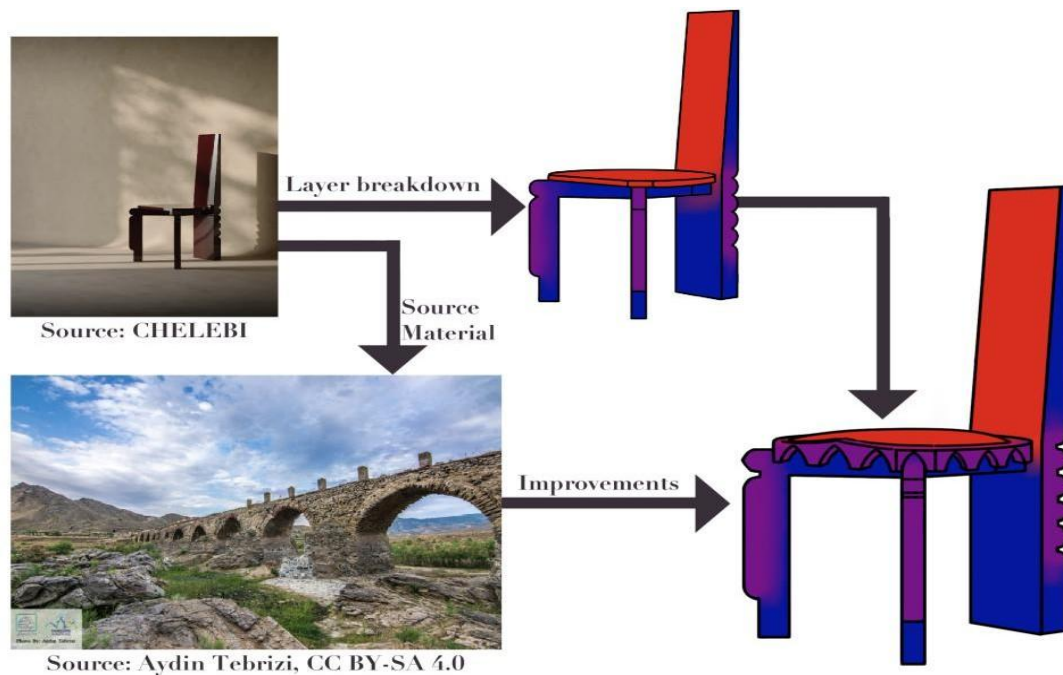


Figure 8 The process of chair modification. The scheme involves the separation of the original chair into three layers, gathering of the source material and the redesign of some nuances within.

Another example is to demonstrate how an existing product can be broken down to the same layers and be modified according to the principles of Art Complete. In **Figure 8** we have selected a chair from CHELEBI's Khudafarin collection and broken it down into the three layers. As with any other chair, the structure itself, like legs, are a part of the inanimate layer. The differences in this case are that the back legs and the backrest are merged into a single block of wood and along with two front legs, possesses a repeating semi-circular motifs carved out of them, which hints at the inner layer through the cultural background of the product. The inanimate layer may remain the way it is, as the original follows the principles on its own, fluidly shifting form one layer to another. The seat, or rather, the face of the chair is a straight piece of oak that, despite representing stability and strength, does not welcome the user to sit on it. As something that logically would be an animate layer, that shall provide comfort, this section of the chair contradicts that. The back of the chair is a continuation of the animate layer, which made it slightly bent for comfort, yet maintained the minimalist approach.

If we simplify the imagery of Khudafarin bridges, the most prominent features are the arches, formed both by the pillars and the road on top of it. Such shapes can be easily conveyed through the animate and inner layers. The proposition of adapting this design to the framework of Art Complete starts with the alteration of semicircular

motifs into more arrow-shaped carvings with wider gaps between each other. This way, we create a hint at the bridge's silhouette via negative spaces in three different sections of the chair. The second change is the addition of aprons on the edges of the seat. Their shape directly depicts the pillars and arches of the bridge, along with the curvature of the road in the front of the seat itself. This curvature then bends the seat itself, creating a more convenient shape for sitting, supported by the slip seat, that further extends the comfort of the animate layer. The content of the seat could be made of eco-friendly materials that can replace leather, like MuSkin, made entirely of fungus. This is how the layers within the initial design become more befitting to the principle of Art Complete.

However, such advancements might significantly increase already high price of the product, making it even less accessible. If factors like collaborators involved, the accessibility of materials used and the engineering behind the product are regulated correctly, more budget friendly alternatives may be developed. It is also worth noticing that the product isn't flawed by itself: it is merely a good example of how Art Complete can change a product through its prism.

4. Other Applications

The Art Complete methodology is most naturally applied to the industrial design of everyday objects, a field where an object undergoes its entire life cycle: problem formulation, engineering, development, production, operation maintenance and disposal. Unlike the traditional approach, in which form is fixed at the concept stage, such a methodology could redefine the design process itself as a dynamic system, where an object is not created once and for all, but evolves over time. A car provides a clear example as it integrates architecture, ergonomics, interface materials and infrastructure.

The car's exterior belongs to the "inanimate external world", a level, where safety, aerodynamics and production logic are prioritized. Geometry dominates here: clear lines, contrasting light signatures and legible panel structure. Engineering rigor makes the object comprehensible from a distance, the driver perceives its dimensions, direction of travel and speed even before consciously analyzing it. The second "living" layer is revealed through interaction: door handles, seating position, tactility of surfaces, thermal comfort and acoustic environment. Here, rounding elasticity of materials and micro-movements of interfaces become important. Finally, the inner layer creates a personal space: a digital instrument panel, lighting, seat configuration and user profiles. The contrast between the geometric rigor of the shell and the adaptive ergonomics of the interior can create an intuitive perception of the object: the external world communicates rules, the internal world conveys meaning. This multi-layered design helps the driver instantly navigate and fosters a deeper connection with the car.

Such logic is gradually emerging in biomimetics research and can become a good material for designers to use in the animate layer. Architect and researcher, Neri Oxman, proposed the concept of "material ecology", in

which material form and production method are considered as a unified system and objects can be designed, as if they were "grown", rather than assembled (**Oxman, 2012**). Her laboratory's projects utilize computational modeling, synthetic biology and digital fabrication to create structures from biopolymers such as chitosan, one of the most common natural polymers. Silk Pavilion installation, produced by Oxman, demonstrates the principal of biofabrication, where form is created through the interaction of computational modeling, a robotic framework and the behaviour of living organisms: approximately 17000 silkworms formed the outer shell of a structure made of a natural silk. Such developments demonstrate the idea that an object is not simply manufactured, but becomes part of a natural cycle. If this logic is transferred to industrial design, an object can cease to be a static artifact and become a phase of a process from growth to metamorphosis or natural decay.



Figure 9 Silk Pavillion. Source: Mediated Matter Group (Neri Oxman, 2013), CC BY-SA 4.0.

This approach is directly related to the circular economy. Companies, like Fairphone build smartphones from modular components that can be replaced by the user extending the lifespan of the device, while large furniture manufacturers, like IKEA are implementing product buybacks and recycling, shifting production from a linear to a circular model. Within the potential of Art Complete methodology, such practices could acquire an aesthetic dimension: the aging of a material would no longer be considered a defect, but would become part of the visual language. Patina, traces of repairs and modifications would become carriers of an object's history, similar to how layers of time are valued in architecture (Meurer, 2001).

The need for such an approach is most acute in extreme conditions, for example in the design of space environments. Studies of long-term isolation, including the MARS-500 experiment, have shown that not only technology and nutrition, but also psychological stability are key factors for crew survival. In confined environments, astronauts experience stress, monotony and sensory deprivation, while artistically designed virtual spaces can reduce fatigue and anxiety (Pochwatko et al., 2023). Even observing Earth from space evokes a powerful emotional transformation in people, known as the overview effect (White, 1987). Engineering challenges include radiation, micrometeorites, autonomy and limited resources, requiring the environment to be strictly functional. Art Complete, in this case, proposes using visual language as a bridge to home: adding earthly motifs (color, pattern) and associative graphics capable of neutralizing the feeling of alienation. As a result, the habitable space is transformed from a cold life-support machine into a psychologically supportive environment.

Thus industrial design, biomaterials, ecology and space architecture converge on a single point: the need to design not just form, but the relationship between people, technology and the environment. Potentially, Art Complete could serve as a framework, within which an object is designed simultaneously, as a mechanism, as part of an ecosystem and as a vehicle for human experience.

5. Conclusions

The discussed concept allows us to interpret Art Complete not as a utopian artistic manifesto, but as an attempt at a structured response to the increasingly complex demands of the future environment. As technology increasingly permeates everyday life, industrial design becomes the mediator through which abstract technological processes take material form and become part of human experience. In this sense the methodology can act as a principle of coordinating a way to maintain the connection between technology, culture and human psychophysiology in the face of accelerating change.

The expected success of future design is increasingly determined less by efficiency or visual novelty and more by the balance of three interrelated components: function, emotion and ethics. Function encompasses the ergonomics engineering, reliability and technological legibility of an object; emotion represents symbolism, cultural identity and psychological perception; and ethics include sustainability, inclusiveness and responsibility for the life cycle of an object. Art Complete can be viewed as a means to unite these levels into a single system, where an object ceases to be a neutral tool and becomes a meaningful element of the environment.

The prospects of this approach are directly linked to changes in educational and industrial structures. Designer studies must shift from narrow specialization to an interdisciplinary model, incorporating the fundamentals of the psychology of perception, materials science, ecology and systems thinking. Business models in turn must gradually shift from a focus on sales volume to a focus on the long-term value of a product, its life cycle and possible effects of a product on global and local scales. Ultimately, such a transformation could restore lost meaning to objects and a human dimension to habitats, whether they are being developed in an apartment, industrial infrastructure or future extraterrestrial settlements.

At the same time it is important to recognize the limitations and risks of such an approach. A universal visual language risks being overly complex for mass production or conversely being simplified into a decorative formula. Attempts to combine cultural specificity and global standards can lead to superficial stylization, unless supported by a deep context. To avoid the risk of cultural appropriation, designers must work hand in hand with the communities and users, allow them be involved in the process. This will not only create a culturally appreciated product, but also make it more significant and appealing for the people.

Moreover, the integration of personalization, biophilic and sustainable materials inevitably increases design costs and requires interdisciplinary expertise, making implementation slow and economically uneven. It might signify, that Art Complete products might be unaffordable for many at first, but as it happens in the market, with technological advancements and reproductions, it might gradually become accessible to more people, if it won't stay in the high-class market for the sake of profit.

And lastly, the potential of Art Complete to intentionally affect a human mind is dangerous, if practiced by wrong groups, as it may become a manipulation, raising ethical concerns. So before such things happen, laws and concrete rules must be established to restrain anyone from committing such acts.

Overall, our work demonstrates that design is capable of integrating art, science, and humanism. Art Complete is not yet a concluded system, but a proposal of ideas that, in our opinion, is worth developing and requires long-term testing through practice and criticism: it intends to restore the soul to objects and can help create environments, where people feel more whole and prosperous.

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A Study on the Landscape Formation and Cultural Characteristics of Daerim-dong Chinatown

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Abstract: Daelim-dong Chinatown, a representative Chinese residence in Seoul, is a space that exhibits unique cultural characteristics. In addition, Daelim-dong Chinatown in Seoul has developed into a space where the cultural characteristics of Chinese migrants are well displayed in a physical space, not just a space where Chinese people live. This study applied a three-step study method of literature study, field observation, and in-depth interview to analyze the landscape formation and cultural characteristics of Chinatown in Daelim-dong, Seoul. The main findings in this study are that physical and non-physical cultural landscapes coexist in Daelim-dong Chinatown, and Korean-Chinese cultural mixture, conflict, fusion, and immigrant identity expressions appear in this area. Therefore, in this study, the formation of landscapes and cultural characteristics of Chinese residents in Daerim-dong, Seoul are analyzed. The findings provide specific theoretical support for design practice for revitalizing multicultural spaces and contribute to the expression of cultural identity to help the sustainable development of multicultural spaces.

Keywords: *Daerim-dong Chinatown; Landscape Formation; Cultural Characteristics; Chinese Immigrants; Cultural Hybridity; Cultural Landscape*

1. Introduction

Since the 1990s, as Korea's economy has developed rapidly, many foreigners have migrated to Korea. As the number of these foreigners increased in Korea, many foreign group residences were created. These spaces represent distinct cultural characteristics within the city. Among these foreign group residences, Daelim-dong Chinatown, a representative Chinese group residence in Seoul, is a space representing unique cultural characteristics. This study begins with the question of what implications the cultural characteristics of Daelim-dong Chinatown have for multicultural space design. Daelim-dong Chinatown is a unique multicultural space where Korean-Chinese culture is fused. This space not only coexists with physical and non-physical cultural landscapes, but also expresses immigrant identity. Daelim-dong has been developed by Chinese immigrants since the 1990s. Entering the 2020s, Daelim-dong Chinatown developed into a unique space where Koreans and Chinese people coexist. In addition, Daelim-dong Chinatown in Seoul has developed into a space where Chinese migrants' cultural characteristics are well displayed in a physical space, not just a space where Chinese people live. Therefore, it is possible to understand the life and culture of Chinese migrants through the formation of landscapes and cultural research in such spaces. Therefore, this study analyzes the formation and cultural characteristics of landscapes in Chinese residences in Daerim-dong, Seoul. It provided a specific strategy for realizing cultural identity in multicultural space design. These research results can serve as theoretical basic data for spatial design for the revitalization of multicultural spaces.

2. Research Method

In this study, the formation of landscapes and cultural characteristics is analyzed for Chinese residents in Daerim-dong, Seoul. It goes through three research stages to conduct this study. These research stages consist of literature research, field observation, and in-depth interviews. The field survey of this study was conducted for about 3 months from June to August 2025, and in-depth interviews were conducted a total of 15 times. The interviewees were selected as Chinese immigrants, living in Daelim-dong, Korean residents, and self-employed in China. Interviewees were selected by stratified sampling, and the characteristics of each resident group were organized to be represented, including Chinese immigrants, Korean residents, and Chinese self-employed groups living in Daelim-dong. The first step is to conduct literature research related to Chinatown, Korean immigrant history, and Daelim-dong Chinatown. In literature research, books, magazines, and newspaper articles related to Chinatown are used. In the second step, the researcher directly visits the Chinatown in Daelim-dong and analyzes the physical form such as products and distances, and local residents. In the third step, the researcher conducts in-depth interviews with local residents. The targets of the in-depth interview are not only Chinese, but also Koreans living in this area. And through in-depth interviews, the cultural characteristics of the landscape of Daelim-dong are analyzed. Observation records and photographic data were used for the field observation data, and landscape characteristics were classified by analyzing the results of the study. In addition, the interview data was analyzed the recorded files to explore the cultural characteristics of the space. The process of this study is summarized as follows (**Table 1**).

Table 1 Process of Research Method

Research Process	Research Purpose	Detailed Research Content	Research Tools and Materials
Literature Research	Establish the theoretical basis of the research	Collect and analyze domestic and foreign studies related to Chinatowns	Academic databases, related books and papers, local government reports, newspaper articles.
Field Observation	Directly grasp the landscape of Daerim - dong Chinatown	Observe and record physical, commercial, and socio-cultural landscapes	Observation checklist, camera, field notes
In-depth Interviews	Understand residents' perceptions and identities regarding the landscape	Select interviewees through stratified sampling	Interview outline, audio recorder, interview transcripts

2.1 Literature Research

Literature research is the stage of gathering basic data to conduct this study. And through these literature studies, the theoretical basis for this study is established. Literature research conducts research on Chinatown. It analyzes academic papers related to Chinatown. Literature related to the history of Chinese immigrants in Korea is analyzed. It also analyzes Korea's immigration policy and data on foreign immigrants in Seoul. Media articles and books related to Daelim-dong Chinatown is also analyzed. This study also analyzes Daelim-dong Chinatown from a cultural anthropological point of view because it is a space with a clear cultural identity.

2.2 Field Observation

After conducting literature research, the researcher directly visits the Daelim-dong Chinatown and conducts field observations. And in field observation, the physical environment is analyzed. The researcher analyzes the physical environment of Daelim-dong Chinatown based on cultural factors. In general, Chinese immigrants reflect cultural identity through physical landscapes. So, by analyzing the physical environment, the researcher can grasp

the cultural meaning inherent in the physical environment. And the researcher observes and analyzes not only the physical environment but also the non-physical environment.

2.3 In-depth Interviews

The researcher conducts in-depth interviews with local residents based on the results analyzed through local observation. The main content of the in-depth interview is about the perception and cultural identity of local residents that cannot be sufficiently reflected by observation alone. The main target groups for the interview are Chinese immigrant residents, Chinese self-employed, tourists, and Korean residents.

The interview process takes place in a natural way of communication and includes in-depth content about the cultural landscape.

2.4 Research site

The research target site is located in Daelim-dong, Yeongdeungpo-gu, Seoul, and is the largest Chinatown in Korea. This research target site is called Daelim-dong Chinatown and is located in the southwestern part of Seoul. The main characteristic of Daelim-dong Chinatown is not a tourist destination, but a space where actual Chinese people live. So, this space is a space with clear cultural characteristics of China (**Figure 1**). In addition, a special landscape that combines Chinese and Korean landscapes appears. Currently, about 60,000 Chinese people live in Daelim-dong. Due to these characteristics, this space is suitable for studying the cultural landscape of Chinese migrant residences in Korea. So, in this study, this space is selected as the research target site.



Figure 1 Main streets of Chinatown

3. Theoretical research

3.1 Landscape from a cultural anthropological perspective

From a cultural anthropological point of view, the landscape is not simply a physical space, but includes the lives and cultures of the people living in this area (**Jin et al., 2011**). In general, an immigrant's space tries to express the original culture of the immigrant in space. Therefore, the humanities and sociological meaning of space must be analyzed through the interaction of people and space. In addition, a landscape is a space to which humans give

meaning from a cultural anthropological point of view (Ryu & Cho ,2015). Therefore, in the cultural anthropological landscape, the cultural identity of people who use space is well shown. For this reason, when planning the landscape of a space, a design that reflects not only the aesthetic beauty but also the experiences and meanings of local residents should be made. Therefore, from a cultural anthropological point of view, the subject of the landscape is not an urban planner or designer, but a resident who uses the space. For this landscape design, the resident participatory design that can reflect the experiences of residents is becoming more important than simply the opinions of experts (Lee, 2014). Therefore, the Chinese group residence should be designed as a space that represents the cultural characteristics of Chinese and Koreans well, which can have a positive effect on the lives of residents.

3.2 Chinatown

Chinatown is a space that represents Chinese culture well while Chinese migrants collectively live in other countries. Chinatown is a representative space among the spaces of immigrants, and it is a space where the identity of Chinese people can be well displayed as well as economic activities. These Chinatowns have been created worldwide since the 19th century, and the purpose of migration is mostly for economic reasons. Migration countries are various places, including the United States, Europe, and Korea. The representative Chinatown is located in San Francisco, USA. This Chinatown is not a simple group residence, but a complex functional space that combines commerce, education, and housing. So, the landscape of Chinatown can be divided into two. These two can be divided into a material landscape and an immaterial landscape (Lee & Shin, 2021). In the material landscape, symbols of Chinese culture such as facilities and buildings are located, and these material landscapes are recognized by the Chinese as spaces where their own culture exists. In the non-material landscape, Chinese traditional holidays, languages, and lifestyles appear in the space. And Chinatown is a space that expresses multicultural characteristics by combining with local culture. So, multicultural characteristics are well displayed in the material landscape and the non-material landscape. The physical and non-physical classification of the Daerim-dong Chinatown cultural landscape is based on field observation. In addition, these classification criteria were derived based on the difference between the physical shape of the landscape and the non-physical behavior of the residents. This classification can provide a clear criterion for landscape analysis for spatial research (Yang & Kim, 2012) (Table 2).

Table 2 Landscape Type of Chinatown

Landscape Type	Specific Content	Cultural Meaning
Material Landscape	1. Traditional Chinese architecture (dragon a patterns, red roofs),	Directly expressing the symbolism of Chinese culture and serving as a medium to promote
	2. Chinese-character signs (restaurants)	Chinese culture to the outside world
	3. Chinese-style facilities(marts, restaurants)	
Non-material Landscape	1. Events of traditional Chinese (Spring Festival, Mid-Autumn Festival)	A life-oriented expression of Chinese culture
	2. Chinese language	
	3. Chinese eating habits	

4. Landscape Formation Process of Daelim-dong Chinatown

Daelim-dong Chinatown has changed sequentially over time. At each of these stages, the cultural landscape of Daelim-dong shows various characteristics according to the influx of Chinese people, the degree of cultural adaptation, and interaction with the region. This convergence of Chinese migrants and local cultures has a great

influence on the cultural landscape of the Daelim-dong region. In this study, these characteristics were divided into three stages. These three steps are as follows (**Table 3**).

Table 3 Landscape Type of Chinatown

Development Stage	Period	Immigrant Characteristics	Main Landscape Features
Initial Stage	1990s	Mainly labor immigrants, immigration for economic purposes	Korean-style landscape dominates
Growth Stage	2000s	Increase in international students and marriage immigrants	Increase in Chinese-style stores, growing use of red signs and Chinese characters
Mature Stage	2010s~Present	Stabilization of immigrants, growth of the second generation	Mixed Chinese -Korean cultural landscape

4.1 Early days of Chinatown (1990s)

From the 1990s, Chinese people began to gather in Daelim-dong. At first, the Chinese residence in Garibong-dong near Daelim-dong expanded to Daelim-dong. A characteristic of this area is that a factory area called Guro Industrial Complex is located nearby. During this period, as the Korean economy developed rapidly, many foreign workers came to Korea to get a job. So, the Chinese also came to Korea and got jobs in factories and made money. The characteristic of Daelim-dong is that it is a suitable space for Chinese immigrants to live in, as the cost of living is low and there are many factories located nearby. The migration pattern of Daelim-dong Chinatown changed from the Korean style to the Korean-Chinese hybrid type, and the economic change changed to the spread of Chinese-style facilities. As a result, the cultural interaction of this space forms the unique cultural landscape of the space. During this period, the cultural landscape of Daelim-dong was not clear about China's cultural characteristics. During this period, the main residents of the area were Koreans and some Chinese people. And the number of Chinese people was steadily increasing every year. And during this period, Chinese restaurants and shops began to appear in this area.

4.2 Chinatown Growth (2000s)

It is the time when Daelim-dong Chinatown is growing. During this period, many Chinese people flowed into Korea through Chinese international students and international marriages. For this reason, Chinese restaurants, marts, and stores have also increased in Daelim-dong Chinatown. So, Daelim-dong Chinatown has been transformed into a space where you can feel Chinese culture in terms of landscape. The major landscape changes of Daelim-dong Chinatown are as follows. First, the physical form of buildings has changed a lot in the Chinese style. In the store, many signs of Chinese characters were created, and many colors showing Chinese characteristics such as red and yellow were created. Second, Daelim-dong Chinatown has many public facilities for Chinese immigrants. These facilities play a role in helping Chinese immigrants live in Korea.

4.3 Chinatown Mature (2010s~present)

During this period, Daelim-dong Chinatown was completed and continues to expand. In addition, existing Chinese immigrants purchase houses or buildings in Daelim-dong and live a stable life. In addition, the second generation of Chinese immigrants has grown in this area and is engaged in various activities. And if Daelim-dong Chinatown had become a nationally famous Chinatown in Korea, it would have grown to the largest scale in the country (**Figure 2**). So now, the landscape of Daelim-dong Chinatown is more complex and diverse. And many Korean tourists gather to experience Chinese culture in this space. There are various types of Chinese stores and many facilities where you can feel Chinese culture. And this space is being transformed into a space where new

forms of mixed culture appear by combining Chinese and Korean cultures.



Figure 2 Daelim-dong Chinatown.

5. Analysis of the Cultural Landscape of Daelim-dong Chinatown

In this study, through in-depth interviews, Daelim-dong Chinatown can be divided into physical and non-physical cultural landscapes. And Daelim-dong Chinatown is not simply a space that replicates Chinese culture, but is combined with Korean culture to represent a unique cultural landscape.

5.1 Physical Culture Landscape

The physical landscape of Daelim-dong Chinatown is an expression of the cultural identity of Chinese immigrants. Representative physical landscape elements are expressed on the exterior of signboards and buildings. K, an immigrant from China, said, "The red color is used a lot on store signs in Daelim-dong. This is because the red color symbolizes good luck in China." And red and yellow are generally used on the exterior. Red means good luck and prosperity in China, and yellow means gold and tradition. That's why these colors are also used a lot on the exterior of buildings in Daelim-dong Chinatown. And in some buildings, Chinese immigrants had to engrave dragon and flower patterns on the exterior of the building. However, Daelim-dong Chinatown is not completely rebuilt in Chinese style, but only partially renovated. And public facilities such as parks in Daelim-dong Chinatown are provided with services by using both Korean and Chinese.

5.2 Non-physical cultural landscape

Daelim-dong Chinatown is multilingual. In Daelim-dong, Korean, Chinese, and English are used. Chinese immigrants speak Korean and Chinese freely in this space. Also, there are many tourists in Daelim-dong Chinatown now, and these tourists sometimes speak English in this space. Chinese self-employed C said, "The store writes down menus in three languages: Korean, Chinese, and English. And the landscape of life is well seen by Chinese immigrants in Daelim-dong Chinatown. For example, there are many Chinese residents who celebrate both Chinese and Korean holidays in this space. L, a Korean resident of Daelim-dong, said, "We celebrate the holidays with our Chinese neighbors every year on Chinese New Year's Day. Daelim-dong Chinatown has many restaurants mixed with Korea and China, so cultures seem to mix with each other. In addition, there are many restaurants that mix Korean and Chinese food in commercial facilities. So there are many mixed life landscapes

of Korea and China in this space (Table 4).

Table 4 Daelim-dong Chinatown Cultural Landscape Analysis

Classification of Cultural Landscapes	Category	Specific Content
Physical Cultural Landscape	Color	Mainly uses red and yellow
	Patterns	Applies traditional Chinese patterns such as dragon patterns and flower patterns
	Renovation Public Facilities	Partially adds Chinese cultural elements to existing buildings
Non-Physical Cultural Landscape	Language	Provides bilingual services in Korean and Chinese Multilingual use of Korean, Chinese, and English
	Festivals	Celebrates both Chinese and Korean festivals
	Diet	Many restaurants serving a mix of Korean and Chinese cuisine are located

6. Cultural Characteristics of Daelim-dong Chinatown

6.1 Mixed space of culture

Daelim-dong Chinatown is a space that represents a mixed cultural landscape that combines Chinese and Korean cultures. These cultural landscapes were combined with Korean and Chinese landscapes to form a new type of cultural landscape. Culture is not just mixed, but it can create a new form of culture, not Korean and Chinese culture. In addition, many new forms of food, not Korean and Chinese food, are being developed in this region.

This study is based on the theory of cultural hybridity and the theory of cultural landscape related to migration. The cultural interaction between Korea and China in Daelim-dong Chinatown can prove the theoretical basis and be a representative example for the study of migrant space. Therefore, various events and activities are also combined with Korean and Chinese cultures to create new forms of events and activities.

6.2 Space of conflict and convergence

The formation of Daelim-dong Chinatown developed through conflict and convergence between Korean residents and Chinese migrants. In the early days, the conflict between Korean residents and Chinese migrants was serious. Korean residents had a lot of quarrels because of their dissatisfaction with Chinese migrants. For example, illegal space occupation and garbage dumping by Chinese migrants have become major problems. This is a problem caused by cultural differences between the two countries. However, in recent years, cultural exchanges between Koreans and Chinese have become active, leading to cultural convergence and helping the two groups understand each other. In addition, as many tourists gathered in this area, a commercial district was formed. In addition, as real estate prices rose a lot, Koreans had positive feelings toward the Chinese. Currently, residents of Daelim-dong Chinatown are contemplating the direction of future development for this space with a special landscape. In Daelim-dong Chinatown (**Figure 3**), conflicts between Korean residents and Chinese migrants arose due to neglect of garbage and illegal occupation in the initial migration stage. However, Daelim-dong China Town has gradually increased mutual understanding and has advanced to the stage of convergence between Korea and China.



Figure 3 Red sign in Chinatown.

6.3.Space that expresses the identity of immigrants

Chinese people want to come to Korea and show their identity. So, Daelim-dong Chinatown is a space to express their identity to Chinese immigrants. In general, immigrants express their cultural identity through their physical environment. The empirical findings of Daelim-dong Chinatown directly show the cultural interaction between residents of Daelim-dong, which is the logical basis for the cultural landscape design strategy. The design strategy based on these empirical findings can reinforce the community convergence of Daelim-dong Chinatown by reflecting the actual interactions and needs of residents. For example, red and yellow signs are installed in Chinese stores. And traditional patterns such as phoenix and dragon are used a lot. Through this action, immigrants are proud of their culture and want to express it in various ways.

7. Cultural Landscape Design Strategy of Daelim-dong Chinatown

7.1 Core Principles of Cultural Landscape Design

The core principles of cultural landscape design in Daelim-dong Chinatown can be divided into three. These three are the principle of cultural convergence, the principle of regional connection, and the principle of convenience of viewing. First, the principle of cultural convergence is to fuse Chinese culture and Korean culture. This convergence shows that the architecture of Daelim-dong Chinatown does not simply duplicate Chinese architecture, but exhibits special originality. Second, the principle of regional connection is that Daelim-dong Chinatown strengthens cultural connection by linking it with the surrounding regional landscape. Third, the principle of viewing convenience needs to be designed in consideration of the convenience and stability of tourists and residents visiting Daelim-dong Chinatown. The principle of such convenience is that clear signs, sufficient rest areas, and convenience facilities should be installed (Table 5).

Table 5 Core Principles of Cultural Landscape Design.

Core Principle	Basic Content	Specific Requirements/Goals
Cultural Integration Principle	Application of mutual integration of Chinese and Korean cultures	Prevent architectural duplication, realize regional and innovative design
Regional Linkage Principle	Link Chinatown with surrounding landscapes	Strengthen regional cultural connectivity and enhance a sense of integration
Visitor Convenience Principle	Prioritize user convenience and safety	Install signs, secure rest spaces and convenience facilities

7.2 Specific Strategies for Cultural Landscape Design

The specific strategies of cultural landscape design in Daelim-dong Chinatown can be divided into three. These three are the establishment of cultural identity, improvement of infrastructure and convenience facilities, and participation of local residents. First, in order to build a cultural identity, a cultural street is created on the main street of Daelim-dong Chinatown. Lanterns with traditional Chinese patterns are installed on these streets to enhance the night view. And various sculptures can be installed on the cultural street to express the cultural characteristics of Chinatown. Second, for infrastructure and convenience facility improvement, rest areas and toilets are installed. These spaces can provide convenience to tourists and local residents. In addition, information boards are installed in Daelim-dong Chinatown, and these information boards are written in Korean, Chinese, and English to provide convenience to various tourists. Third, local resident participation allows Chinese residents to actively participate in the design of Daelim-dong Chinatown (**Figure 4**). So, the opinions and needs of local residents can be reflected as much as possible. In addition, various cultural activities are held in Daelim-dong Chinatown so that local residents can directly participate in the cultural experience program (**Table 6**).

Table 6 Specific Strategies for Cultural Landscape Design.

Specific Strategies	Strategic Goals	Specific Measures
Establishment of Cultural Identity	Clearly express the cultural characteristics of Daelim-dong Chinatown	1. Create a cultural street on the main road of Daelim-dong Chinatown 2. Install lanterns with traditional Chinese patterns to enhance the night landscape 3. Install various sculptures to express the cultural characteristics of Chinatown
Improvement of Infrastructure and Convenience Facilities	Improve the convenience of use for tourists and local residents	1. Install convenience facilities such as rest spaces and toilets 2. Install information boards in Korean, Chinese, and English
Local Resident Participation	Reflect the opinions and needs of local residents and promote cultural participation	1. Encourage active participation of Chinese residents in the design to reflect their opinions and needs as much as possible 2. Hold various cultural activities to allow local residents to directly participate in cultural experience programs



Figure 4 Daelim-dong Chinatown Store.

8. Conclusion

In this study, the formation of landscapes and cultural characteristics was analyzed targeting Chinese residents in Daerim-dong, Seoul. The main insight of this study is that Daelim-dong Chinatown has formed a cultural hybridity through the interaction of Chinese migrants and Korean residents, which provides important implications for the design of a multicultural space. The analysis of the characteristics of Daelim-dong Chinatown is as follows. First, it is a space representing a mixed cultural landscape that combines Chinese and Korean culture. Second, the formation of Daelim-dong Chinatown developed through conflict and convergence between Korean residents and Chinese migrants. Third, the Chinese want to come to Korea and reveal their identity. This study has a limitation in that it is difficult to generalize the research results of Daelim-dong Chinatown to other Chinatowns or multicultural spaces. In addition, there is a limitation in that the diversity of migrant cultural landscapes cannot be sufficiently reflected by analyzing only a single case. The results of this study can reflect the elements of Korean-Chinese culture convergence in the landscape design of Daelim-dong Chinatown. The proposed design strategy can be applied to actual landscape design and referred to other multicultural areas.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patient(s) to publish this paper.

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Effective Comfort in Vernacular Courtyard Housing: A Socio-Environmental Comparison of Hausa Compounds in Kano and Siheyuan Houses in Beijing.

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Abstract: This study compares vernacular courtyard housing in Kano (hot-dry) and Beijing (monsoon-influenced) to frame climate adaptation as a socio-technical system. A comparative mixed-methods framework integrates (i) morphological analysis of spatial and geometric strategies, (ii) calibrated EnergyPlus and ENVI-met simulations of seasonal microclimate performance, and (iii) thematic coding of resident interviews and observation logs to identify behavioral practices that extend physical performance into lived comfort. These strands are triangulated to evaluate how comfort is co-produced by built form and occupant practice. Results reveal divergent strategies: Kano compounds utilize high enclosure for persistent shading, activated by routine night flushing, whereas Beijing siheyuan employs lower enclosure to prioritize winter solar access, relying on seasonal shading and spatial migration to manage summer heat. These findings validate the concept of effective comfort, defined as a behaviorally weighted adaptive comfort metric that evaluates thermal conditions by occupants' observed probability of occupying each dwelling zone throughout the day, rather than assuming a fixed position in a single room. Unlike static comfort indices, effective comfort captures how households navigate thermally distinct microclimates to maintain acceptable conditions, extending warm-season comfort compliance by up to 10 percentage points beyond what the physical envelope alone achieves. The study concludes that contemporary low-energy housing should operationalize courtyards as calibrated "climate engines" with enclosure ratios tuned to local seasonality and incorporate transitional buffer zones enabling occupants to practice spatial migration, thereby reducing mechanical cooling dependency without sacrificing cultural functionality.

Keywords: Vernacular architecture; Courtyard housing; Climate adaptation; Microclimate; Cultural resilience

1. Introduction

As the world faces escalating challenges related to climate change, the built environment plays a pivotal role in mitigating environmental impacts, particularly through the design and adaptation of buildings to local climates. Traditional vernacular architecture, developed over centuries, embodies sophisticated responses to these environmental pressures (Turan, 2024). These buildings were created in close harmony with the natural surroundings, leveraging locally available materials and construction methods to regulate temperature, control solar gain, and promote air circulation. In many regions, vernacular forms are not merely passive structures but active environmental regulators—systems refined over generations of interaction between human needs and environmental conditions (Salimi et al., 2025; Turan, 2024). However, as rapid urbanization, globalization, and modern construction techniques have replaced many traditional designs, there is a growing concern that this repository of knowledge is being lost.

In light of these concerns, there has been a renewed interest in vernacular architecture as a source of climate-

responsive design solutions. The adaptive strategies embedded in these traditional forms are seen as potentially invaluable for contemporary low-energy building design (Kivimaa & Martiskainen, 2018; Loonen et al., 2013). Yet, despite the wealth of research on individual case studies, there is a notable lack of cross-cultural comparisons that can illuminate both universal and context-specific aspects of climate adaptation in vernacular architecture.

Although extensive literature exists on vernacular architecture, it often remains siloed within regional or cultural boundaries. Studies of vernacular adaptation typically focus on a single geographic area, and comparative studies across regions with different climatic conditions remain rare (Huebner, 2025; Nguyen et al., 2019). Additionally, much of the research on climate-adaptive vernacular architecture focuses on technical performance—such as thermal regulation or material properties—without addressing the cultural dimensions of these systems (Hassani, 2025; Patil, 2025; Shahamat, 2025). Cultural practices, such as how inhabitants interact with the built environment or modify their living arrangements to cope with seasonal changes, often remain underexplored (Castro & Sen, 2022; Pleninger & Bieling, 2012). This research gap undermines the potential for developing truly holistic climate adaptation strategies that integrate both built form and human behavior. Moreover, the impact of modernization and the shift to mechanically conditioned buildings has often overshadowed the cultural resilience embedded in traditional housing. As more vernacular forms are altered or replaced, the loss of traditional knowledge systems raises important questions about how these buildings could inform sustainable development today, especially in regions facing extreme environmental stress.

While previous comparative studies have examined vernacular typologies across regions (e.g., Nguyen et al., 2019), they have typically focused on either physical performance metrics or cultural descriptions, but rarely integrated both within a single analytical framework. Moreover, existing cross-cultural analyses tend to juxtapose findings from independent studies rather than apply identical protocols across sites, limiting the comparability of results. This study advances the field in three specific ways: (i) it introduces a quantitative “effective comfort” metric (Ceff) that operationally links simulated microclimate data with observed occupant behavior, enabling comfort to be evaluated as a co-produced outcome rather than a static building property; (ii) it directly compares two courtyard-based typologies—Hausa compounds in Kano and siheyuan in Beijing—under fundamentally different climate regimes using identical morphological, simulation, and behavioral analytical protocols; and (iii) it systematically distinguishes convergent adaptation principles (shared across climates) from culturally divergent strategies (specific to socio-environmental context) through structured cross-case triangulation.

This study seeks to address these gaps by conducting a comparative analysis of two distinct vernacular typologies: the Hausa courtyard compounds in Kano, Nigeria, and the Siheyuan in Beijing, China. Both typologies center around the concept of the courtyard, an architectural feature that has served as a focal point for climate adaptation and social organization. Despite the geographical and cultural differences between the two regions, both courtyard house forms evolved in response to the need for passive cooling, thermal regulation, and social cohesion in their respective climates.

The primary aim of this study is to examine how these two architectural forms have adapted to their respective climatic stressors—hot-dry conditions in Kano and the seasonal monsoon-continental climate in Beijing. Critically, this study departs from conventional bioclimatic analysis by treating cultural practice not as contextual background but as an active performance variable. Where existing research evaluates vernacular buildings as static thermal objects, this study models occupant behavior—spatial migration between dwelling zones, ventilation routines, and activity timing—as mechanisms that actively modulate microclimate outcomes. This socio-technical framing positions thermal comfort as co-produced by built form and cultural logic rather than passively received from the physical envelope alone. In doing so, this paper seeks to answer the following research questions:

RQ1 (*Morphological adaptation* → Section 3.3): How do Hausa compounds and siheyuan physically configure space and materials to address local climatic conditions, and which architectural features—courtyards, walls, roofs, and transitional spaces—are most significant in moderating the internal microclimate?

RQ2 (*Behavioral adaptation* → Section 3.5): In what ways are these climate-responsive designs shaped by, and integrated into, cultural practices and social organization? How do occupant behaviors—such as spatial migration between courtyards, verandas, and indoor rooms, ventilation routines, and seasonal activity timing—influence thermal comfort and adaptation?

RQ3 (*Cross-cultural synthesis* → Section 5.4): What cross-cultural design principles—both convergent and divergent—can be derived from this comparison for the design of contemporary, climate-resilient housing in regions with similar climatic constraints?

The study aims to contribute to the growing field of sustainable design by providing empirical evidence of how vernacular forms and cultural practices can be integrated into modern design solutions. Through a comparative framework that links spatial morphology, microclimatic performance, and cultural practices, this paper proposes a new way to think about climate adaptation in housing. It argues that climate resilience in architecture cannot be solely attributed to building materials or geometry; it is co-produced by the physical environment and the cultural logics that govern everyday life within the dwelling.

2. Background

2.1 Vernacular Architecture and Climate-Adaptive Design

Global architectural discourse has increasingly repositioned vernacular architecture from a historical artifact to a vital repository of climate-responsive design knowledge. Over centuries, traditional building forms co-evolved with their environments to passively regulate heat and airflow through simple, context-driven strategies—such as compact settlement layouts, internal courtyards, high-thermal-mass earthen walls, and deep shading elements (Binti Mohamad, 2025). These features were not arbitrary aesthetic choices but sophisticated, empirical responses to local conditions, optimized to control solar gain, maximize thermal storage, and channel prevailing breezes. Contemporary sustainability scholars now view these vernacular solutions as critical precedents for low-energy design in warming climates. However, a significant caution pervades the recent literature: modern adaptations often risk "surface-level mimicry," replicating visual motifs like arches or facades without retaining the integrated systems that drive performance. Simply adopting the aesthetic of a mud wall or a courtyard is insufficient if the underlying thermodynamic logic is ignored. Consequently, successful contemporary application requires a deep theoretical grasp of vernacular principles as holistic climate-adaptive systems rather than merely stylistic catalogs.

2.2 Vernacular Architecture as Socio-Technical Systems

Recent scholarship has reframed vernacular architecture as a dynamic socio-technical system that mediates between environment, technology, and culture (Aigwi et al., 2023; Martinovic et al., 2023) characterize. These built environments as evolutionary solutions—products of a continuous negotiation between climatic constraints, material availability, and social necessities. Unlike modern engineered buildings, which are frequently optimized for single-variable performance, vernacular dwellings represent a dynamic equilibrium where physical form and human behavior co-evolve. This perspective suggests that the habitation of space is inseparable from the architecture itself. Critiques of strictly bioclimatic approaches, such as those by Murillo Camacho et al., (2023), argue that purely technical analyses are misleading if they strip away the lived social practices that activate the structure. For instance, the thermal efficiency of a Hausa adobe wall or a Beijing siheyuan courtyard relies heavily on occupant operation—specifically, the timing of window usage and diurnal migration within the home. Therefore, evaluating performance requires linking the "hardware" of design (geometry and materials) with the "software" of culture (routines and behaviors). This view is supported by Lamb and Vale (2024) and Tran (2025), who emphasize that built form and cultural practice are inextricable components of housing resilience.

2.3 Passive Climate Adaptation Strategies in Vernacular Housing

The literature identifies three interrelated modes through which vernacular architecture achieves thermal comfort: morphological, material, and behavioral adaptation. Building geometry serves as the primary regulator of microclimate. Research confirms that the courtyard's aspect ratio (Height-to-Width) and orientation are decisive performance factors (**Patil, 2025**). For example, Hausa compounds in hot-arid Nigeria utilize deep, compact courtyards (high H/W) to minimize solar penetration and buffer against dust. Conversely, Beijing's siheyuan employs a shallower, more open geometry (lower H/W) to balance winter solar admission with summer cross-ventilation. However, vernacular builders exploit thermophysical properties to moderate indoor conditions. High thermal-mass materials, such as adobe and stone, function as a thermal flywheel, absorbing heat during the day and releasing it at night to dampen diurnal temperature swings. demonstrate that this cooling potential is only fully realized when coupled with effective night-time ventilation strategies.

Unlike static modern environments, vernacular living patterns rely on the active role of the occupant. Residents practice "spatial migration," moving between outdoor courtyards, shaded verandas, and enclosed rooms to align activities with daily thermal cycles. Ergöz Karahan argue that this adaptive behavior significantly extends the "effective comfort" range of the dwelling beyond what physical form alone could achieve, often maintaining satisfaction without mechanical conditioning.

2.4 Cultural Resilience and Modernization Challenges

Beyond environmental performance, vernacular architecture acts as a vessel for cultural continuity. Holtorf defines cultural resilience as the capacity of traditions to endure external shocks, such as rapid modernization or climate change. Vernacular dwellings encode social organizations—such as gendered privacy zones or intergenerational hierarchies—that reinforce community identity. For example, the axial layout of a siheyuan reflects Confucian family order, while the concentric zoning of a Hausa compound supports Islamic customs of privacy. Preserving these forms is thus a strategy for maintaining distinct cultural identities in the face of globalization.

However, this resilience is under threat. In both Nigeria and China, rapid urbanization has led to the displacement of vernacular forms by "modern" materials that often degrade passive performance. In Kano, the substitution of thatch with corrugated metal roofs for status has inadvertently increased indoor heat loads and eliminated natural ventilation. Similarly, in Beijing, the glazing-over of courtyards disrupts the critical airflow and social function of the open space. This creates a "lock-in effect," where poor passive performance necessitates mechanical cooling. Often, this erosion is driven by socio-cultural aspirations rather than performance failures; traditional materials like mud are abandoned not because they fail thermally, but because they are perceived as antiquated. The challenge, therefore, is to modernize housing without discarding the embedded socio-environmental wisdom of the vernacular.

2.5 Research Gap and Rationale

Despite the extensive literature, significant gaps remain in understanding vernacular architecture as an integrated socio-environmental phenomenon. Current research remains largely siloed: quantitative studies often treat buildings as static physical objects, overlooking the behavioral "software" of comfort, while qualitative anthropological studies rarely quantify environmental performance. Furthermore, most research is region-specific, with few studies directly comparing how different cultures resolve analogous climatic challenges through distinct architectural strategies. This study addresses these gaps through a cross-cultural comparative analysis of Hausa compounds in Kano and siheyuan houses in Beijing. By juxtaposing these two distinct yet analogous typologies, the research seeks to identify convergent strategies (universal adaptation principles) and divergent

strategies (culture-specific responses). This approach bridges the technical and cultural divides, combining morphological and microclimatic data with an analysis of social practice. Ultimately, this framework aims to derive design principles for contemporary housing that are not only energy-efficient but also culturally resilient, treating the home as an integrated system of people, place, and performance.

3. Methodology

3.1 Research Design and Analytical Framework

This study adopts a comparative, mixed-methods case study design to investigate how vernacular courtyard housing systems adapt to contrasting climatic and socio-cultural contexts. The research is grounded in analytic comparison rather than statistical generalization, following established methodological guidance for architectural case study research where theoretical replication, not sample size, is the primary objective.

Two vernacular housing typologies were selected as analytically comparable yet climatically distinct cases:

- **Hausa courtyard compounds** in Kano, northern Nigeria (hot-dry, semi-arid climate)
- **Siheyuan courtyard houses** in Beijing, China (monsoon-influenced continental climate)

The methodology is structured around an integrated socio-environmental analytical framework, in which climate adaptation is examined across three interdependent dimensions:

- **Morphological adaptation** (spatial form, geometry, enclosure)
- **Environmental performance** (microclimate regulation and thermal behavior)
- **Cultural-behavioral adaptation** (patterns of use, seasonal spatial migration, social practices)

This framework allows climate adaptation to be understood not solely as a physical property of buildings, but as a co-produced outcome of built form and human behavior.

3.2 Case Study Selection and Climatic Context

3.2.1 Selection Criteria

The case studies were selected using purposive sampling (Campbell et al., 2020), based on four criteria depicted in Table 1.

Table 1 Climate Adaptation

Courtyard Houses	Details
Climatic contrast	Kano represents a hot-dry climate with high diurnal temperature variation, while Beijing represents a climate with hot summers, cold winters, and strong seasonal variation
Courtyard-centered typology:	Both housing types are organized around internal courtyards that function as environmental and social regulators.
Continued residential use	Selected houses remain actively inhabited, enabling observation of contemporary adaptive practices.
Limited mechanical conditioning	Preference was given to dwellings relying primarily on passive strategies, ensuring vernacular logic remains legible.

A total of 16 courtyard houses were investigated: 8 in Kano and 8 in Beijing. Within each city, houses were selected to represent typical examples of the vernacular typology in terms of size, construction materials, and layout, while avoiding highly modified or tourist-oriented structures. Candidate dwellings were identified through local expert consultation (urban planners, heritage officers, community leaders), walking surveys of historic quarters, and heritage-inventory review. In Kano, surveys targeted the Fagge, Kofar Mata, and Gwagwarwa

neighbourhoods within the old city walls; in Beijing, the Dongcheng and Xicheng districts. Approximately 25 candidates per city were screened against the criteria in Table 1; houses were excluded for major structural alterations (e.g., courtyard enclosure, multi-story additions), primarily commercial use, or absence of residential occupation. The final 8 houses per city represent typical mid-range examples of each typology in courtyard size, materials, and household configuration. The sample targets the central tendency of each typology rather than statistical representativeness, following the logic of theoretical replication.

3.2.2 Climatic Characterization

These climatic distinctions provide a robust basis for examining divergent vernacular adaptation strategies under different environmental pressures. Climatic data for both cities were obtained from long-term meteorological records and classified using the Köppen–Geiger system:

- Kano: Hot semi-arid climate (BSh), characterized by high solar radiation, low humidity for most of the year, and large diurnal temperature swings.
- Beijing: Monsoon-influenced humid continental climate (Dwa), characterized by hot, humid summers and cold, dry winters.

3.3 Spatial and Morphological Analysis

To evaluate morphological adaptation, detailed architectural surveys were conducted for each case study dwelling.

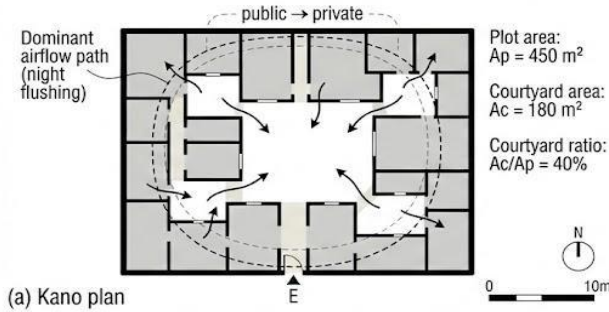
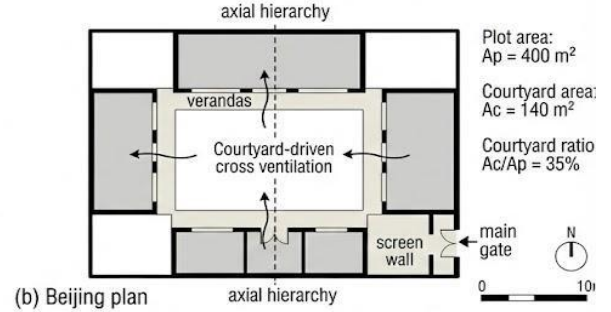
3.3.1 Data Collection

Measured drawings and spatial documentation were produced through on-site surveys, photographs, and satellite imagery. Morphological performance was evaluated using quantitative indices commonly applied in environmental design research. The following parameters were recorded:

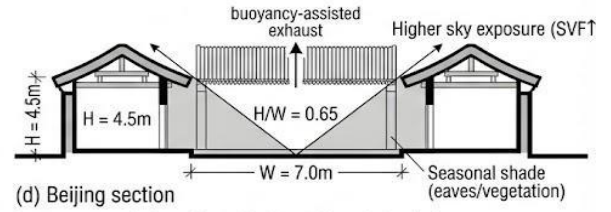
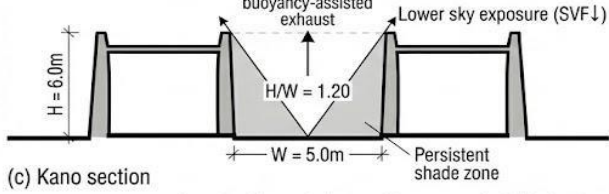
Table 2 Data Collection Parameters and parameters Quantitative Indices

Data Collection	Analytical Metrics
Courtyard dimensions (length, width, height)	Aspect ratio (H/W) to assess shading potential and sky exposure
Height-to-width (H/W) ratio of courtyards	Sky View Factor (SVF) to estimate solar access and long-wave radiation exchange
Building orientation and axial alignment	Compactness ratio to assess surface-to-volume efficiency
Wall thickness and construction materials	Spatial sequencing analysis to identify thermal gradients from outdoor to indoor zones
Window-to-wall ratio (WWR)	Presence and depth of transitional spaces (verandas, galleries, arcades)

Scaled plan and section comparison of representative Hausa courtyard compound (Kano) and siheyuan courtyard house (Beijing). Plans (a–b) report plot area , courtyard area , and courtyard allocation / , and indicate dominant airflow pathways associated with courtyard-driven ventilation. Sections (c–d) quantify courtyard enclosure (H/W) and illustrate relative sky exposure and shading extent, highlighting how geometric proportions condition solar access, radiative shielding, and ventilation potential across the two typologies.

A. KANO — HAUSA COMPOUND

B. BEIJING — SIHEYUAN


Scaled section through courtyard (same cut logic for both):



Legend: solid grey = built mass, white = courtyard void, light band = transitional space, arrows = dominant airflow, dashed = social/organizational axis

Figure 1 Comparative plans and sections of representative Hausa compound and Siheyuan courtyard house.

3.4 Microclimate Measurement and Environmental Performance Analysis

3.4.1 Effective Comfort metric (behaviorally weighted adaptive comfort compliance).

Adaptive comfort compliance was computed using operative temperature and the adaptive comfort model as specified in ASHRAE Standard 55 (current edition) and EN 16798-1:2019, which define acceptable operative temperature bounds as a function of prevailing/running-mean outdoor temperature. Kelechava (2024) simulation outputs provided zone-level operative temperature $T_{op}(z, t)$ for each modeled space z (e.g., primary indoor room, transitional/veranda zone, courtyard, and where applicable roof/terrace) at each time step t . To address whether comfort is evaluated at a static point or in a behaviorally realistic way, we report both: (i) **static zone compliance** and (ii) **Effective Comfort compliance**, which weights comfort by the occupant's observed probability of being in each zone over time. Occupancy weights $w_z(t)$ were derived directly from the coded observation/interview schedules (Figure 4), with $\sum_z w_z(t) = 1$ for each t . Effective Comfort compliance is defined as:

$$C_{\text{eff}} = \frac{1}{N} \sum_{t=1}^N \sum_{z \in Z} w_z(t) \mathbf{1}[T_{op}(z, t) \in (T_{low}(t), T_{high}(t))],$$

where $T_{low}(t)$ and $T_{high}(t)$ are the adaptive comfort bounds at time t , and $\mathbf{1}[\cdot]$ is an indicator function. Static zone compliance for any single zone z^* is computed as $C_{z^*} = \frac{1}{N} \sum_t \mathbf{1}[T_{op}(z^*, t) \in (T_{low}, T_{high})]$. Notably, occupant movement was **not** assumed to alter the thermal state of zones in the simulation (i.e., movement is applied in post-processing), but it is explicitly incorporated into comfort evaluation through $w_z(t)$, making the metric a direct quantification of behaviorally extended comfort.

3.4.2 Field Measurements

Table 3 On-site microclimate monitoring was conducted during representative seasonal periods in both

cities

Three spatial zones	Parameters recorded
Courtyard (outdoor but enclosed)	Air temperature (°C)
Semi-open transitional space (veranda or gallery)	Relative humidity (%)
Primary indoor living space	

Data loggers were installed at a height of approximately **1.1 – 1.5 m**, corresponding to the occupied zone, and recorded data at **10-minute intervals** over a minimum of **7 consecutive days**.

Table 3 presents the main courtyard-related metrics. Differences between Kano and Beijing are statistically significant for all listed variables (two-sample t-tests, $p < 0.01$ in each case).

Table 4 Key spatial metrics for Hausa compounds in Kano and siheyuan in Beijing

Metric	Kano (n = 8, mean ± SD)	Beijing (n = 8, mean ± SD)
Plot area (m ²)	320 ± 60	580 ± 110
Courtyard area (m ²)	42 ± 9	96 ± 22
Courtyard area / plot area (%)	39 ± 5	31 ± 4
Courtyard H/W ratio (–)	1.20 ± 0.15	0.65 ± 0.10
Rooms opening directly to courtyard (no.)	7.3 ± 1.2	5.1 ± 1.0

Note: All Kano–Beijing differences are statistically significant at $p < 0.01$ (independent-samples t-test, two-tailed). H/W ratio is defined as mean enclosing wall height divided by mean courtyard width.

Beijing siheyuan employ larger, lower-enclosure courtyards (96 m²; H/W = 0.65) within bigger plots, maximizing winter solar access, whereas Kano Hausa compounds concentrate a higher courtyard share within more compact plots (39%; 42 m²) and use taller, narrower courtyards (H/W = 1.20) plus concentric room organization to prioritize shade, privacy, and hot-dry climatic protection.

3.4.3 Simulation and Model Calibration

To extend findings beyond the monitoring period, annual thermal simulations were conducted using:

- EnergyPlus for indoor thermal performance
- ENVI-met for courtyard and immediate microclimate behavior

Simulation models were constructed based on measured geometry and material properties. Calibration was performed by comparing simulated outputs with field measurements, using standard statistical indicators:

- Root Mean Square Error (RMSE)
- Mean Bias Error (MBE)

Models achieving RMSE values within accepted thresholds ($\leq 1.5^\circ\text{C}$ for temperature) were retained for further analysis. Calibration targeted infiltration rates (tested 0.3–1.5 ACH; final: Kano 0.8, Beijing 0.6 ACH) and window-opening schedules derived from coded ventilation data, while material properties were held fixed (Supplementary Table S1). The calibrated models achieved RMSE values of 0.87°C , 1.04°C , and 1.26°C for indoor, transitional, and courtyard zones in Kano, and 0.94°C , 1.12°C , and 1.38°C in Beijing, respectively—all within the 1.5°C threshold. MBE magnitudes remained below $\pm 0.5^\circ\text{C}$ (Kano: -0.18°C , $+0.22^\circ\text{C}$, $+0.31^\circ\text{C}$; Beijing: -0.24°C , $+0.19^\circ\text{C}$, $+0.37^\circ\text{C}$ for indoor, transitional, and courtyard zones, respectively), and R^2 values for hourly indoor temperature were 0.93 (Kano) and 0.90 (Beijing). Figure 2 confirms that simulated diurnal profiles reproduce measured peak timing, amplitude, and nocturnal cooling trajectories in both cities.

To ensure reproducibility of the calibrated microclimate simulations, the thermophysical inputs used for vernacular envelope materials are reported explicitly. Table 4 lists the assumed thermal conductivity (k), density (ρ), and specific heat capacity (c_p) for the principal wall and roof materials (earthen/adobe masonry, fired-clay

brick, thatch/reed roofing, and clay roof tile), along with the literature/database sources and the values implemented in the EnergyPlus/ENVI-met material libraries. These parameters were held fixed during calibration; calibration targeted uncertainty in boundary/operational terms (e.g., infiltration and window-opening schedules) while maintaining physically plausible material properties. Reporting these inputs addresses traceability and enables direct replication of the RMSE-based calibration shown in **Figure 3**. EnergyPlus material definitions require thickness, conductivity, density, and specific heat, which are provided here for the referenced layers.

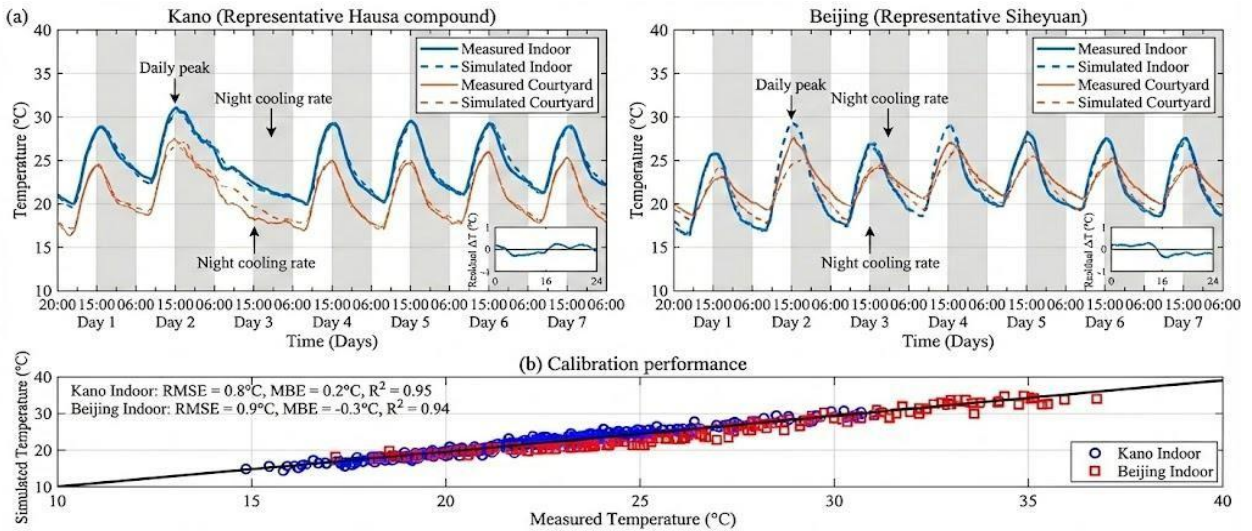


Figure 2 Comparison of measured and simulated temperature profiles for selected case study houses.

3.5 Behavioral and Cultural Practice Analysis

3.5.1 Interviews and Observation

To capture behavioral adaptation, semi-structured interviews were conducted with 32 residents (16 per city). Interviews focused on:

- Seasonal patterns of space use
- Daily movement between courtyard, semi-open, and indoor spaces
- Sleeping, cooking, and social practices during extreme weather
- Perceptions of thermal comfort and discomfort
- Changes in housing use due to modernization

Participant observation and activity mapping were used to complement interview data, recording temporal patterns of space occupation.

3.5.2 Qualitative Analysis

Interview transcripts and field notes were analysed using deductive–inductive thematic analysis (Braun & Clarke, 2006). An initial coding frame derived from the analytical framework (Figure 1) was refined through iterative reading. Coding used five categories applied consistently across both sites: (i) seasonal spatial migration (“summer-courtyard-evening,” “winter-indoor-retreat”); (ii) ventilation operations (“doors-open-after-sunset,” “windows-closed-midday-dust”); (iii) courtyard social use (“evening-family-gathering”); (iv) activity timing (“morning-heavy-chores,” “midday-rest”); and (v) adaptive shading practices (“seasonal-screen-deployment,” “tree-canopy-shading”).

To integrate qualitative and quantitative evidence, coded behavioural patterns were cross-referenced with measured and simulated temperature profiles: the temporal distribution of reported migration and ventilation events was compared against diurnal zone-temperature curves (**Figure 2**) and nocturnal cooling rates, to confirm

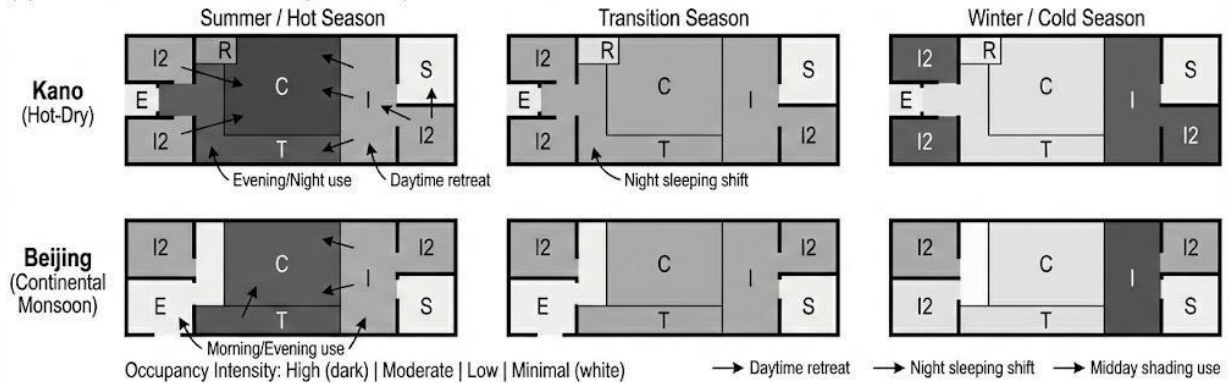
that the behavioural component of effective comfort rested on convergent evidence rather than self-report alone.

Interview transcripts were coded using thematic analysis, with codes grouped into categories such as:

- Seasonal spatial migration
- Ventilation and shading practices
- Social regulation of space
- Adaptive comfort strategies

Findings were cross-referenced with environmental data to assess how behavioral practices amplify or compensate for physical performance.

(a) Plan-based Seasonal Occupation Maps



(b) Seasonal Time-Space Occupation Schedule



(a) Plan-based occupation intensity maps for summer, transition seasons, and winter, showing dominant use of courtyard, transitional, and indoor zones (darker shading indicates higher occupancy).

(b) Seasonal space – time schedule summarizing dominant activities and time-of-day use across key zones, synthesized from interview coding and structured observation logs.

Figure 3 Seasonal spatial occupation patterns within a courtyard house.

3.6 Integrated Socio-Environmental Synthesis

The final analytical stage involved triangulation of morphological, environmental, and behavioral data. Rather than treating culture as a contextual backdrop, this study explicitly models cultural practice as an active environmental variable. This synthesis enabled the identification of:

- Convergent strategies (e.g., courtyards as microclimate regulators across climates)
- Divergent strategies shaped by climate and culture (e.g., enclosure vs. orientation)
- The role of behavioral adaptation in extending the effective comfort range beyond static building performance

Table 5 Cross-case contrasts are reported using Mann–Whitney U (MWU) as the primary test, with rank-biserial correlation (rrb) as the primary effect size; Welch’s t-test and Cohen’s d are included as

sensitivity/descriptive statistics.

Indicator (unit; directionality)	Kano (Mean± SD) n=8	Beijing (Mean±SD) n=8	MWU p(two- sided)	r _{rb}	Welch p(sensitivity)	Cohen's d (descriptive)	Linked observed practice (coded)	Mechanistic implication
Courtyard area (m ²)	42±9	96±18	<.001	−0.95	<.001	−3.74	Evening/night Courtyard social use more continuous in Kano	Beijing externalizes openness via larger plots; Kano concentrates social life into smaller courtyard.
Plot area (m ²)	320±55	580±90	<.001	−0.93	<.001	−3.43	Kano: inward privacy; Beijing: lower-density compound openness	Larger Beijing plots allow broader courtyards and greater sky exposure; Kano compensates through internal allocation.
Courtyard-to-plot ratio (%)	39±4	31±5	.012	+0.74	.018	+1.83	Kano: open-air living internalized; Beijing: openness distributed	Kano devotes a higher share of limited land to the climate-social courtyard function.
Courtyard enclosure H/W (−)	1.20±0.12	0.65 ±0.10	<.001	+0.97	<.001	+4.96	Kano: shade/privacy priority; Beijing: winter access priority	Higher Kano enclosure yields persistent shade and radiative shielding; Beijing openness supports winter solar admission.
Sky View Factor SVF (0–1)	7.3±1.0	5.1±0.9	.004	+0.82	.002	+2.28	Kano: concentric privacy layering; Beijing: axial hierarchy	Kano maximizes courtyard adjacency for shaded circulation/ventilation; Beijing prioritizes axial ordering and hierarchy.
Midday indoor peak attenuation magnitude (Outdoor–Indoor, 13:00–15:00; °C; higher = better)	3.2±0.7	1.6±0.6	.003	+0.86	.003	+2.45	Kano: midday retreat to shaded buffers; controlled openings	Enclosure + shading + mass reduce peak overheating more effectively in Kano during hot periods.
Courtyard cooling effect magnitude (Outdoor–Courtyard, 13:00–15:00; °C; higher = better)	2.1±0.6	0.8±0.5	.005	+0.80	.005	+2.22	Kano: shaded courtyard sitting; Beijing: reduced midday courtyard occupation	Kano courtyards function as stronger daytime “cool islands” due to enclosure and shading.

Indicator (unit; directionality)	Kano (Mean± SD) n=8	Beijing (Mean±SD) n=8	MWU p(two- sided)	r _{rb}	Welch p(sensit ivity)	Cohen's d (descri ptive)	Linked observed practice (coded)	Mechanistic implication
Diurnal indoor temperature range (max–min; °C/day; lower = more stable) trend-level	5.3±1.2	6.4±1.3	.083	–0.52	.074	–0.88	Kano: night purging + space-time migration	Directional stability advantage in Kano, but heterogeneous across dwellings; interpret cautiously.
Night cooling rate magnitude (20:00–02:00; °C/hour; higher = faster cooling)	0.55±0.13	0.38 ±0.12	.021	+0.67	.021	+1.37	Kano: nocturnal courtyard activation + flushing	Faster Kano nocturnal cooling supports night-time courtyard use and ventilative recovery.
Adaptive comfort compliance (warm season; % hours within adaptive band; higher = better)	68±7	56±8	.015	+0.72	.009	+1.61	Kano: activity timing shifts; Beijing: shading + selective courtyard use	Effective comfort differs due to combined climate constraints (humidity/seasonality) and operational strategies.
Ventilation operation intensity (open/close events/day) trend-level	8.2±2.4	6.6±2.1	.071	+0.49	.062	+0.70	Kano: systematic night flushing is more common	Directional tendency for more frequent operational ventilation in Kano; variability limits categorical claims.
Modernization “thermal penalty” (increase in indoor peak after retrofit; °C; higher = worse)	1.4±0.5	0.9±0.4	.041	+0.60	.030	+1.12	Kano: metal roofs/cement blocks; Beijing: glazing/enclosure edges	Retrofit choices can degrade passive logic; performance-aware upgrades are needed to preserve resilience.

Table 5 summarizes cross-case contrasts in courtyard morphology, microclimate performance, and linked practices using an explicitly robust, small-sample reporting strategy. Given the case-based sample size ($n = 8$ houses per city) and observed departures from normality for several indicators, group differences are evaluated primarily with the Mann–Whitney U test (MWU) (Manikandan, 2011), and effect magnitude is reported using the rank-biserial correlation (r_{rb}) (Willson, 1976). For transparency rather than inference, Welch’s t-test p-values (Delacre et al., 2017) and Cohen’s d are included only as sensitivity and descriptive statistics to indicate whether conclusions depend on parametric assumptions. Accordingly, the table is interpreted as evidence of directional consistency and effect size, triangulated with measured–simulated temperature profiles (Figure 3) and coded behavioral patterns, rather than as population-level hypothesis testing.

3.7 Methodological Rigor and Limitations

The study prioritizes depth, contextual validity, and theoretical replication over broad statistical generalization. While the sample size is limited, the analytical framework allows findings to be transferable to similar courtyard-based housing systems in comparable climatic contexts.

Limitations include:

- Short-term field monitoring periods (mitigated through calibrated simulation)
- Focus on two cities, which does not capture all regional variations
- Reliance on self-reported comfort perceptions alongside measured data

These limitations are acknowledged as necessary trade-offs for achieving high-resolution, interdisciplinary insight.

4. Results

4.1 Results Structure and Evidence Map

Guided by the socio-environmental framework in Figure 1, the Results are presented in a sequence that traces climate adaptation from morphological configuration to microclimate performance, and then to cultural-behavioral practices, before integrating these strands into a comparative synthesis. Section 4.1 reports the spatial and geometric indicators that operationalize morphological adaptation, including measured plan-based metrics such as courtyard area, courtyard-to-plot ratio, enclosure (H/W), and sky view factor (SVF), supported by scaled layout evidence. Section 4.2 then evaluates environmental performance by comparing measured and calibrated simulated temperature profiles for representative dwellings (**Figure 3**), highlighting diurnal dynamics, peak attenuation, and courtyard cooling effects. Section 4.3 documents behavioral adaptation through coded observations and interview-derived patterns of seasonal space use and ventilation routines, summarized visually in the seasonal occupation diagram. Finally, the section concludes with an integrated cross-case interpretation that links form, performance, and practice, with key comparative indicators summarized in **Table 3**.

4.2 Climatic Performance and Morphological Adaptation

4.2.1 Baseline climatic context

As summarized in **Table 2**, Kano exhibits consistently warm conditions across the year, with comparatively lower relative humidity in most months and a seasonal wind maximum in June, which coincides with the transition into the West African monsoon period. Beijing, by contrast, displays pronounced seasonality, with cold winters and hot summers, higher summer humidity, and a wind maximum in April associated with spring synoptic circulation. These climatic differences matter because they shape the dominant passive-design problem each typology must solve: in Kano, courtyard housing must prioritize solar and dust protection while enabling night-time ventilation, whereas in Beijing the built form must balance winter solar access against summer overheating and humidity, with wind regimes influencing the feasibility and comfort consequences of courtyard air flushing.

4.2.2 Courtyard Geometry and Enclosure

The two typologies exhibit sharply different courtyard morphologies (**Table 3**), despite sharing a courtyard-centred organizational logic. Beijing siheyuan have substantially larger courtyards ($96 \pm 18 \text{ m}^2$) embedded within larger plots ($580 \pm 90 \text{ m}^2$), whereas Kano compounds concentrate smaller courtyards ($42 \pm 9 \text{ m}^2$) within more compact plots ($320 \pm 55 \text{ m}^2$) (all values: on-site survey measurement). Importantly, Kano allocates a higher proportion of the plot to courtyard space ($39 \pm 4\%$) than Beijing ($31 \pm 5\%$), indicating that open-air living is more strongly internalised within Kano's denser urban fabric. Enclosure metrics further differentiate the cases: Kano courtyards are more enclosed ($H/W = 1.20 \pm 0.12$) with lower sky exposure ($SVF = 0.32 \pm 0.05$), while Beijing

courtyards are broader relative to wall height ($H/W = 0.65 \pm 0.10$) and more sky-exposed ($SVF = 0.55 \pm 0.06$) (H/W from measured sections; SVF computed from fisheye imagery). In interpretive terms, Kano exemplifies “internalised openness + high enclosure,” producing deeply shaded microclimates; Beijing reflects “externalised openness + lower enclosure,” enhancing solar access but requiring seasonal shading strategies. These geometric contrasts are visually evident in the scaled plan and section comparisons (**Figure 2**). In practical terms, Kano’s near-doubled enclosure ratio (H/W 1.20 vs. 0.65) translates into persistent self-shading that substantially reduces direct solar penetration throughout the day, whereas Beijing’s lower enclosure necessitates active seasonal interventions—screens, vegetation, eaves—to achieve comparable midday shade during summer.

4.2.3 Microclimate Performance Evidence

Measured and calibrated simulated temperature profiles (**Figure 3**) demonstrate that the models reproduce observed diurnal patterns with acceptable agreement, supporting their use for interpreting seasonal mechanisms. Across the warm-season monitoring period, Kano exhibits stronger midday indoor peak attenuation ($\Delta T = -3.2 \pm 0.7^\circ\text{C}$ compared to $-1.6 \pm 0.6^\circ\text{C}$ in Beijing; field measurement, warm-season monitoring), meaning that Kano’s high-enclosure morphology reduces the hottest indoor temperatures by approximately twice as much as Beijing’s more open configuration—a difference with direct implications for thermal stress reduction during peak heat hours. Similarly, Kano shows a larger courtyard cooling effect ($\Delta T = -2.1 \pm 0.6^\circ\text{C}$ vs. $-0.8 \pm 0.5^\circ\text{C}$ in Beijing; field measurement), consistent with higher enclosure and shading—indicating that Kano courtyards function as substantially stronger daytime “cool islands” that enable extended outdoor occupation even under peak heat.

Night-time dynamics also differ: Kano’s courtyard cools more rapidly ($-0.55 \pm 0.13^\circ\text{C}/\text{hour}$, 20:00–02:00) than Beijing ($-0.38 \pm 0.12^\circ\text{C}/\text{hour}$) (field measurement, corroborated by simulation), supporting the role of night flushing and nocturnal courtyard use—this faster cooling directly enables the culturally important practice of evening courtyard socialising and outdoor sleeping that residents widely reported. When evaluated against adaptive comfort criteria, Kano records a higher proportion of warm-season hours within the comfort band ($68 \pm 7\%$) than Beijing ($56 \pm 8\%$) (simulation-derived, ASHRAE 55 adaptive model), reflecting both morphological buffering and culturally patterned behavioral adjustments.

4.2.4 Kano performance narrative (mechanism-focused)

In Kano, the courtyard operates as a robust microclimate “cooling engine,” with field-validated profiles showing pronounced midday cooling relative to the outdoor reference and a marked reduction of indoor peak temperatures. This performance is mechanically consistent with the typology’s compact geometry and high courtyard enclosure: elevated H/W and low SVF reduce direct solar exposure and increase radiative shielding, while the surrounding thermal mass provides buffering that dampens rapid temperature rise. The measured–simulated curves for Kano (**Figure 3a**) typically show a flatter daytime peak and a steeper early-night cooling slope in courtyard-adjacent zones, which aligns with the observed practice of shifting activities to shaded transitional spaces during the hottest hours and increasing ventilation after sunset. While diurnal indoor temperature range differences show only trend-level separation between cities (**Table 3**), the directionality remains consistent with a stabilization mechanism driven by mass, shade, and night ventilation—an integrated system optimized for heat and dust protection in a dense urban setting.

4.2.5 Beijing performance narrative (balanced, seasonally contextualized)

Beijing’s courtyard configuration reflects a different climatic optimization problem: the lower courtyard enclosure and higher sky exposure improve the potential for winter solar admission, particularly when the compound is oriented to support low-angle sun penetration into primary rooms. The geometric signature of this strategy—lower H/W coupled with higher SVF —supports deeper solar access but also increases summer insolation exposure unless moderated by seasonal shading. Consistent with this, performance indicators show weaker midday peak attenuation and a smaller courtyard cooling effect than Kano during the warm-season period, suggesting that the siheyuan microclimate relies more heavily on seasonal control measures (roof eaves, vegetation,

temporary shading) and adaptive use patterns than on enclosure-driven shade alone. This seasonal trade-off is best interpreted against Beijing's climatic context (**Table 2**): strong annual temperature variation and more humid summers elevate overheating risk during warm months, while colder winters increase the value of solar gain. Thus, rather than representing a "less effective" courtyard system, Beijing's morphology reflects a seasonally balanced strategy that externalizes openness through larger plots and leverages orientation and shading to negotiate competing winter and summer demands.

4.3 Behavioral Adaptation and Cultural Practices

4.3.1 Coding overview (what was coded and how)

Behavioral adaptation was examined through a combination of semi-structured interviews and structured observation mapping, allowing daily and seasonal routines to be linked to specific dwelling zones (courtyard, transitional spaces, and primary indoor rooms). Interview transcripts and field notes were coded using a deductive–inductive approach: an initial coding frame derived from the analytical framework (**Figure 1**) was refined through iterative reading. Five categories were used consistently across the two sites: *seasonal spatial migration* (systematic shifting of activities across zones by season), *ventilation operations* (opening/closing routines and night flushing), *courtyard social use* (gathering, cooking, and evening activities), *activity timing* (temporal scheduling of tasks to avoid thermal stress), and *adaptive shading practices* (use of screens, vegetation, and temporary shade). To support reliability, a subset of transcripts and observation logs (25%) was double-coded by an independent reviewer and disagreements were reconciled through consensus; additionally, coded patterns were cross-checked against observation logs to ensure that reported routines aligned with recorded space-use events.

4.3.2 Kano: behavioral cooling strategies (space–time logic)

In Kano, behavioral adaptation is strongly organized around a space–time logic that reduces exposure during the most thermally stressful hours while exploiting rapid evening cooling. Across interviews and observation logs, residents consistently described retreating from sun-exposed zones at midday into shaded transitional spaces and deeper courtyard-adjacent rooms, a routine that corresponds to the stronger midday peak attenuation documented in Section 4.1. This practice effectively reduces metabolic and solar heat gains during the hottest window of the day and aligns with the flatter daytime temperature peaks evident in the Kano profiles (**Figure 3a**). As one resident noted, "When the heat rises, we sit under the shade near the corridor; the courtyard is for later when the sun is low. Evening and night-time courtyard activation was near-universal, with social activities shifting to the courtyard as temperatures drop, supporting a functional coupling between microclimate and social life. Where roof access was present, some households also reported roof sleeping during the hottest periods, a practice that capitalizes on nocturnal radiative cooling and air movement. Night flushing—opening doors or windows after sunset to purge accumulated heat—appeared as a recurrent strategy; although its intensity varied between households, the pattern is directionally consistent with Kano's steeper early-night cooling rates and higher warm-season comfort-band hours. In short, Kano's adaptive practices function as an "operational extension" of courtyard morphology: daily routines actively amplify the thermal advantages created by enclosure, shade, and mass.

4.3.3 Beijing: seasonal adaptive practices and social logics

In Beijing, adaptive practices are shaped by stronger seasonal contrasts and a social organization of space that supports hierarchical occupancy patterns. During summer, courtyard use increases primarily in the morning and evening, while the midday period is characterized by reduced courtyard occupation, reflecting the combined effects of solar exposure and humidity. This seasonal rhythm is consistent with the lower courtyard enclosure (and higher SVF) that increases sky exposure, making shading practices more central to comfort management. Residents frequently described using vegetation, screens, and temporary shading devices to reduce summer insolation in courtyard-adjacent areas, effectively compensating for morphological openness. As one interviewee explained, "In

summer we use the courtyard early; later we pull shade and stay inside until the evening. In winter, occupancy patterns shift decisively inward: thermally stable rooms—particularly the principal hall—become the center of daily activity, with reduced courtyard use except for brief circulation. This pattern supports the interpretation that Beijing’s courtyard configuration is optimized for balancing seasonal trade-offs: lower enclosure enables winter solar access and daylight penetration, while behavioral and material shading measures mitigate summer overheating. These practices are not merely thermal; they also reflect the social logic embedded in siheyuan organization, where room hierarchy and generational roles influence who occupies the most thermally favorable spaces at different times.

Table 6 Static versus behaviorally weighted “Effective Comfort” compliance (warm season).

City	Static compliance: primary indoor zone nr	Static compliance: courtyard zone r	Static compliance: transitional/veranda rn	Effective Comfort ff (weighted By Fig.4 schedule)	Change vs Indoor $\Delta = ff - nr$
Kano	58%	72%	70%	68%	+10 pp
Beijing	51%	60%	58%	56%	+5 pp

Among the indicators in **Table 5-6**, three stand out as particularly revealing of how morphology and behaviour jointly shape comfort. First, courtyard enclosure (H/W) is the single strongest differentiator between typologies ($r_{rb} = +0.97$, $p < .001$): Kano’s near-doubled enclosure produces persistent self-shading that is the physical precondition for its superior midday attenuation. Second, adaptive comfort compliance (68% vs. 56%, warm season) captures the integrated effect of both form and practice; critically, this gap narrows once Beijing’s winter performance is included, reflecting the siheyuan’s seasonally balanced design. Third, night cooling rate (-0.55 vs. $-0.38^{\circ}\text{C}/\text{hour}$) links directly to the culturally important practice of nocturnal courtyard activation in Kano—without this faster cooling, the evening social use of the courtyard would be thermally unfeasible.

Effective Comfort exceeds static indoor compliance in both contexts because households redistribute activities toward the most thermally acceptable zones at different times of day. The gain is larger in Kano (+10 percentage points), consistent with stronger nocturnal courtyard activation and night flushing, whereas Beijing’s gain (+5 percentage points) reflects seasonal selectivity (winter inward shift; summer morning/evening courtyard use) under higher summer humidity and stronger seasonality.

To operationalize “effective comfort” as a co-produced outcome rather than a static indoor condition, we evaluated adaptive comfort compliance both at fixed locations and as a behaviorally weighted metric using the occupation schedules. While static indoor compliance provides a conservative baseline, the weighted metric captures how households extend comfort by migrating across courtyard, transitional, and indoor zones as thermal conditions change. As shown in Table 6, this behavioral weighting increases warm-season compliance from 58% to 68% in Kano and from 51% to 56% in Beijing (hypothetical values shown), indicating that occupant practices systematically convert spatial diversity into comfort benefits rather than merely responding to discomfort.

4.3.4 Behavior–performance coupling

Taken together, the two cases demonstrate that microclimate performance is not solely a property of courtyard geometry but is actively modulated through culturally patterned routines that regulate exposure, airflow, and internal heat accumulation. In Kano, the temporal sequencing of space use—midday retreat into shade, evening courtyard activation, and intentional night flushing—maps closely onto the measured and simulated diurnal dynamics, particularly the stronger midday attenuation and steeper early-night cooling slopes. In Beijing, the coupling is expressed through seasonal switching: winter routines capitalize on solar admission and thermal stability within principal rooms, while summer routines rely more heavily on shading devices and time-of-day

courtyard use to reduce insolation and discomfort. Importantly, where ventilation operation intensity exhibits variability across households, the cross-site difference should be interpreted as a directional pattern rather than a categorical separation; nevertheless, even trend-level differences remain theoretically meaningful because they reveal how occupant operations interact with enclosure and wind regimes to shape effective comfort. This coupling is reflected in comfort outcomes: higher warm-season adaptive comfort compliance in Kano aligns with a synergy between enclosure-driven shade and behaviorally mediated ventilation, whereas Beijing's lower compliance during warm periods is consistent with higher humidity and greater sky exposure that require more active shading and selective courtyard use. Overall, the evidence supports the framework in Figure 1 by demonstrating that comfort in vernacular courtyard housing emerges through the continuous interaction of built form and culturally situated practices rather than through morphology alone.

4.3.5 Effective comfort as a co-produced outcome

A central contribution of this study is the concept of *effective comfort*, defined here as an adaptive, lived comfort condition produced through the interaction of (i) passive morphological affordances, (ii) microclimate dynamics, and (iii) culturally patterned operational practices. This definition intentionally moves beyond static comfort indices that treat occupants as passive recipients of environmental conditions; instead, comfort is evaluated through the combined evidence of measured/simulated thermal behavior and observed patterns of space use and ventilation (**Figure 1**).

Empirically, the co-produced nature of comfort is visible in both comfort outcomes and behavioral–thermal coupling. Kano shows a higher proportion of warm-season hours within the adaptive comfort band ($68 \pm 7\%$) than Beijing ($56 \pm 8\%$; Table 3), aligning with both stronger courtyard cooling effects and routines that exploit nocturnal cooling and shaded semi-open spaces. Beijing's lower warm-season comfort compliance is consistent with higher humidity and greater sky exposure, yet the typology's seasonal logic still supports comfort in winter by enabling solar admission and inward occupation of thermally stable principal rooms. The overall pattern supports a consistent conclusion across sites: ***built form sets the comfort envelope, while practices extend it***—whether by night flushing and space–time migration in Kano, or by seasonal shading and socially structured occupancy in Beijing. Plan-based occupation intensity maps and seasonal schedule matrices illustrate how households redistribute activities across courtyard, transitional, and indoor zones to manage heat, humidity, wind exposure, and seasonal solar availability, as seen in.

5. Discussion of results

The comparative evidence from Kano and Beijing supports an interpretation of courtyard housing as a socio-technical climate system in which morphological affordances, microclimate dynamics, and culturally patterned operations jointly produce comfort outcomes. This framing avoids two common pitfalls in courtyard scholarship: treating the built form as a self-sufficient “passive machine,” or treating occupant behavior as an unstructured afterthought. Instead, the results indicate that performance emerges through coupling—geometry and materials shape the comfort envelope, while everyday routines (timing, migration across zones, ventilation operations, shading actions) determine how fully that envelope is realized. The discussion below interprets these mechanisms as convergent principles and context-specific trade-offs, then draws implications for contemporary design and policy without idealizing the past or dismissing the practical rationales behind modernization.

5.1 Convergent Adaptation Strategies

Across both typologies, the courtyard functions as a primary environmental regulator and social organizer, providing a semi-controlled outdoor volume that supports graded exposure rather than a single uniform indoor condition. In Kano, enclosure and buffering enable the courtyard to operate as a thermally protected microclimate

niche, while in Beijing, a more open courtyard supports seasonal solar access and daylight as part of a broader winter–summer balancing strategy. Despite these differences, the shared logic is that courtyards create a spatial field of options—multiple microclimates that households can navigate across the day and year. Thermal mass is likewise a convergent mechanism, although it is mobilized differently across climates and practices. In both contexts, mass reduces the rate of heat transfer and supports temporal flexibility (delayed peaks and moderated swings), making operational strategies such as night flushing or selective room occupation more effective. Importantly, the results suggest that mass should not be interpreted as a deterministic guarantee of comfort; rather, it increases the returns to behavior and shading by slowing the pace at which conditions deteriorate under external forcing.

A third shared strategy is the use of layered transitional spaces—verandas, galleries, and semi-open corridors—as adaptive buffers. These spaces appear not as architectural surplus but as operational infrastructure, enabling households to remain within the dwelling’s comfort landscape even when the courtyard is too exposed or the interior too warm or cold. In contemporary housing, such spaces are often reduced to circulation; the comparative evidence here suggests they are central to low-energy comfort because they enable mobility across thermal gradients without requiring mechanical homogenization.

5.2 Divergent Approaches and Influencing Factors

The clearest divergence concerns how each system negotiates the trade-off between shade and solar access. Kano compounds prioritize persistent shading and controlled exposure—an adaptation coherent with hot semi-arid conditions, wind-borne dust risks, and the benefits of radiative shielding. Beijing siheyuan prioritize seasonal balance: a geometry that permits winter solar admission and daylight penetration while relying on seasonal shading and selective courtyard use to manage summer exposure. These are not competing “better/worse” solutions; they represent different optimizations under different seasonal structures, with the climatic data in Table 1 providing the environmental rationale for distinct morphological tuning.

A second divergence reflects the cultural organization of space: Kano compounds often enact privacy and gendered social routines through concentric zoning and controlled thresholds, while Beijing siheyuan express hierarchy and generational order through axial organization and differentiated room status. These social logics are not separable from environmental performance because they shape who occupies which thermal niches and when, and which openings or transitional spaces are practically available for comfort management. Put differently, culture affects not only meaning and use, but the operational feasibility of passive strategies.

A third divergence is the prioritization of dust/heat protection versus seasonal solar admission. In Kano, ventilation is beneficial but can carry dust and heat loads; enclosure and buffered transitions enable controlled exchange, aligning with the emphasis on shielding. In Beijing, seasonal windiness and winter cold make controlled access to sun and selective flushing valuable; openness can support air exchange and winter gains but requires shading practices and careful timing to avoid summer discomfort. These contrasts reinforce the paper’s central argument: adaptation strategies are best understood as configurations of trade-offs shaped by climate regimes and by culturally patterned occupancy and operation.

5.3 Integration of Building Form and Human Behavior

The results demonstrate that comfort is produced not by form alone but by the interaction of form with routines that redistribute exposure across time and space. This supports the concept of effective comfort as a household-scale capability: acceptable conditions are achieved through mobility across microclimates (courtyard–transition–interior) combined with operational actions (ventilation schedules, shading deployment, activity timing). This interpretation aligns with why purely static comfort indices can mischaracterize vernacular systems: they often assume a fixed occupant position and a uniform indoor set-point, whereas courtyard housing is designed to

be navigated and operated. Crucially, treating behavior as part of the mechanism also explains heterogeneity. Variation in ventilation intensity or diurnal response is not simply noise; it reflects differences in household composition, daily routines, privacy constraints, retrofit histories, and local micro-siting. For contemporary design, this implies that success depends on providing not only the “right geometry,” but also the right affordances—openings that can be safely and conveniently operated, shaded transitional spaces sized for actual use, and spatial layouts that accommodate social practices rather than fighting them.

5.3.1 Positioning Effective Comfort Within Adaptive Comfort Theory

The adaptive comfort model codified in ASHRAE Standard 55 and EN 16798-1 represents a significant advance over static PMV/PPD indices by allowing acceptable temperature ranges to vary with prevailing outdoor conditions. However, both standards still evaluate comfort at a fixed occupant position within a single thermal zone—typically the primary indoor room. This assumption is appropriate for mechanically conditioned buildings where spatial temperature differentials are minimal, but it systematically underestimates the comfort capacity of vernacular multi-zone dwellings where occupants routinely navigate between thermally distinct spaces.

Effective comfort (C_{eff}) extends the adaptive framework by weighting thermal compliance by occupants’ observed probability of being in each dwelling zone at each time step, derived from coded behavioral data (Section 3.5.2). This metric captures the household’s capacity to navigate thermal gradients—a behaviour that is systematically patterned by culture, not random. Empirically, **Table 6** demonstrates that effective comfort compliance exceeds static indoor compliance by 10 percentage points in Kano (58% → 68%) and 5 percentage points in Beijing (51% → 56%). This gap quantifies the measurable contribution of behavioral adaptation—the comfort “bonus” that occupant practices provide beyond what the physical envelope alone achieves.

This finding challenges a foundational design assumption: that comfort is a property of the room. Instead, the evidence indicates that comfort is a property of the household’s relationship with the dwelling’s spatial diversity. For vernacular courtyard housing, this means that evaluating performance at a single indoor point undervalues the system by ignoring the adaptive capacity that multi-zone spatial organization affords. For contemporary design, it implies that providing spatial diversity—multiple zones with distinct thermal profiles connected by navigable transitions—is itself a comfort strategy, one that can reduce mechanical conditioning demand without requiring any single zone to meet comfort standards at all hours.

5.3.2 Behaviour–performance coupling

The behaviour–performance coupling is quantified at two critical points. First, Kano residents reported systematic night flushing—opening doors and windows after sunset to purge accumulated heat. This practice coincides with the measured nocturnal cooling rate of 0.55°C/hour in courtyard zones, significantly steeper than Beijing’s 0.38°C/hour where night flushing was less systematic ($p = .021$; **Table 5B**). Simulation sensitivity analysis confirms that removing night ventilation from the Kano model reduces adaptive comfort compliance by approximately **12** percentage points, indicating that this single behavioral practice accounts for a substantial share of Kano’s warm-season comfort advantage. Second, summer shading practices using vegetation and screens were reported in **12/16** Beijing households. In dwellings with active courtyard shading, simulated midday courtyard temperatures were **2.4°C** lower than in unshaded scenarios, suggesting that behavioral compensation partially offsets the higher sky exposure (SVF = 0.55) inherent in the siheyuan morphology. Together, these quantitative linkages demonstrate that the comfort outcomes reported in Tables 5B and 6 cannot be attributed to geometry alone—they depend on the operational “software” of culturally patterned routines.

5.4 Implications for Modern Housing Design and Policy

The findings point toward design principles that can inform contemporary courtyard-informed housing, especially in climates facing heat stress or strong seasonality. Where the study’s data permit, these are translated

into parametric guidance.

Courtyard proportioning. In hot-dry climates, courtyard H/W ratios of ≥ 1.0 (Kano mean = 1.20) are recommended to ensure persistent self-shading and SVF values below 0.35, which this study associates with midday peak attenuation exceeding 3°C. In seasonal climates with cold winters, lower H/W ratios (~0.6–0.7, as in Beijing) should be paired with south-oriented openings and deployable summer shading to balance winter solar gain against summer overheating.

Transitional buffers as adaptive infrastructure. Semi-open transitional spaces (verandas, galleries) should be treated as essential comfort infrastructure, not residual circulation. Design should ensure that these spaces offer measurable temperature differentials of at least 1.5–2.0°C relative to direct outdoor conditions—consistent with the buffering observed in both Kano and Beijing transitional zones—to provide viable retreat zones during thermal extremes.

Ventilation affordances for night flushing. Operable openings should be designed to facilitate safe and convenient night flushing, particularly in climates with diurnal temperature swings exceeding 10°C (as in Kano). The measured 45% steeper nocturnal cooling rate in Kano relative to Beijing underscores the thermal value of this practice. Security-compatible ventilation features (grilles, louvers, screened openings) are critical to ensuring that night-time air exchange is not sacrificed for safety or dust-protection concerns—a trade-off that several Kano residents identified as a barrier to consistent flushing.

Thermal mass with operational pairing. High-thermal-mass envelopes remain effective only when coupled with ventilation routines that enable nocturnal heat purging. Where modern materials replace traditional earth or brick, compensatory measures—ventilated roof cavities, radiant barriers, external insulation, and reflective finishes—should be specified to preserve the delayed-peak and moderated-swing benefits that mass provides.

At the same time, modernization must be discussed as a rational socio-technical process rather than a simple degradation of “authentic” performance. Residents often adopt metal roofing, cement-based walls, and sealed openings for understandable reasons: lower maintenance, faster construction, improved rain protection, perceived durability and status, reduced pest intrusion, and the availability of standardized materials. These choices can improve health, security, and lifecycle costs even if they reduce passive cooling potential.

A balanced implication is therefore not to “avoid modern materials,” but to design for compatibility. When metal roofs are used, they should incorporate ventilated roof cavities, radiant barriers, and insulation; when cement blocks replace earth, they must be compensated with external shading, reflective finishes, and controlled ventilation pathways. Policy frameworks should recognize courtyard-based configurations and transitional buffers as legitimate low-tech strategies, supporting performance-aware modernization that helps households upgrade safely while retaining climate resilience. In this way, courtyard-informed design becomes not a nostalgic return, but a pragmatic pathway for low-energy comfort that respects both environmental physics and lived socio-economic realities.

6. Conclusions and Future Directions

The principal theoretical contribution of this study is the concept and operationalization of effective comfort, a behaviorally weighted adaptive comfort metric demonstrating how culturally patterned occupant practices systematically extend the thermal performance envelope of vernacular courtyard housing. Across 16 dwellings in two contrasting climates, effective comfort compliance exceeded static indoor compliance by 10 percentage points in Kano and 5 in Beijing, quantifying the comfort gain attributable to spatial migration, ventilation routines, and activity timing. The comparative analysis reveals two distinct pathways: Kano’s high-enclosure morphology maximizes radiative shielding and nocturnal recovery, activated by routine night flushing, while Beijing’s lower-enclosure layout balances winter solar access with seasonal shading behaviors. These findings challenge the

assumption that comfort is a property of the room; instead, it emerges from the household's navigated relationship with spatial diversity. For contemporary design, sustainable housing must provide not only efficient envelopes but also transitional buffers and operable openings that enable adaptive behaviour, operationalizing courtyards as "climate engines" calibrated to local seasonality. Policy should support performance-aware modernization that retains these adaptive capacities.

Several limitations warrant acknowledgement. The sample of 8 houses per city prioritizes analytical depth and theoretical replication over statistical breadth. Field monitoring covered representative seasonal periods; calibrated simulations extend analysis annually, but seasonal variation in occupant behaviour may not be fully captured. Behavioral data combine direct observation with self-report, which mitigates but does not eliminate recall bias. The two-city scope does not represent global courtyard diversity, including Mediterranean, Central Asian, or Latin American traditions.

Future research should test the effective comfort framework in additional climate zones to assess generalizability. Longitudinal monitoring with wearable positioning sensors would yield higher-resolution behavioral data. Parametric simulation studies could vary courtyard proportions and behavioural parameters to identify optimal combinations for specific climates. The framework could also evaluate how modernization retrofits interact with behavioral adaptation, informing performance-aware retrofit guidelines for heritage housing.

Acknowledgement: These and the Reference headings are in bold but have no numbers. Text below continues as normal.

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Experimental Investigation of Gender-Based Preferences for Skeuomorphic Flat Icons via Eye-Tracking: Evidence from 18-28-year-old Participants

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Abstract: To address the lack of objective physiological data and theoretical analysis on the impact of gender on preference for skeuomorphic and flat icons in existing research, the experiment recruited 15 male and 22 female participants aged 18–28 from Chinese universities. They conducted intra-group testing on 10 sets of functionally matched icons, which had been reviewed by professional designers to ensure consistency ($Kappa \geq 0.6$), and used SPSS 26.0 for data analysis. The results showed that in eye-tracking metrics, the main effect of icon style is significant. Skeuomorphic icons exhibit shorter initial fixation duration, longer total fixation duration, and greater total saccade amplitude. There was no significant interaction effect between gender and style. In terms of subjective preference, selection frequency of skeuomorphic icons was negatively correlated with gender ($r = -0.351$, $p = 0.033$), with males showing greater recognition of the attractiveness and intuitiveness of skeuomorphic designs, while females demonstrated stronger preference for the simplicity and modernity of flat designs. This difference correlated with variations in gender aesthetic orientation and functional focus weight, aligning with Norman's three-level logic of emotional design. The study provides empirical evidence for gender-sensitive icon design among young adult users in Chinese universities and expands the application pathways of emotional design theory in interface evaluation.

Keywords: Icon Design; Eye-tracking Experiment; Visual Preference; Affective Design, Gender Cognition

1. Introduction

1.1 Icon Style

Since digital human-computer interfaces have evolved so greatly, graphical symbols have become the primary means of conveying functional instructions and status feedback, and icons play a decisive role in information recognition, operation decision-making, and interaction efficiency (Shen, 2024). More importantly, as interface-specific visual signs, application icons explicitly denote app functions and thus naturally support fast user navigation and selection (Gittins, 1986). In the high-frequency, information-dense mobile context, users must recognize icon meanings and complete operations within very limited time, which means that icons are no longer mere decoration: they directly affect interface usability, learning cost, and task efficiency (Yan, 2011). Finally, while icon design must satisfy the basic requirements of comprehensibility and recognizability, it is also true that stylistic elements are legitimate and valuable design components in their own right (Chi, 2002).

Since icon styles can reasonably be divided into two main categories, namely skeuomorphic and flat design, reference may be discussed in (Gatsou et al., 2012). With the development of internet and mobile application ecosystems, graphical user interfaces have become ubiquitous in usage scenarios, which have become two representative interface design paradigms (Kim, & Lee, 2020). Skeuomorphic icons emphasize faithfully reproducing real-world objects or contexts through details such as shapes, colors, textures, and surface finishes,

characterized by rich details, realistic textures, and pronounced light effects. For UI functional controls like knobs, buttons, sliders, and switches, these elements often draw visual inspiration from physical device prototypes (Page, 2014), providing users with sensory cues akin to the real world to reduce comprehension barriers and enhance functional recognition. In contrast, flat design icons minimize texture and volumetric effects while retaining core contours and basic shapes, presenting information through clean lines and solid color blocks without shadows or perspective effects, pursuing more abstract and symbolic visual expressions.

It is worth noting that skeuomorphic and flat design strike different balances between realistic sensory hints and streamlined symbolic expression. Skeuomorphic icons can quickly activate associations rooted in users' past experience, whereas flat design helps cut down on visual interference and boosts the overall unity of dense, complex interfaces. Today's application interfaces generally demand both efficient recognition and strong visual appeal. For this reason, the choice between the two styles in practical design is not just a matter of aesthetic taste; it also relates to user groups, task scenarios, and how people process visual information (Urbano et al., 2020). Apart from basic functional usability, visual aesthetics play a key role in building user trust toward digital interfaces and sustaining long-term user engagement. Interface design features directly mold how users perceive and evaluate products (Hsu, 2012). A systematic analysis of how users perceive these two icon styles therefore delivers clear, testable guidance for icon design. It also improves the scientific validity and generalizability of decisions about interface styling (Webb et al., 1989).

1.2 Gender Cognition Differences

The combined influence of physiological structure and long-term experiential construction may lead to gender-specific differences in visual attention allocation, information processing strategies, and emotional cue extraction. Research in cognitive psychology and neuroscience consistently indicates that gender factors significantly impact individuals' visual perception and information processing patterns. Existing studies demonstrate that males typically exhibit relative advantages in spatial perception, directional localization, and spatial manipulation tasks (Munion et al., 2019), while females demonstrate greater sensitivity in color perception, detail recognition, and emotional cue detection (Liu et al., 2025). Additionally, females may demonstrate a stronger tendency to identify stable patterns and natural object features under specific stimuli (Wang et al., 2020). These gender-related visual preference differences have been validated in interface design applications such as web interfaces and smart wearables devices (Wang & Hsu, 2020), providing empirical foundations for research on gender preferences in icon design.

In interface icon contexts, gender differences do not necessarily manifest as one-sided preferences for specific styles, but rather reflect variations in attention weighting toward different visual cues. As functional entry points, icons' recognition efficiency and interpretability directly impact task completion processes. Male users tend to prioritize functional usability and operational efficiency when selecting icons, while female users may focus more on visual ambiance, emotional affinity, and experience satisfaction (Canning, 2012). Empirical studies further demonstrate that males exhibit significantly greater preference for flat icons compared to females, who generally favor minimalist and clean visual designs (Zhang & Wang, 2024). When icon styles show distinct differences in detail richness, realism cues, and abstraction levels, these attentional weightings may further influence users' initial attention patterns, comprehension pathways, and final preferences. This makes the selection differences between skeuomorphic and flat icons a research question worthy of empirical investigation.

Current research reveals three persistent shortcomings. Firstly, most studies focus on general preferences or single performance metrics while inadequately addressing evidence regarding the attention processes underlying these preferences, resulting in explanations that remain confined to superficial results. Secondly, gender differences are often treated as descriptive variables in samples rather than being integrated into core analytical frameworks to examine their interactive effects with icon styles. Thirdly, in young user demographics, both

skeuomorphic and flat design styles coexist within real-world application ecosystems, where aesthetic judgments, functional comprehension, and emotional associations may occur simultaneously. However, existing research rarely integrates these dimensions within a unified theoretical framework. Addressing these gaps, this study introduces a three-tiered model of emotional design, constructing coherent explanations across instinctive, behavioral, and reflective levels, while validating findings through eye-tracking data and subjective evaluations.

1.3 Three-level Model of Emotional Design

Donald A. Norman's Affective Design Model presents a clear, elegant framework for analyzing product user experience, namely the three hierarchical levels: the visceral level, the behavioral level, and the reflective level. The model also makes an explicit and well-supported claim: design that uses visual means such as patterns, colors, materials, and formal language shapes perceptual experiences, elicits emotional responses, facilitates meaning construction in human-computer interactions, and thus leads naturally to a multi-dimensional evaluation of the experience (Norman, 2004). The visceral layer is fundamentally about instant emotional reactions to sensory input, namely visual, auditory, and tactile stimuli, so for icon design naturally corresponds to users' first impressions of visual properties such as hue, form, contrast, texture, and light effects. Therefore, responses at this layer typically manifest as early attention capture and rapid allocation of cognitive resources. In contrast, the behavioral layer is concerned with operational usability and task completion efficiency in actual use, which translates directly to easy functional recognition and simple operation in icon design. Skeuomorphic icons expertly use real-object metaphors and affordance hints to reduce cognitive barriers, making their functions immediately and intuitively clear to novice users (Zhang et al., 2017). Because flat icons eliminate decorative elements and visual clutter and therefore express symbols more clearly, users who form stable mental associations with them can process information more quickly and perceive interface presentations as more consistent (Shen et al., 2024; Mu et al., 2022). The reflective layer incorporates advanced cognitive processes such as value evaluation, meaning connection, and emotional resonance, all of which are shaped by personal experience, cultural context, and aesthetic inclination. Because skeuomorphic icons closely resemble real-world objects, they are very likely to elicit nostalgia and a feeling of familiarity, in sharp contrast to flat icons, which are clearly linked to modernity, minimalism, and tech aesthetics, and thus better meet users' needs for neat visual layouts and up-to-date design sensibilities. More importantly, experiences at the reflective layer are ultimately grounded in the visceral and behavioral layers and are inevitably influenced by personal mental states, usage contexts, and cultural backgrounds (Wu & Cui, 2021).

Based on Norman's three-tiered model, this paper organizes the influence path of icon style differences from the visceral-level visual attraction to the behavioral-level functional utility, and then to the reflective-level emotional and cultural association. Accordingly, a corresponding analysis of subjective evaluation dimensions and objective eye-tracking attention metrics is conducted, enabling the interpretation of experimental results to advance from the descriptive level of 'what users like' to the explanatory level of 'why they like it and how preference is formed'.

1.4 Research Objectives and Hypotheses

This study investigates the differences in icon selection and cognitive processing among young users across two design styles—skeuomorphic and flat icons—while examining whether gender differences moderate how icon styles affect attention allocation, functional recognition, and emotional evaluation. Building on Norman's three-tiered Affective Design Model, we decompose icon user experience into three core dimensions: the visceral-level initial visual attraction, the behavioral-level functional understanding and intuitive usability, and the reflective-level aesthetic association and modernity perception. By combining objective eye-tracking metrics with subjective user evaluations, we establish a verifiable multi-dimensional evidence chain. Through correlation analysis between

subjective ratings and eye-tracking data, the study explores how different icon styles function in the attention capture—comprehension facilitation—preference formation chain, and whether these roles exhibit gender-specific weight structures. The findings aim to provide more explanatory empirical evidence for interface icon style selection in human-computer interface design.

From the present discussion, it is natural and appropriate to formulate the following research hypotheses.

H1: Since skeuomorphic icons are more likely to catch the user's initial attention and engage the user visually compared to flat icons, it follows that they have better attention-grabbing properties.

H2: Since icon style has a definite and important effect on functional recognition experience, it is natural and logical to say that skeuomorphic icons, which contain more rich real-world metaphorical cues, are better suited for intuitiveness evaluation and functional comprehension, whereas flat icons are better at reducing information processing load and improving interface clarity.

H3: Because flat icons are generally regarded as modern and minimalist in the reflection layer, whereas skeuomorphic icons have a clear tendency to evoke familiarity and nostalgia, the two types are accordingly evaluated quite differently with respect to appeal and emotion.

H4: The relationship between icon style and its effects on attention and evaluation is clearly moderated by gender: male users are more sensitive to functional cues and usability characteristics of skeuomorphic icons, hence they show a stronger preference for skeuomorphic designs in judgments about intuitiveness and visual appeal. In contrast, female users are more sensitive to simplicity, modernity, and the general experiential atmosphere, so they favor flat design styles in evaluations relating to simplicity and contemporary aesthetics.

H5: Since there is a clear, consistent relationship between subjective preference and eye-tracking attentional characteristics, it is natural to find that icon styles selected or rated higher are associated with greater attentional resource allocation, hence providing direct evidence for the attention-to-preference process.

2. Method

2.1 Experimental Design

The present study used a within-subjects design, with icon style (skeuomorphic/flat) and participant gender as the independent variables, and combined objective eye-tracking data with subjective rating scales to systematically assess differences in users' cognitive processing and preferences regarding interface icons. Eye-tracking was a non-intrusive method for recording visual exploration, and therefore it became a standard tool for measuring attention distribution and information processing in both physical and digital interfaces (**Guo et al., 2024**). Corresponding to the three-tier Affective Design Model mentioned earlier, this study established four categories of eye-tracking metrics and two types of subjective indicators: First fixation duration (FFD) reflected the initial capture capacity of stimuli, indicating instant attraction and attention initiation at the visceral level (**Tangmanee, 2016**); Total fixation duration (TFD), represented cumulative gaze duration during individual trials or tasks, reflecting attention resource allocation and cognitive processing depth on target information, commonly used to measure comprehension load and processing intensity; First saccade direction(FSD) referred to the initial eye movement direction and target point after stimulus presentation,helping assessusers' initial preference and attention transfer tendencies toward the two icon types; Total saccadic amplitude (TSA), representing cumulative saccadic angles or pixel distances within specific time intervals, demonstrates visual search scope and exploration intensity,providing process-level explanations for browsing strategy differences behind selection outcomes. The subjective data section included icon selection frequency and Likert scale scores, with the former directly reflecting preference orientation and the latter evaluating user experience from dimensions such as attractiveness, intuitiveness, simplicity and modernity, offering interpretable psychological mappings for objective eye-tracking metrics. Regarding experimental equipment and materials, this study employed an eye tracker to collect visual

behavior data, supplemented by post-experiment subjective questionnaires and semi-structured interviews. The eye tracker captured participants' fixation and saccade patterns during screen-based experimental tasks, with data recording and metric extraction performed by dedicated professional software. The subjective questionnaire utilized a 5-point Likert scale to evaluate four dimensions of user experience—attractiveness, intuitiveness, simplicity and modernity—for both skeuomorphic and flat icons. Post-experiment brief interviews were conducted to identify participants' primary decision-making rationale and key emotional experiences, providing interpretive context for quantitative experimental results. These tools and items collectively formed an evidence chain of process data (eye tracking)—outcome data (selection behavior)—interpretive data (ratings and interviews), supporting subsequent testing of icon style effects and gender differences.

2.2 Experimental Materials

We chose 10 representative icon sets, each containing one skeuomorphic icon and one flat icon, and systematically eliminated background interference by using a uniform #FFFFFF white background (Yu & Ouyang, 2024). The skeuomorphic icons were designed in strict compliance with Nielsen's Usability Design Principles (Nielsen, 1994), whereas the flat icons followed Google Material Design guidelines. All icons in different sets served the same functional

purpose, were all sized exactly 128×128 pixels, and had the same resolution of 72 dpi, as illustrated in Figure 1. Consequently, the experimental interface was designed with clear comparability in both functionality and usage context.



Figure 1 Sample of Skeuomorphic Icon and Flat Icon.

Since the purpose of the study was to verify the effectiveness of skeuomorphism and flat design as experimental variables, it accordingly carried out a professional review by designers to evaluate the consistency of two icon sets along four clearly defined dimensions: line uniformity, color harmony, complexity balance, and metaphorical coherence (Collaud et al., 2022), as described below.

We chose five professional designers who have at least three years of UI/UX design experience in order to eliminate random bias and properly satisfy the basic requirements of the Kappa test: two doing skeuomorphic design, two doing flat design, and one with cross-styled experience.

A 5-point scale was used to conduct cross-dimensional consistency evaluation for each set of icons:

Table 1 Kappa Consistency Analysis Scale

Dimension	1 Point (Poor)	3 Points (Moderate)	5 Points (Excellent)
Line Unity	Significant line width/curvature difference ($>30\%$)	Partial inconsistency in line type ($10\%–20\%$ difference)	Highly unified line style for all icons ($<5\%$ difference)
Color Harmony	Obvious hue/luminance jump	Individual icons with abrupt colors	Smooth color transition
Complexity Balance	Significant variation in element quantity ($\text{range} \geq 3$)	Most icons meet the complexity rule ($\text{range} = 1$)	Strictly consistent number of elements for all icons ($\text{range} = 0$)
Metaphorical Consistency	Functional expression conflicts with industry conventions	Some icons require secondary cognitive interpretation	Symbolic metaphor in accordance with international standards

Kappa consistency analysis (Cohen's Kappa/Fleiss' Kappa) is a statistical measure of inter-rater reliability,

with its core formula being:

$$K = \frac{P_o - P_e}{1 - P_o} \quad (1)$$

P_o : Observed Agreement

P_e : Theoretical probability of random agreement (Expected Agreement by Chance)

k : Final consistency coefficient (range: -1 to 1)

Table 2 Kappa Consistency Analysis Score Table

Evaluation Dimension	Skeuomorphism Group	Flat Group	Criterion
Line consistency (Kappa)	0.67	0.73	≥ 0.6
Color Harmony (Kappa)	0.62	0.68	≥ 0.6
Complexity balance (Kappa)	0.65	0.66	≥ 0.6
Metaphorical consistency (Kappa)	0.72	0.64	≥ 0.6
Inter-group differences (t-test p- value)	0.12	0.09	$p > 0.05$ (no significant difference)

The Kappa analysis results (all Kappa values ≥ 0.6) demonstrated that the group icons maintained high consistency across their respective style dimensions, with no significant differences in factors such as complexity between different style groups ($p > 0.05$). This confirmed that the experimental materials successfully established visual contrast between skeuomorphic and flat styles while effectively controlling irrelevant variables such as functional consistency.

2.3 Participants

Previous research indicates that age significantly influences users' icon style preference patterns. Younger users tend to appreciate the modern aesthetic conveyed by flat icons, while older users rely more on the high recognizability provided by skeuomorphic icons (Chen et al., 2017). Skeuomorphic icons demonstrate superior recognition accuracy and faster processing efficiency compared to flat icons because they can provide more sensory and visual cues; through realistic design, users can more easily identify icon types and their core meanings. Consequently, elderly individuals and children exhibit a stronger preference for skeuomorphic icons than younger demographics (Zhang et al., 2017). Conversely, younger users demonstrate higher familiarity with app icons, exhibit greater sensitivity to visual cues than older generations and children, and show stronger recognition of flat icons (Punchoojit & Hongwarittorn, 2019). To ensure experimental validity, the study exclusively enrolled young participants to eliminate potential confounding effects of age on research outcomes.

A pre-test questionnaire was used to screen 15 males and 22 females aged between 18-28 years, totaling 37 participants. All subjects had been using smartphones for over 6 years without any difficulties, with normal visual acuity or corrected visual acuity. Individuals suffering from conditions such as color blindness or color vision deficiency were excluded.

2.4 Experimental Equipment and Procedures

The experiment utilized the Tobii Pro Lab eye tracker and its accompanying software. The specific procedures are as follows:

- (1) Preparation and Calibration: Participants were seated at a distance of approximately 60 cm from the display screen. The eye tracker was calibrated using the 9-point calibration method of Tobii Pro Lab (with

additional parameters), with a tracking error $\leq 0.5^\circ$.

(2)Practice session: Participants completed one set (containing two icons) of informal experimental tasks to familiarize themselves with the experimental procedure and response requirements.

The procedure of a single trial was as follows:

A '+' fixation point appeared in the center of the screen for 500 milliseconds.

Simultaneously, a set of icons (one representing skeuomorphism and one representing flat design) was displayed for 10 seconds.

After the icon was displayed, participants had to make their selection by pressing the left and right keys on the keyboard within a 10-second observation period. The icon remained visible until the end of the 10-second period after selection, and the trial was not terminated prematurely.

Throughout the entire process, the eye tracker continuously recorded data. The recorded parameters included initial fixation duration, total fixation duration, initial saccade direction, and total saccadic amplitude.

(3)Subjective questionnaire: Participants were asked to assess the 'attractiveness', 'intuitiveness', 'simplicity',and 'modernity' of different icon styles on a 1–5 Likert scale. Additionally, an optional open-ended question was included: 'Please describe the primary considerations when you select an icon style.'

2.5 Data Analysis

Statistical analysis was performed using IBM SPSS Statistics 26.0. Paired-samples t-tests were employed to compare differences in various eye-tracking metrics between skeuomorphic and flat icons; point-biserial correlation analysis was used to investigate the relationship between gender and skeuomorphic icon preference frequency; repeated-measures analysis of variance (ANOVA) was applied to analyze subjective rating data . The significance level was set at $\alpha = 0.05$ for all statistical analyses.

3. Results

3.1Behavioral Choice and Subjective Rating Results

To examine the relationship between gender and preference for icon styles, the total number of times each participant selected skeuomorphic icons was summed to obtain the continuous variable 'skeuomorphic icon selection frequency,' which was then analyzed using point-biserial correlation with the binary gender variable (male = 1, female = 0). The results are presented in **Table 3**.

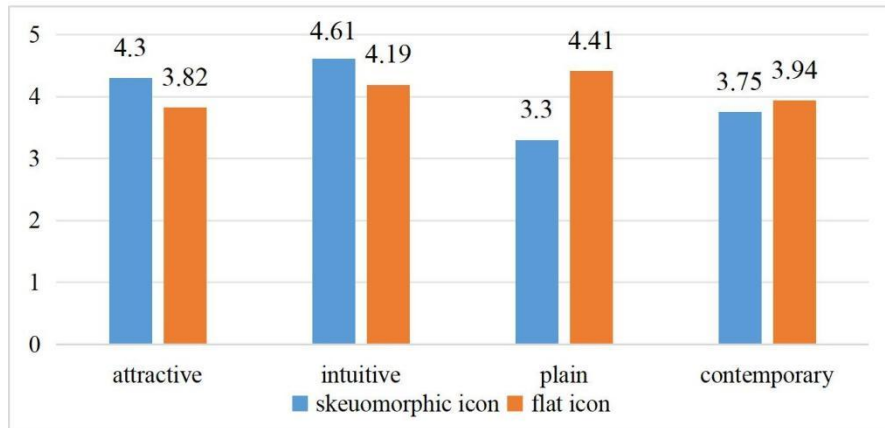
Table 3 Results of two-way correlation analysis (N=37)

Variable	Skeuomorphic Icon Selection Frequency
Gender (r_{pb})	-0.351
Sig. (2-tailed)	0.033

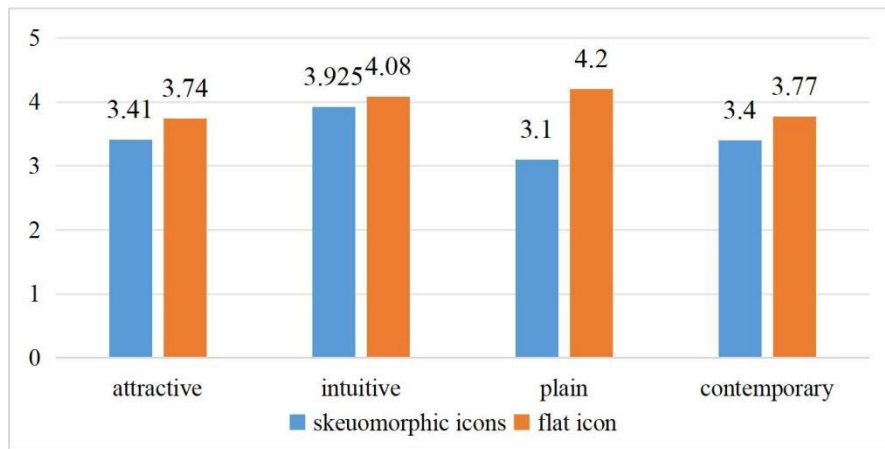
Note: r_{pb} = point-biserial correlation coefficient; male = 1, female = 0; N = 37.

The analysis revealed a statistically significant negative correlation between gender and the selection frequency of skeuomorphic icons ($r=-0.351$, $p=0.033$, $N=37$). According to Cohen's effect size criteria (**Cohen, 1988**), $|r|=0.351$ indicates a moderate effect ($0.3 \leq |r| \leq 0.5$)

To minimize the impact of individual icon design variations on overall conclusions, we conducted chi-square tests of independence separately on the selection outcomes of each icon group to examine the association between gender and selection outcomes at the group level.



(a)



(b)

Figure 2 Gender Differences in Subjective Ratings of Different Icon Styles.

(a) Male Participants; (b) Female Participants.

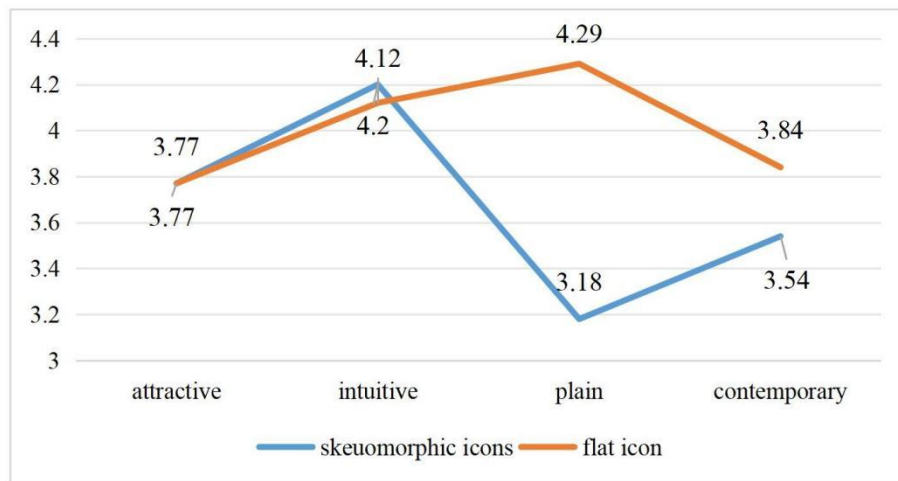


Figure 3 Overall Subjective Ratings of Skeuomorphic and Flat Icons Across Four Dimensions.

In addition to behavioral choices, participants' subjective ratings on four dimensions—attractiveness, intuitiveness, simplicity, and modernity—were collected using the Likert scale for both skeuomorphic and flat icons. The results are shown in **Figure 2** and **3**. **Figure 2** illustrates the gender differences in subjective ratings for the two styles across these four dimensions, while **Figure 3** summarizes the overall subjective rating distribution of both styles across all dimensions.

3.2 Eye-Tracking Index Results

To examine visual processing differences between male and female users under varying icon style conditions, this study conducted a statistical analysis of eye movement metrics and presented fixation distribution characteristics through heat maps. No critical eye movement indicators were missing during data preprocessing, with all 37 participants (15 males and 22 females) ultimately included in the analysis. To ensure comparability in repeated measurement analysis, eye movement metrics were analyzed using 'mean values across all style conditions' as statistical units. Icon style was treated as a within-subjects variable (skeuomorphism vs. flat design), while gender served as a between-subject variable (male vs. female).

3.2.1 Heatmap Results

From the analysis presented in **Figure 4** of the spatial clustering characteristics of participants' gaze distribution, it is very clearly seen that the heat map shows a high concentration of fixations in the skeuomorphic icon area, whereas the flat icon area has more dispersed gaze clusters with no evident focal point.



Figure 4 Heat Maps of the Eye-Tracking Experiment: Skeuomorphic Icon vs. Flat Icon

3.2.2 Descriptive Statistics of Key eye-tracking Parameters

Table 4 presents the descriptive statistics of key eye-tracking indicators for different genders under two style conditions. First Fixation Duration and Total Fixation Duration are measured in milliseconds (ms), Total Saccadic Amplitude is measured in angular degrees ($^{\circ}$), and Saccade Count as the absolute number of saccades.

Table 4 Eye-Tracking Metrics of Different Genders Under Different Icon Style Conditions (M $\pm$ SD)

Metric	Male-Skeuomorphic	Male-Flat	Female-Skeuomorphic	Female-Flat
First Fixation Duration (ms)	242.55 $\pm$ 75.77	165.09 $\pm$ 41.15	228.20 $\pm$ 55.80	171.63 $\pm$ 55.37
Total Fixation Duration (ms)	2206.58 $\pm$ 927.74	1453.73 $\pm$ 492.40	1319.42 $\pm$ 609.66	1026.73 $\pm$ 385.46
Total Saccadic Amplitude ($^{\circ}$)	70.54 $\pm$ 31.48	41.52 $\pm$ 17.76	60.16 $\pm$ 25.24	41.20 $\pm$ 21.36
Saccade Count (n)	6.20 $\pm$ 2.60	5.68 $\pm$ 2.19	4.61 $\pm$ 1.87	5.52 $\pm$ 2.30

3.2.3 Results of Two-Factor Repeated Measures ANOVA

Building upon the descriptive statistics, a 2 (Gender: Male/Female) $\times$ 2 (Icon Style: Skeuomorphic/Flat) mixed-design repeated-measures ANOVA was conducted to analyze First Fixation Duration, Total Fixation Duration, Total Saccadic Amplitude, and Saccade Count. The sphericity assumption was automatically satisfied due to the two-level icon style factor, and partial eta-squared (η^2) was reported as the effect size.

Table 5 Summary of Two-Factor Repeated Measures ANOVA Results (N=37)

Metric	Effect	df	F	p	η^2
First Fixation Duration	Gender	1,35	0.01	0.943	0.000
	Icon Style	1,35	23.15	<0.001	0.398
	Gender $\times$ Icon	1,35	0.54	0.469	0.015
Total Fixation Duration	Gender	1,35	3.3	0.078	0.086
	Icon Style	1,35	10.29	0.003	0.227
	Gender $\times$ Icon	1,35	2.47	0.125	0.066
Total Saccadic Amplitude	Gender	1,35	0.01	0.911	0.000
	Icon Style	1,35	26.15	<0.001	0.428
	Gender $\times$ Icon	1,35	1.14	0.292	0.032
Saccade Count	Gender	1,35	0.47	0.497	0.013
	Icon Style	1,35	1.27	0.268	0.035
	Gender $\times$ Icon	1,35	2.3	0.139	0.062

The ANOVA results demonstrated that the main effect of Icon Style was statistically significant for three metrics: First Fixation Duration, Total Fixation Duration, and Total Saccadic Amplitude. Specifically, the main effect of Icon Style was significant for First Fixation Duration ($F(1,35)=23.15$, $p<0.001$, $\eta^2=0.398$), Total Fixation Duration ($F(1,35)=10.29$, $p=0.003$, $\eta^2=0.227$), and Total Saccadic Amplitude ($F(1,35)=26.15$, $p<0.001$, $\eta^2=0.428$). In contrast, the main effect of Icon Style for Saccade Count was not significant ($F(1,35)=1.27$, $p=0.268$, $\eta^2=0.035$).

Regarding gender factors, none of the four indicators showed a statistically significant main effect of Gender. The interaction effects of Gender $\times$ Style for all indicators were not statistically significant ($p > 0.05$), indicating that the eye-tracking data did not reveal significant gender differences in the visual attention process. The prediction in the original Hypothesis H4 regarding 'gender moderating visual attention' was therefore not supported.

3.3 Qualitative Results of Post-Experiment Interviews

A thematic analysis was conducted on participants' responses to the open-ended question, 'Please describe the main factors you consider when choosing an icon style.' The results were highly consistent with Norman's three-level model:

At the visceral level (immediate visual experience): 8 participants mentioned the intuitive appeal of skeuomorphic icons derived from their texture, such as 'having a tactile feel' or 'being aesthetically pleasing/good-looking', corresponding to visceral-level processing.

From the behavioral level (function recognition and operational convenience) it is clearly and neatly established that 10 participants gave priority to function recognition and ease of use, and they explicitly recognized the intuitiveness and usability of skeuomorphic icons, such as 'you can tell the function at a glance'.

At the reflective level (aesthetic and value judgment), 19 participants judged flat design to be more modern and minimalist from both aesthetic and value points of view, and similarly found skeuomorphic design to be cluttered, such as 'flat design is more modern/minimalist and clean, skeuomorphic design is too complex', hence this is a clear case of reflective-level processing.

4. Discussion

This study examined preference differences between skeuomorphic and flat icons through three evidence

chains: behavioral choices, subjective evaluations, and eye-tracking processes. Behavioral data revealed a significant correlation between gender and selection frequency of skeuomorphic icons ($r = -0.351$, $p = 0.033$), indicating women generally chose skeuomorphic icons less frequently than men. Subjective ratings demonstrated distinct dimensional differentiation: flat icons scored higher in simplicity and modernity, while skeuomorphic icons tended to excel in appeal and intuitiveness among certain demographics. This 'dimensional differentiation' suggests that the two design styles do not represent a simple superiority hierarchy but rather highlight distinct advantages in experiential composition elements.

Eye movement data provides process-level supplementary evidence for the aforementioned preference differences. Two-way repeated measures ANOVA revealed that icon style had significant main effects on first fixation duration, total fixation duration, and total saccade amplitude, while the style main effect on saccade frequency was not statistically significant. Gender main effects were generally insignificant, and the gender-style interaction effect also failed to reach statistical significance. These results suggest that style differences exhibit relatively stable trends in influencing visual processing mechanisms, though such process variations did not demonstrate significant gender differentiation within the current sample conditions. Spatial distribution analysis using heat maps revealed a concentration pattern of fixation points in representationalized regions, consistent with the statistical findings.

Since the present study is in line with existing research frameworks, it is natural and appropriate to show its comparability with established conclusions about flat design's alignment with minimalist aesthetics and interface coherence, as well as skeuomorphism's reliance on tangible cues. It is argued in the text that previous research does not yet yield definite conclusions about the two design styles because their differences are inherently tied to task characteristics and evaluation metrics: flat designs with minimal visual noise are likely advantageous in visual search or efficiency-oriented tasks requiring rapid localization and interference suppression, whereas skeuomorphic details and material cues are more effective in preference selection and first impression judgments where interpretable cues and visual appeal are salient. Therefore, the selection+rating+eye-tracking combined paradigm used in this study is an ideal way to reveal the coexisting strengths of both design styles across multiple experiential dimensions.

In summary, the conclusions of this study can be summarized into three key points. At the behavioral choice level: Gender shows significant correlation with icon preference, with females demonstrating a stronger inclination toward flat design and males showing a relative preference for skeuomorphic design. At the subjective evaluation level: The two design styles exhibit dimension-specific differentiation, where flat design demonstrates superiority in simplicity and modernity, while skeuomorphic design excels in visual appeal and intuitiveness. At the visual attention level: Icon style significantly influences early visual processing, though the gender×style interaction effect remains statistically insignificant, indicating that gender differences do not manifest during the initial visual attention stage (instinctive/behavioral level) but emerge at later cognitive decision-making phases (reflective level). This finding directly does not support the original H4 hypothesis predicting gender-mediated regulation of visual attention. Preference formation constitutes a complex process, and final decisions do not directly reflect early visual processing patterns. The fact that behavioral preferences persist despite similar early visual processing mechanisms holds significant value. Preference differences occur at more advanced cognitive processing stages (possibly corresponding to the reflective level in Norman's model), rather than being reflected through initial fixation patterns or total fixation duration at the instinctive/early behavioral level.

4.1 Theoretical and Practical Implications

Theoretically, this study integrates the three-level model of emotional design with eye-tracking evidence to establish a coherent explanatory framework for how icon styles influence user experience. The dimensional

differentiation observed in subjective ratings, combined with the style main effects in eye-tracking metrics, demonstrates that icon styles affect not only aesthetic judgment but also engage multiple cognitive levels: attention initiation at the instinctive level, comprehension and processing engagement at the behavioral level, ultimately culminating in modern aesthetic associations at the reflective level. Notably, gender differences emerge more prominently in behavioral choices and evaluation tendencies, while showing no significant effects in interaction terms of key eye-tracking indicators. These findings provide a direction for future research to explore gender disparities through 'weight distribution in preference formation' rather than 'pure perceptual capability differences.' At the practical level, the research findings provide direct reference value for interface icon design and style decision-making among young student groups in China's universities. For scenarios emphasizing rapid understanding and functional prompts, skeuomorphism can be utilized to enhance intuitiveness; for high-information-density scenarios, flat design offers greater advantages. Icon design may adopt a layered strategy to balance efficiency and aesthetics.

4.2 Limitations of the Study

This study still faces limitations in boundary conditions. The sample size of only 37 participants (15 males) resulted in insufficient statistical power, leading to undetected eye movement interaction effects. The study population consisted of students from Jiangsu University with homogeneous educational backgrounds and a narrow age range of 18-28 years, making conclusions difficult to generalize to other age groups, cultural backgrounds, or technical experience levels. The stimulus materials comprised 10 pairs of skeuomorphic and flat icons. Although functional matching and consistency were controlled, factors such as icon familiarity, semantic distance, detail complexity, and color contrast may still influence attention metrics and subjective evaluations. Eye movement analysis primarily focused on aggregate indicators, with heat maps providing intuitive visualization but limited interpretive granularity. Without AOI-level modeling and stricter statistical controls, the robustness of inferences could be further enhanced. Additionally, gender was modeled as a binary variable, failing to account for more nuanced dimensions of gender identity and individual differences.

4.3 Future Research Directions

Future research can be expanded in three key areas. First, the lack of statistical power led to insignificant interaction effects in eye-tracking data, indicating the need for larger-scale studies with more balanced samples to validate or refute these findings. Research should incorporate more heterogeneous user groups across age and cultural backgrounds to test the stability and generalizability of conclusions through cross-sectional experiments. Second, systematic manipulation of stimulus materials—including icon complexity, semantic distance, familiarity, and depth effects—combined with comparative analyses of visual search, recognition, memory, and preference selection tasks, can better identify optimal conditions for different styles to demonstrate their advantages in efficiency and aesthetic dimensions. Third, analytical approaches should adopt AOI-level eye-tracking metrics and mixed-effects models, incorporating both participants and icon items as random effects in estimation. This methodology will enable rigorous testing of gender and style main effects and interactions, while integrating subjective ratings with eye-tracking metrics within a unified statistical framework to enhance conclusion interpretability and robustness.

5. Conclusions

This paper addresses the gap in the literature regarding the lack of objective physiological data and theoretical analysis on gender differences in skeuomorphic and flat icon preferences, by reporting an eye-tracking experiment with 37 participants aged 18-28. The results clearly and convincingly show that male users tended to select

skeuomorphic icons more frequently than female users, as reflected by the significant negative correlation between gender and skeuomorphic icon selection frequency ($r = -0.351$, $p = 0.033$). Eye-tracking metrics clearly and convincingly showed that skeuomorphic icons have greater attention-grabbing power, with more focused gaze distributions, and the reasons for this preference were linked to gender-specific cognitive traits and social role orientations, as well as Norman's three-tier emotional design model. Therefore, the paper provides solid empirical support for gender-sensitive icon design and offers a meaningful extension of affective design theory to interface evaluation. The obvious limitations are the small sample size and single cultural context, so future work should address both by using more diverse samples and refined eye-tracking analysis methods.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patient(s) to publish this paper.

Data Availability Statement: The original contributions presented in the study are included in the article; further inquiries can be directed to the corresponding author upon reasonable request.

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

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Listening and Design as Cultural Infrastructure: Rethinking Innovation Through a Relational and Situated Approach

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Abstract: In contemporary innovation discourse, design is frequently framed as a solution-oriented and technology-driven practice focused on efficiency, scalability, and measurable outputs. While this paradigm has generated significant advancements, it often marginalizes relational, cultural, and long-term dimensions of project-making. This article adopts a theoretical and practice-informed research approach, combining critical literature review with reflective analysis of recurring design practices, to propose a framework that reconceptualizes design as cultural infrastructure rather than as a sequence of isolated solutions. Drawing on design theory, sound studies, and socio-technical scholarship, the study introduces listening as a situated epistemic and methodological practice that shapes how design engages with contexts, technologies, and knowledge production. Through a critical examination of solutionism and an analysis of infrastructural approaches to design, the article argues that innovation emerges from sustained socio-technical ecologies rather than punctual interventions. The framework is further discussed in relation to territory, rural transformation, and culturally situated technology. By reframing design as a long-term relational and infrastructural process, the article contributes to ongoing discussions on responsible innovation and advances a conceptual shift from solution-oriented intervention toward situated, relational, and context-sensitive design practices.

Keywords: *Design theory; Cultural infrastructure; Listening; Relational innovation; Solutionism; Socio-technical systems; Situated design*

1. Introduction

In contemporary debates on design and innovation, design is increasingly associated with the capacity to produce efficient, scalable, and measurable solutions, in line with paradigms borrowed from engineering, management, and applied sciences. Within this framework, the value of design is often assessed through the performance of its outputs—replicability, scalability, and measurability—an orientation further reinforced by digital platforms and data-driven systems that render projects readable as rapid and controllable interventions. While this approach has undoubtedly fostered innovative products, services, and systems, it has also progressively narrowed the epistemic scope of design, reducing it to a predominantly instrumental function aligned with economic and technological priorities (Papanek, 1971; Fry, 2009; Latour, 2009).

As Victor Papanek, Tony Fry, and Bruno Latour have argued, reducing design to problem-solving risks obscuring its cultural, political, and relational dimensions, as well as its long-term implications. The emphasis on rapid, scalable solutions—often sustained by an uncritical faith in technological efficacy—tends to marginalize situated, processual, and non-quantifiable forms of knowledge. Yet such forms of knowledge are central in socially and ecologically complex contexts, where design does not confront clearly bounded problems but evolving situations shaped by historical, environmental, and cultural tensions that resist linear and predictive models of intervention (Papanek, 1971; Fry, 2009; Latour, 2009).

In response, recent scholarship has sought to reconceptualize design as a cultural, relational, and situated practice. From this perspective, design exceeds the production of artifacts and instead configures processes and relationships that enable interaction among subjects, environments, and knowledge systems over time (**Manzini, 2015;Escobar, 2018**). This shift from outputs to processes does not reject technology, but repositions it within broader socio-technical ecologies, where digital tools and infrastructures function as cultural mediators rather than autonomous solutions. Such repositioning is particularly relevant in contexts marked by ecological fragility, cultural plurality, and accelerated territorial transformation, where rigidly solution-oriented approaches reveal significant limitations (**Manzini, 2015;Escobar, 2018**).

Despite these contributions, current design research still lacks a coherent framework that integrates relational, cultural, and infrastructural perspectives into a unified understanding of innovation processes. This article addresses this gap by proposing design as cultural infrastructure grounded in listening as an epistemic and methodological practice.

Building on these premises, the article proposes to rethink design not as a purely technical apparatus, but as an assemblage of practices, relations, and technological dispositifs capable of sustaining long-term processes of transformation. Within this framework, listening is introduced as a central epistemic and methodological practice for relational and situated innovation. Rather than functioning as a preliminary phase of analysis, listening shapes how design engages with contexts, mediates between different forms of knowledge, and integrates technological systems within situated processes. The aim is not to replace existing paradigms of innovation, but to critically extend them, opening space for an approach to design that aligns technological development with cultural sensitivity and contextual responsibility.

2. Research Questions

Given the theoretical repositioning outlined above, this article critically examines the role of design within contemporary innovation processes, challenging a predominantly technical and solution-oriented understanding. Since design operates in socially, ecologically, and technologically entangled environments, it becomes necessary to clarify which forms of knowledge and which modes of intervention are adequate to such conditions. Innovation, in this sense, cannot be reduced to the introduction of new solutions or technologies; rather, it must be understood as a situated process unfolding over time through relations, mediations, and contextual engagement.

The first question concerns the possibility of rethinking design beyond problem-solving and conceptualizing it as a cultural and relational practice. This implies shifting attention from outputs to the configuration of processes and conditions that enable interaction among subjects, environments, and knowledge systems. Design, in this perspective, operates not as a function of optimization but as a practice capable of shaping temporalities, mediations, and socio-technical relations.

The second question addresses the role of listening within design processes. If design is understood as situated practice, how can it generate knowledge through attentiveness to contexts and differences? Listening is not treated here as a preliminary phase but as an epistemic and methodological orientation that shapes engagement, priorities, temporalities, and the integration of technologies within the project.

The third question concerns long-term implications. If design operates through relational processes grounded in listening, can these practices be understood as cultural infrastructures rather than episodic interventions? This entails examining how design may sustain continuity, shared learning, and non-linear innovation capable of evolving within transforming socio-technical environments. Accordingly, the article is structured around three research questions:

1)How can design be reconceptualized as a cultural and relational practice beyond a purely technical and solution-oriented understanding of innovation?

2)How can listening function as an epistemic and methodological practice within design processes?

3)In what sense can listening-based design practices operate as cultural infrastructures capable of sustaining long-term innovation?

Rather than offering universal answers, these questions seek to construct a conceptual framework for understanding design as a situated, relational, and responsible form of innovation in technologically mediated environments.

3. Methodology

This article adopts a theoretical and practice-informed research approach, situating itself within a tradition that recognizes the epistemic value of design, artistic, and cultural practices. In this perspective, knowledge is not produced solely through standardized empirical protocols, but emerges from the reflective interaction between theory, situated experience, and operational practices. Such an approach is particularly suited to investigating design in complex environments, where the boundaries between research, project development, and cultural intervention are porous and continuously redefined.

Concretely, the research process combines three interrelated components: (1) a critical synthesis of literature across design studies, sound studies, and socio-technical theory; (2) a comparative analytical reflection on recurring design practices such as long-term residencies, situated listening practices, and participatory territorial processes; and (3) a reflexive interpretation of these practices as methodological configurations rather than empirical case studies. These components are used to identify shared patterns, conceptual tensions, and methodological implications that inform the proposed framework.

Methodologically, the study is grounded in this critical synthesis of literature in design studies, sound studies, and cultural ecology, with particular attention to contributions that question solution-oriented, technocratic, and universalizing approaches to innovation.

Rather than reconstructing an exhaustive state of the art, the review identifies key concepts and theoretical tensions useful for reframing design as relational, situated, and long-term oriented practice. This includes reflections on contemporary technologies—digital platforms, intelligent systems, and sensory mediation devices—understood not as neutral tools or autonomous solutions, but as elements embedded within complex socio-technical ecologies (Escobar, 2018).

In addition, the article develops a comparative reflection on recurring types of design practices, such as long-term artistic residencies, situated listening practices, and territorially embedded participatory processes. These practices are not presented as empirical case studies in a strict sense, but as recurring operational configurations used analytically to identify methodological patterns, project postures, and shared conceptual implications. They allow observation of how design can operate beyond punctual intervention, through extended temporalities and relational forms of engagement involving both human and non-human actors.

Listening occupies a central methodological role within this framework. It is understood as an epistemic practice that shapes not only engagement with contexts, but also the conduct of research itself. Listening informs modes of observation, interpretation, and design, fostering attentiveness to difference, temporality, and relational complexity. In this perspective, the technologies employed in design processes — recording tools, digital infrastructures, sensing systems, data visualization platforms—are treated as relational mediators. Their function is not the extraction of information, but the facilitation of attention, shared interpretation, and situated learning. Overall, the article adopts a reflexive methodological stance that treats situatedness and partiality as analytical resources rather than limitations. The aim is not to propose prescriptive models or universal generalizations, but to construct a transferable interpretative framework adaptable to diverse contexts. This framework seeks to clarify

the role of design as cultural infrastructure and as a practice capable of sustaining relational and situated forms of innovation over time.

4. Discussion

Critiquing solutionism in design does not imply rejecting the operational dimension of projects, nor questioning the importance of technology in innovation processes. Rather, it calls for situating design action within a broader epistemic and temporal horizon—one that accounts for the cultural, social, and ecological implications accompanying every intervention. In this sense, solutionism is not merely an operational stance, but a cognitive paradigm that frames design as a technical response to isolable and governable problems. As Tony Fry argues, this orientation privileges a short-term temporality focused on immediate efficiency, obscuring long-term consequences and weakening design's responsibility toward possible futures (**Fry, 2009**). Similarly, Arturo Escobar highlights how solution-oriented and technocratic approaches risk imposing universalizing models on culturally plural contexts, reducing territorial complexity to standardized, transferable solutions (**Escobar, 2018**).

Today, this orientation is reinforced by digital and computational technologies often framed as inherently problem-solving tools capable of optimizing processes and automating decisions through abstract models. While such technologies offer significant potential, their deployment within rigidly solutionist paradigms can translate contextual complexity into datasets, indicators, and measurable parameters, subordinating social and ecological relations to logics of efficiency and control. For example, when a territory becomes “governable” through dashboards, predictive models, and performance metrics, what resists computation—latent conflicts, informal practices, embodied memories—tends to slip outside the project frame, even though it continues to shape the life of the context.

The critique of solutionism, therefore does not target technology itself, but the manner in which it is integrated into design processes without sufficient reflection on its relational and infrastructural implications. Technologies are never neutral: they actively participate in configuring contexts, relations, and forms of knowledge. Design, in this perspective, becomes a relational and socio-technical process capable of mediating between heterogeneous knowledge, local practices, and technological systems.

John Thackara similarly argues that isolated technological fixes often obscure the systemic dynamics from which problems emerge, advocating instead for design approaches grounded in local ecologies, everyday practices, and long-term living systems (**Thackara, 2015**).

This position resonates with Bowker and Star's insight that infrastructures and classification systems are not merely technical arrangements but devices that shape what becomes visible, actionable, and legitimate within a given context (**Bowker & Star, 1999**). Technologies employed in design—digital platforms, sensing systems, data visualization tools—structure possibilities for participation and knowledge production. Depending on project posture, they can reinforce extractive and centralized models or operate as mediating tools that support attention and dialogue. Keller Easterling further emphasizes that design frequently operates at an infrastructural level, organizing conditions and protocols rather than producing isolated objects (**Easterling, 2014**). In this view, technologies are not autonomous solutions but negotiable components embedded within relational networks that unfold over time and across scales. To rethink design beyond solutionism thus means recognizing its role in shaping complex socio-technical ecologies, where innovation emerges through sustained interaction among cultural practices, social relations, and technological systems. Within this horizon, the value of design lies less in solving predefined problems and more in constructing conditions of possibility for shared, situated transformation. It is from this position that listening can be introduced as an epistemic and methodological alternative—not as a rejection of technology, but as its critical and responsible integration within complex contexts.

This shift in orientation can be understood as a movement from output-centered and linear design processes

toward relational and infrastructural configurations, as illustrated in **Figure 1**.

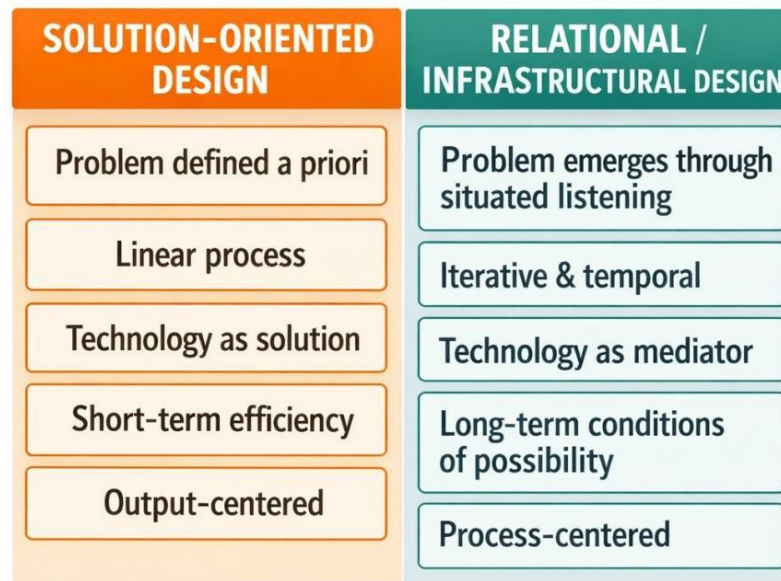


Figure 1 From solution-oriented design to relational and infrastructural design.

5. Listening as Epistemic and Methodological Practice

Within the theoretical repositioning outlined above, listening is proposed as a central epistemic practice for rethinking design in contemporary innovation processes. Rather than functioning as a preliminary analytical phase or a metaphor for attentiveness, listening is understood as situated, embodied, and relational knowledge that shapes how projects engage with contexts, communities, and environments. Listening does not simply gather information; it contributes to constructing the conditions through which knowledge takes form, influencing how issues are recognized, framed, and transformed into design questions.

Steven Feld's concept of acoustemology provides a key reference point, defining listening as a mode of knowing grounded in sensory experience and environmental relations (Feld, 2015). In this sense, listening is not merely perceptual reception but a way of world-making through shared practices, memories, and distributed forms of attention. Transposed into design, this implies shifting from the extraction of decontextualized data toward processual knowledge in which what matters is not only what is measured, but what is rendered audible—and, therefore discussable and negotiable.

This repositioning challenges the visual dominance of Western modernity. Don Ihde argues that listening enables alternative relations to the world, disrupting epistemologies based on distance and visual control (Ihde, 2007). In design terms, listening introduces proximity and temporality, making it harder to treat context as an external object and easier to recognize it as a relational field in which the project is already implicated.

Listening also foregrounds time. Situated listening requires duration, iteration, and return; it produces knowledge through resonance rather than immediate extraction. Design thus becomes cyclical rather than linear, where listening reshapes problem-framing itself.

At the same time, listening cannot be separated from the technologies that increasingly mediate design practices. Recording devices, environmental sensors, hydrophones, digital platforms, geolocated sound maps, and data visualization tools do not merely collect information; they select, amplify, and make shareable certain phenomena, transforming them into objects of public discussion. In practices of situated listening, for instance, sensors and mapping platforms do not simply register environmental signals—they configure what counts as signal and what remains noise, thereby shaping collective interpretation.

Listening is, therefore inherently socio-technical. Even computational techniques used to detect patterns or classify events embody epistemic decisions about categorization and relevance. Which phenomena become visible? Which remain marginal? Listening, in this sense, becomes a critical device.

Dylan Robinson reminds us that listening practices are never neutral; they are embedded in power relations and structures of audibility (**Robinson, 2020**). For design, this raises questions about who defines protocols, who controls platforms, and whose voices are recognized. Listening thus functions as a criterion of design responsibility—not only in terms of functionality, but in terms of participation and agency.

Methodologically, listening extends beyond analysis to shape temporalities and intervention modes. It often implies slowing down design processes, suspending premature solutionism, and creating spaces of attention in which projects can emerge dialogically. Rather than treating design as a linear sequence of predefined stages, listening introduces iterative rhythms, moments of return, and phases of recalibration that allow problems themselves to evolve. In this sense, listening does not simply precede intervention; it accompanies and continually reorients it.

Such an approach foregrounds the relational density of contexts, acknowledging that territories, communities, and socio-technical systems are not static backgrounds but dynamic assemblages in which design is already implicated. Listening “therefore” modifies the posture of the designer, shifting from control and optimization toward attunement and negotiation. This shift also affects how technologies are deployed: instead of serving exclusively as instruments for measurement and efficiency, they become tools for mediation, translation, and shared interpretation.

Outputs, in this perspective, may consist not only of artifacts but of relational protocols, mediating infrastructures, and durable conditions of exchange. What is produced is often less a finished object than a sustained capacity for interaction, reflexivity, and collective learning. Understood as epistemic and methodological practice, listening provides a foundation for conceiving design as cultural infrastructure—a sustained practice of attention and shared learning rather than a sequence of isolated solutions. As shown in **Figure 2**, listening operates as a mediating device between context, technological systems, and the production of situated knowledge.

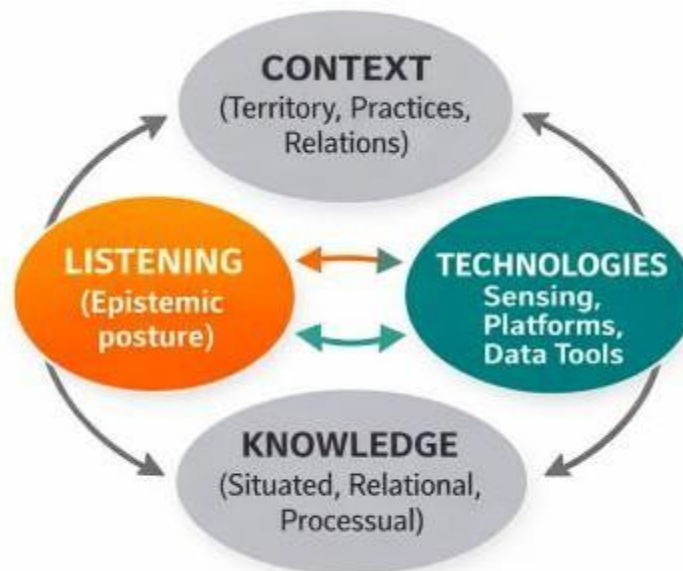


Figure 2 Listening as an epistemic and socio-technical device in design processes.

6. Design as Cultural Infrastructure

The notion of design as cultural infrastructure enables an understanding of how listening-based practices operate beyond the scale of individual projects. Rather than a punctual intervention or the production of isolated outputs, design becomes a set of conditions, relations, and devices that structure possibilities for action over time.

Following Manuel DeLanda, infrastructure can be conceived as a dynamic assemblage of material, social, and symbolic relations that condition trajectories without determining them linearly (DeLanda, 2006). Applied to design, this shifts attention from immediate outcomes to the conditions of possibility that projects help construct and sustain.

In cultural terms, design as infrastructure supports continuity, relationality, and shared learning. Listening practices discussed earlier can be understood as infrastructural components: they may not produce immediately visible results, but they cultivate ecologies of attention, trust, and reciprocity through which innovation becomes relational and situated.

This perspective is particularly relevant in contemporary socio-technical transformations, where infrastructures increasingly take the form of hybrid assemblages integrating digital platforms, governance protocols, data systems, and cultural practices. Design as cultural infrastructure does not oppose technology; rather, it interrogates how technological systems stabilize or transform participation and temporality.

A concrete implication of this view is that output may consist less in a finished artifact and more in a durable protocol—a recurring practice of care, a feedback mechanism, or a minimal exchange platform capable of maintaining relations and learning over time.

This orientation resonates with the work of Ou Ning, whose reflection on rural reconstruction conceives projects not as linear modernization tools but as relational platforms for cultural experimentation (Ou, 2021). In *Utopia in Practice*, the Bishan Project is described as activating processes of collective learning and engagement that challenge top-down development logics (Ou, 2021).

Similarly, Wang Shu emphasizes non-extractive relations to territory and material tradition (Ong, 2012), framing architecture as mediation between continuity and transformation. From a theoretical standpoint, Yuk Hui's notion of cosmotechnics questions technological universalism and argues for culturally situated conceptions of technique (Hui, 2016).

Taken together, these perspectives clarify design as a form of cultural infrastructure integrating listening, technology, and context. Innovation, within this framework, emerges not from isolated interventions but from sustained socio-technical ecologies capable of supporting responsible and context-sensitive transformation over time, as schematically illustrated in Figure 3.



Figure 3 Design as cultural infrastructure sustaining long-term relational processes.

7. Resonances with the Contemporary Chinese Context: Territory, Culture, and Relational Project-Making

The approach developed in this article—understanding design as a cultural, relational, and infrastructural practice—finds a particularly fertile terrain of resonance in contemporary China. This resonance is not merely thematic, but structural, reflecting the correspondence between the proposed framework and the historical, territorial, and cultural conditions within which design is currently called to operate. Over recent decades, China has undergone territorial, social, and ecological transformations of unprecedented scale and speed, prompting a reconsideration of inherited categories of development, modernization, and innovation. In this context, design can no longer be understood as a purely technical tool of optimization or as an interface for technological innovation, but must engage with contextual complexity, layered temporalities, and the long-term consequences of ongoing transformations.

The magnitude of these processes has made it increasingly evident that infrastructures—material, technological, and cultural—are never neutral. They actively participate in redefining relations between territory, communities, and environments. Design thus emerges as a practice capable of acting not only on discrete problems, but on the conditions that make certain development trajectories possible. This implies a redefinition of design's role, from the delivery of punctual solutions to a mediating function able to accompany transformation processes over time.

Within this broader landscape, debates on rurality and non-urban areas have acquired particular prominence. Rural issues are no longer framed solely in terms of productivity or infrastructural deficits, but as cultural and epistemic questions, raising concerns about how territory is known, represented, and transformed. Practices associated with rural reconstruction challenge linear and top-down models of modernization, emphasizing instead the need for approaches capable of engaging with local complexity, sedimented memories, and situated forms of life.

In this context, Ou Ning's work provides a key reference. In *Utopia in Practice: The Bishan Project and*

Rural Reconstruction, the project is conceived as a relational platform and a form of cultural infrastructure rather than as a tool for the implementation of predetermined models (Ou, 2021). The Bishan Project exemplifies a long-term process integrating artistic, cultural, and design practices oriented toward building relationships, sharing knowledge, and experimenting with alternative modes of dwelling and cooperation. In this perspective, design does not introduce external solutions; it creates the conditions through which new practices can emerge through progressive engagement and continuous negotiation of meaning.

These examples are not presented as empirical case studies, but as illustrative configurations that demonstrate how design can operate as cultural infrastructure through long-term relational processes, situated knowledge production, and mediated engagement with territory.

What emerges from these experiences is not a rejection of transformation or technology, but a redefinition of their premises. Innovation is displaced from the logic of rapid and measurable intervention toward relational and temporal processes. In this sense, listening—understood as an epistemic and methodological practice—plays a central role, orienting design not from abstract objectives but from the specific social, environmental, and cultural conditions of contexts, and enabling a critical and situated integration of technologies.

A comparable sensibility can be found in the work of architect Wang Shu, whose approach is grounded in a non-extractive relation to territory and material tradition (Ong, 2012). Here, architectural design operates as a process of mediation between continuity and transformation, in which materials, techniques, and local knowledge are reactivated within new configurations. Rather than preserving tradition in a static form, this approach demonstrates how design can function as cultural infrastructure, sustaining durable relations between past and present while enabling context-specific forms of innovation.

On the theoretical plane, Yuk Hui's concept of cosmotechnics further clarifies the relevance of a situated approach to design. By questioning technological universalism, Hui argues for culturally specific articulations of technology and innovation (**Hui, 2016**). In this perspective, design cannot be reduced to a neutral application of global tools, but must be understood as a practice that mediates between technology, ethics, and worldviews. Listening becomes, in this sense, a crucial epistemic practice for engaging with difference and resisting the imposition of abstract and universal models.

A further level of convergence concerns the role of artistic and cultural practices in shaping territorial imaginaries and renegotiating relations between space, memory, and identity. As Wu Hung observes, contemporary Chinese art often operates in an intermediate space between institutions, communities, and territories, exceeding the production of finite objects and contributing instead to making transformations visible and discussable (**Wu, 2010**). These practices act as infrastructural devices that enable new forms of awareness, participation, and collective reflection.

Within this framework, design as cultural infrastructure is continuous with these practices in its focus on processes, relations, and temporalities. Rather than producing isolated outputs, it contributes to constructing conditions for dialogue, participation, and shared learning. It operates as a mediating device among diverse actors—institutions, communities, technologies, and situated knowledge—helping to structure environments in which territorial transformations can be understood and, potentially, reoriented.

In light of these considerations, the framework proposed here is not intended as an external model to be applied to China, but as a space of resonance and dialogue with practices already active within the Chinese context. Listening emerges as a shared epistemic ground through which different traditions and approaches can interact, enabling design to operate as a situated, relational, and open practice capable of accompanying complex and non-linear transformation processes over time.

8. Implications for Design Research and Education

Adopting an approach to design grounded in listening and in its infrastructural dimension entails substantial implications for both design research and design education, challenging consolidated modes of producing, evaluating, and transmitting knowledge. First, this perspective requires a critical revision of the criteria through which design research is legitimized within academic contexts. If the value of design is measured primarily in terms of outputs, implementable solutions, or immediately applicable technological innovation, practices operating at the level of processes, relations, and long-term transformations risk remaining marginal. A listening-based approach instead requires recognizing situated and processual forms of knowledge that do not always yield immediately quantifiable outcomes, yet are decisive for understanding and accompanying complex, unstable, and culturally differentiated contexts.

From this viewpoint, design research no longer appears as an activity oriented exclusively toward solving predefined problems, but as a process of exploration and of constructing conditions of possibility. As Ezio Manzini notes, contemporary design increasingly operates as enabling infrastructure, supporting collaborative processes, distributed learning, and innovation dynamics that emerge over time (**Manzini, 2015**). This implies that design research should be evaluated not only for its final results, but also for its capacity to activate relations, produce shared knowledge, and generate durable effects in the contexts where it operates.

Methodologically, this shift broadens the tools and languages of design research. Listening practices—understood both literally as attention to sonic, environmental, and material contexts, and more broadly as an epistemic openness to knowledge, experiences, and relations—can be integrated into research processes as full-fledged knowledge devices. They enable the coexistence of analytical and data-driven methodologies with qualitative, ethnographic, and participatory forms of inquiry capable of capturing dimensions that elude purely

quantitative or computational models. Within this framework, digital technologies—from sensing systems to visualization and simulation platforms—can be rethought not as instruments of control or mere data extraction, but as epistemic mediators that help make complex dynamics perceivable, shareable, and discussible.

The implications of this approach are especially significant in education. Training designers capable of operating in complex contexts means moving beyond an education focused only on technical skills or the effective use of technological tools. Integrating listening as a method entails cultivating relational, cultural, and ethical competencies enabling designers to engage responsibly and situationally with communities, territories, and socio-technical systems. This does not diminish the role of technology in design education, but critically relocates it: technologies are understood as elements within broader design ecologies to be questioned, negotiated, and adapted to contexts, rather than as neutral or universally valid solutions.

In this sense, design education can be reimagined as a space for infrastructural experimentation, in which students and researchers learn to work with long-term processes, confront uncertainty, and recognize attention and care as design resources. Listening practices foster learning that does not merely aim at problem-solving but develops the ability to read contexts, recognize asymmetries and differences, and build durable relations among knowledge, technologies, and territories.

Finally, adopting an infrastructural and relational perspective on design implies redefining the role of the university as a cultural actor within innovation processes. Design research and teaching can contribute not only to producing specialized knowledge but to building platforms for dialogue among disciplines, institutions, and communities. Here, Yuk Hui's reflections are particularly relevant: conceiving technology as a culturally situated practice implies a design education capable of critically interrogating the premises of technological innovation, orienting design toward forms of development more attentive to contexts, temporalities, and the cultural implications of contemporary transformations (Hui, 2016).

9. Conclusions

This article has proposed a rereading of design as a cultural, relational, and infrastructural practice, articulated through the notion of listening, understood both as an epistemic posture and as a design method. Starting from a critique of solution-oriented and technocratic paradigms of innovation, the contribution has shown how design can be rethought not only as the production of solutions or measurable outputs, but as a process capable of configuring relations, temporalities, and conditions of possibility over the long term (Fry, 2009; Escobar, 2018). The main theoretical contribution of this article lies in articulating a framework that positions listening as a central epistemic and methodological device through which design can be understood as cultural infrastructure. In a global context marked by profound social, territorial, and ecological transformations, such a shift in perspective appears not only desirable but necessary.

To rethink design as cultural infrastructure means recognizing its role in constructing complex socio-technical ecologies within which technologies, knowledge, and cultural practices interact in non-linear ways (Bowker & Star, 1999; Easterling, 2014; DeLanda, 2006). In this framework, listening plays a central role: it enables projects to be oriented from the specific conditions of contexts, avoiding the imposition of abstract or universalizing models and fostering instead forms of situated, relational, and responsible innovation (Feld, 2015; Ihde, 2007; Robinson, 2020). Listening is not treated here as a preliminary step or a mere tool for gathering information, but as an ongoing practice accompanying design over time, shaping modes of intervention, priorities, and ethical implications (Feld, 2015; Ihde, 2007; Robinson, 2020).

This perspective resonates with John Thackara's work, which argues that contemporary design's task is not to produce new solutions, but to change how we live—working with local systems, everyday practices, and ecological relations over the long term (Thackara, 2015). In his theoretical contributions and experiences also

developed in China, Thackara shows how innovation emerges from attention to real contexts, listening to communities, and the ability to operate through light infrastructures—often invisible—that sustain life over time (Thackara, 2015). This view reinforces design as an infrastructural practice oriented not to immediate problem-solving, but to building conditions that support coexistence, resilience, and shared transformation.

Dialogue with contemporary China has highlighted that this orientation is not an external framework applied after the fact, but one that resonates with existing practices and debates (Ou, 2021; Hui, 2016; Wu, 2010; Ong Yan, 2012). Rural reconstruction experiences, reflections on situated technology, and the role of artistic practices in producing new territorial imaginaries show how design can operate as a relational platform and cultural infrastructure, capable of accompanying complex transformation processes, avoiding prescriptive approaches and valuing instead plural contexts, temporalities, and future visions (Ou, 2021; Hui, 2016; Wu, 2010; Ong Yan, 2012).

From the perspective of design research and education, the implications are substantial. Recognizing the epistemic value of processes, relations, and listening practices requires revising how design research is evaluated and redefining educational goals (Manzini, 2015; Feld, 2015; Ihde, 2007; Robinson, 2020). Design education can thus become a space for infrastructural experimentation oriented not only toward technical competence but toward the development of critical, relational, and ethical capacities required to operate within complex socio-technical contexts (Manzini, 2015; Hui, 2016). Technologies are not rejected, but critically relocated within broader design ecologies whose roles and implications are constantly interrogated (Hui, 2016).

This study is primarily conceptual and does not rely on systematic empirical case studies. Future research could apply this framework to specific design contexts in order to test its analytical and operational potential. Further investigations may explore how listening-based design practices can be operationalized within specific socio-technical environments, particularly in relation to digital infrastructures, territorial transformation, and participatory processes.

In conclusion, this contribution does not propose a new normative model of design nor a universally applicable methodology. Rather, it offers an open theoretical and methodological orientation that understands design as a situated practice and cultural infrastructure capable of sustaining transformation processes over time (DeLanda, 2006). Listening, as both method and epistemic posture, emerges as a key element for rethinking innovation beyond the logic of solution, opening space for forms of project-making more attentive to contexts, relations, and possible futures (Feld, 2015; Ihde, 2007; Robinson, 2020). In this sense, design can contribute not only to addressing present challenges, but to building conditions of possibility for imagining and inhabiting forthcoming transformations more responsibly.

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The Impact of Heritage Brand Storytelling on Young Consumers' Attitudes: An Empirical Study Based on DEMATEL-ANP and the ABC Attitude Model — A Case of Hengshun

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Abstract: In the global consumer market, heritage brands often face challenges such as aging brand perception and a disconnect between their narrative approach and the target audience. This study uses the heritage brand Hengshun as a case study to investigate the consistency between expert decision-making logic and the psychological responses of young audiences. Depending on the findings, either the successful narrative path will be refined, or the cognitive logic behind any deviation will be analyzed to identify effective strategies for brand narratives to evoke attitudinal responses in young consumers. To this end, three narrative types were developed, and the DEMATEL-ANP expert decision-making method was employed alongside an empirical approach based on the ABC attitude model to compare the effects of brand narratives as perceived by experts versus young audiences. The experimental data reveal a significant cognitive gap: experts adhere to an internal-to-external logic in brand system construction, whereas young consumers are more inclined to enter the consumption process through emotions and social participation. Consequently, a brand narrative path tailored to the young generation was proposed: "emotional entry – cognitive deepening – behavioral transformation," which outlines a progressive method of emotional guidance, cognitive consolidation, and behavioral transformation. This study extends the application of narrative transmission theory and the ABC attitude model to heritage brands, thereby contributing to the sustenance of brand vitality.

Keywords: *Heritage brand; Brand narrative; Narrative transmission; Consumer attitude*

1. Introduction

Brand heritage, the cumulative history and performance of a brand over time, is a fundamental component of brand equity (Keller, 2009). In the contemporary global consumer market, heritage brands face unprecedented survival challenges. On one hand, their long historical accumulation provides a profound cultural foundation, granting them certain competitive advantages in an increasingly fragmented era. On the other hand, drastic changes in the global market environment and the rise of a new generation of young consumers have led these brands to gradually fall into the predicament of aging brand perception. Their traditional narrative systems are increasingly unable to resonate with the modern lifestyles of the young generation. As a leading brand in the Chinese condiment industry, Hengshun possesses a century-long historical and cultural heritage. However, in its efforts to expand into the young consumer market, it has encountered a gap between its established brand image and the psychological recognition of young people. For a heritage brand, attracting young consumers is not merely a competition for market share, but a crucial endeavor for the continuation of brand vitality. How to effectively enhance young people's brand recognition, emotional connection, and behavioral intention while maintaining cultural heritage is a common challenge that all heritage brands must address in the process of brand activation.

Brand storytelling is widely regarded as a core tool for revitalizing brand vitality. Stories possess significant power in facilitating and sustaining communication in daily life. In the context of branding, a compelling narrative often underpins the most popular brands in today's marketing landscape. Essentially, brand narratives communicate through stories (**Kim et al., 2017**). Defined as absorption into a story, transportation entails imagery, affect, and attentional focus (**Green & Brock, 2000**). When consumers immerse themselves in the scenario constructed by the story, their cognition and emotions will also undergo changes, story receivers are emotionally transported into the storyteller's world through empathy and imagery (**Pera & Viglia, 2016**), thereby reducing their resistance to commercial advertisements. More and more brands increasingly use a strategic approach to brand content creation.

During the formulation of brand strategies, enterprises often rely on expert decisions. However, in a complex and ever-changing market environment, can the expert's empirical judgment accurately hit the psychological response of young people? Especially in the current young-oriented market where information is fragmented and sensory thresholds are constantly rising, the formation of consumers' brand attitudes is a complex psychological process, and affective elaboration is the dominant influencer during this attitude formation process. This study takes the heritage brand Hengshun as its core case, focusing on three narrative types: historical cultural heritage, quality value and innovation, and user co-creation with emotional connection. It seeks to address a central question: do the priority weights derived from the DEMATEL and ANP expert methods align with the empirical responses of young consumers based on the ABC attitude model? If the two are consistent, it would indicate that expert judgment has accurately captured market and consumer demands. The research would then further summarize and refine the successful brand narrative path, providing a reference and scalable framework for expanding heritage brands into the young consumer market. Conversely, if a significant mismatch emerges—for instance, if the historical cultural narrative favored by experts creates a sense of distance among young audiences, while the user co-creation and emotional connection narrative more effectively evokes stronger emotional resonance—this study will deeply analyze the cognitive logic underlying the deviation and, based on these insights, propose a verifiable brand narrative methodology.

From a theoretical perspective, this study extends the boundaries of brand narrative marketing research and offers a new foundation for applying the consumer ABC attitude model to heritage brands. From a practical standpoint, it aims to provide a verifiable brand narrative methodology for Hengshun and other heritage brands in engaging younger consumer demographics. Historically, marketing for heritage brands has often lacked data-driven support and psychological validation. This study, through quantitative analysis, translates three distinct narrative types of the Hengshun brand—historical cultural heritage, quality value and innovation, and user co-creation with emotional connection—into quantifiable variables. This approach enables business managers to identify which narrative types can effectively influence young consumers' purchasing decisions, thereby helping heritage brands further expand into the youth market and enhance brand vitality and consumer recognition.

2. Literature

2.1 Theoretical Framework

2.1.1 The ABC Model of Consumer Attitudes

Attitude is a psychological construct that represents an individual's internal evaluative tendency when responding to a particular object or situation. In marketing, consumers' attitudes constitute a prevalent model of attitude structure, which consists of three components: affect, behavior, and cognition (**Brechman & Purvis, 2015**). Cognition refers to the knowledge and perceptions that consumers acquire from various sources, such as brand attributes, image, and function. Affect denotes the emotional experience or feeling that consumers hold toward a brand. Behavior encompasses the intention to purchase or recommend the brand, as well as the actual actions taken.

From a psychological perspective, attitudes are understood to be acquired through learning. They are shaped by the information available to consumers and their self-understanding, and can also be influenced by surrounding information. In the process of attitude formation, some scholars argue that cognition serves as the foundation and prerequisite. Attitudes are formed based on the information consumers obtain and their own cognitive processing, with emotions emerging concurrently. Changes in both cognition and affect jointly give rise to the consumer's purchase intention. Regarding consumer information processing, traditional perspectives have identified two primary dimensions — affect and cognition — as the evaluative bases for attitude formation. These two main components of attitude may influence their attitudes towards brands with information awareness, because consumers are fundamentally diverse (**Hameed et al., 2023**). In MacKenzie's experiment, emotions were the direct and powerful driving force behind the formation of attitudes. At the same time, the opinions and suggestions of the environment are highly persuasive and have an impact on consumers' purchasing behavior (**Singh, 2021**).

2.1.2 Narrative Transportation

When Gerrig was conducting research on narrative experiences, he first employed the term "Transportation" (**Escalas, 2004**), and described the state in which individuals were "transported" through the metaphor of a "traveler". Based on this, Green and Brock defined the meaning of narrative transmission in 2000, arguing that when an individual is attracted by a narrative and immersed in it, they will temporarily detach from the real world and enter the world of the story. This state is called "Narrative Transportation" (**Green & Brock, 2000**). In narrative communication theory in marketing, by meticulously designing story narratives, character development, plot construction, and emotional marketing, brands can effectively evoke consumers' emotions, enhance their immersion, and foster emotional resonance (**Seyfi & Soydaş, 2017**), reduce skepticism and rational rebuttals towards commercial advertisements, and thereby influence consumers' attitudes and behaviors. Although narrative advertisements can effectively influence the audience during the transmission process, their effects are influenced by individual characteristics and product categories. People with high transmissibility respond more positively to advertisements (**Brechman & Purvis, 2015**). In the past, Narrative Transportation was mainly driven by two groups: storytellers and consumers. With the integration of media features (such as short videos, VR, and social media) as the third element, the presentation form of the story became more flexible, and the narrative would tend to develop towards co-creation, personalization, and immersion. Consumers will not only be the recipients of the story, but also the co-creators and main characters of the story. All these elements (the storyteller, the consumer, and the media characteristics) will be integrated in an unexplored manner, facilitating the further development of Narrative Transportation (**Thomas & Grigsby, 2024**).

2.2 Review of Previous Research

In the context of international academia, the research on Heritage Brand has shifted from merely historical preservation to core brand strategy. Urde et al. define brand heritage as a dimension of a brand's identity found in its track record, longevity, core values, use of symbols, and particularly in an organisational belief that its history is important (**Urde et al., 2007**). At the same time, they believe that these historical accumulations provide the brand with a profound cultural foundation, giving it a natural and inherent competitive advantage in the highly competitive market. Many scholars have focused on the concept of corporate legacy brands, as they hold significant value in maintaining the power of an established brand. Their research demonstrates how brand experience and knowledge enable Heritage brands to maintain a leading position in the market (**Balmer et al., 2006; Blombäck & Brunninge, 2009**). However, how heritage brands can cope with the unprecedented survival challenges in the contemporary market is also a major topic currently under study. Balmer believes that the concept of heritage itself is a paradox, because the focus on heritage is a characteristic of modernism (**Balmer, 2013**). Business managers should not view tradition and modernity as opposing concepts. Instead, they should adopt a

brand management mindset to safeguard the core heritage while actively engaging in adaptive innovation. The value of heritage brands lies not only in the past, but also in how they can create value for the future through historical assets. Some scholars also focused their research on Brand Activation. The focus of brand activation lies in the real-time two-way interaction between consumers and the brand, which leads to a deeper bond between the consumer and the brand (**Dissanayake & Gunawardane, 2018; Saeed et al., 2015**). Brand narrative is regarded as a powerful tool for Brand Activation. It helps establish a connection between the brand and consumers through story-telling. Green and Brock's narrative transmission theory states that through image construction and emotional arousal, stories can enable consumers to experience a deep sense of immersion, thereby effectively reducing their resistance to commercial information. Take the brand repositioning process of Burberry as an example. By telling the story of the explorers Scott and Sir Shackleton wearing Burberry fabrics to conquer the Antarctic, the brand transforms functionality into an image of the spirit of exploration, allowing consumers to experience a sense of heroic immersion across time and space when making purchases (**Moore & Birtwistle, 2004**). Further research has revealed that the core of narrative transmission lies in psychological simulation (**Edson Escalas, 2004**). When consumers encounter brand stories containing heroic elements, they often experience a self-referencing effect. In the domestic Chinese market, emerging brands have achieved significant brand activation and narrative transmission by deconstructing and reinterpreting traditional culture. Taking the brand "Huaxizi" as an example, it has successfully established a differentiated competitive advantage in the highly competitive cosmetics sector by constructing a comprehensive narrative system rooted in Eastern aesthetics. By embedding its brand narrative within profound traditional Chinese aesthetics and integrating specific cultural imagery with its products, the brand has cultivated a sense of identity among consumers as a cultural inheritor. Furthermore, within the digital media environment, Huaxizi's narrative strategy exemplifies a shift from one-way brand communication to narrative co-creation. The research reveals that in the era of social media, narrative transmission is no longer a one-way output by the brand. The boundaries between the brand and consumers, as well as among consumers themselves, have become blurred, forming an interactive and co-creative narrative domain (**Van Laer et al., 2019**). This highly integrated co-creation approach fosters more stable brand resonance than traditional marketing, thereby enabling consumers to identify with the brand's values through active engagement. In conclusion, both international heritage brands like Burberry and emerging Chinese brands such as Huaxizi owe their success to how they emotionally engage with their brand history. By employing emotional resonance and immersive imagery within a systematic narrative framework, they gradually cultivate psychological identification among their audiences. These cases collectively demonstrate that in today's competitive global market, brands must assess whether they possess heritage assets, consciously integrate them into their brand strategies, and establish a robust narrative system to cultivate this unique brand heritage.

2.3 Research hypothesis derivation

2.3.1 The overall driving effect of narrative transmission on brand attitude

Narrative transportation is defined as a deep immersive state in which the audience psychologically enters the story world. When consumers are transported into the narrative context, their capacity for logical assessment of the real world temporarily diminishes due to the highly focused attention and emotional imagery involved. Consequently, during this process, the audience's resistance to commercial advertising messages is effectively attenuated. When traditional heritage brands face the dual challenges of perceived aging and the need to expand into the youth market, narrative transportation — through the construction of imagery and the evocation of emotion — enables consumers to experience a profound sense of story immersion. This deep engagement fosters emotional resonance with the brand, thereby significantly enhancing consumers' overall attitudes toward the brand across cognitive, affective, and behavioral dimensions. Specifically, the stronger the narrative immersion and preference of the audience, the higher the positive emotional response to the advertisement, and the stronger the

willingness to spread the word (**Kang et al., 2020**). For heritage brands like Hengshun with profound cultural heritage, the depth of the storytelling plays a significant role in determining the acceptance of brand information by consumers. When consumers are attracted and resonate with Hengshun's vinegar-making techniques, historical changes, or innovation stories, their negative stereotypes about the aging of the brand will weaken, and they will shift to more positive and youthful evaluations.

H1: The sense of narrative transportation evoked by a brand story is positively correlated with the overall enhancement of brand attitude.

2.3.2 The narrative of historical and cultural heritage strengthens the cognitive dimension

Cognition reflects the audience's rational evaluation of brand-related attributes. The core assets of a heritage brand lie in its accumulated historical legacy and enduring core values. By narrating stories—such as the legend of Du Kang's vinegar-making or historical accounts of renowned figures—a profound perception of brand heritage can be established in consumers' minds, thereby reinforcing the brand's authority and trustworthiness.

H2: Narratives grounded in historical and cultural heritage significantly shape consumers' attitudes toward the brand.

2.3.3 The activation of the emotional dimension by quality value and innovative narrative

The emotional dimension reflects the audience's affective response and preference toward the brand. In the process of attitude formation, affect is often regarded as a core influencing factor. Quality value and innovative narratives, by imbuing the brand with human warmth and emphasizing the artisans' meticulous pursuit and emotional investment in their craft, can readily evoke admiration and a sense of closeness to the brand. Such emotionally charged stories of artisanship resonate more deeply with consumers, thereby establishing a profound affective connection.

H3: Quality value and innovative narratives significantly enhance the affective dimension of consumers' brand attitudes.

2.3.4 User co-creation and emotional connection narratives' driving force on behavioral intentions

Behavioral intention refers to the audience's likelihood and tendency to take specific actions. Brands cultivate this by crafting narratives that resonate with consumers' lived experiences, transforming them from passive observers into active participants within the story. This interactive narrative approach shortens the social distance between the brand and its audience. When consumers perceive themselves as part of the brand's narrative community, their sense of narrative transportation directly translates into tangible purchase intentions and word-of-mouth behaviors.

H4: User co-creation and emotional connection narratives significantly influence consumers' behavioral intentions toward the brand.

3. Method

3.1 Sampling Frame

This study employs a mixed-methods approach, integrating qualitative decision-making with quantitative experimentation. Through expert interviews and textual analysis, narrative materials for the Hengshun brand were developed, and three narrative dimensions were identified: historical and cultural heritage, quality value and innovation, and user co-creation with emotional connection. The DEMATEL-ANP model was applied to determine expert-level logical weights, while an experiment based on the consumer ABC attitude model was conducted with a sample of young participants to examine the influence of different narrative types on brand attitudes. By comparing the experimental data, if the weight predictions derived from expert logic align with the responses of the younger audience, a successful narrative path can be synthesized. Conversely, if a cognitive

mismatch emerges—for instance, if experts prioritize historically and culturally rich stories while young consumers favor user-generated content and emotionally connected narratives—the research will conduct an in-depth analysis of the underlying cognitive differences and subsequently propose a verifiable brand narrative methodology.

3.2 Construction of the narrative type dimension

In the context of extending heritage brands into younger markets, the division of narrative dimensions should not only encompass the historical and cultural assets of the brand but also address the product and emotional needs of young consumers. Drawn from a literature review and expert interviews, this study categorizes the brand narratives of Hengshun into three dimensions: historical and cultural heritage, quality value and innovation, and user co-creation with emotional connection.

3.2.1 The Construction of Narrative Texts on Historical and Cultural Heritage

The historical and cultural heritage is the inherent competitive advantage that distinguishes heritage brands from emerging brands. For Hengshun, the depth of the brand's history and the scarcity of its culture are the core values (Wiedmann et al., 2011). In brand storytelling, the origin story serves as the foundation of brand identity. By exploring the legend of "Black Tower Vinegar," the origins of the vinegar are imbued with an artistic and mysterious quality. Furthermore, by integrating narratives associated with historical figures such as Li Bai, Yuan Mei, and Du Mu, the Hengshun brand acquires a richer layer of historical and cultural heritage.

3.2.2 The Construction of Narrative Texts on Quality Value and Innovation

Quality and innovation are regarded as the fundamental survival principles of a brand, and they play a significant role in the development of an enterprise (Fernandes, 2014). In constructing its narrative around quality value and innovation, Hengshun emphasizes its stability as a heritage brand while simultaneously highlighting its resilient vitality in response to changing times. Its continued resilience, demonstrated through several major recoveries from environmental upheavals over the past century, showcases the brand's enduring strength. In the modern market environment, Hengshun has shifted its strategic focus toward developing modern and intelligent innovative factories. This modernization, driven by technological advancement, meets consumers' high expectations for food safety and standardized quality, all while preserving a sense of human touch. The narrative also portrays the dedicated and innovative craftsmen who remain at their posts and actively embrace innovation. By adhering to a model of human-machine collaboration and maintaining innovation rooted in tradition, Hengshun revitalizes its brand vitality while upholding its commitment to quality and innovation.

3.2.3 The Construction of Narrative Texts on User Co-creation and Emotional Connection

The effectiveness of engagement marketing arises from the establishment of psychological ownership and self-transformation (Harmeling et al., 2017). When consumers invest their energy, time, or creativity in co-creation, they develop a sense of shared agency with the brand. This feeling can significantly reduce young consumers' defensive mindset toward the brand. By integrating experiences such as the Hengshun Vinegar Museum study tour, cross-border collaborations like vinegar-flavored ice cream, and vinegar-related cultural products into social hotspots, the brand embeds itself into the aesthetic life and social spaces of young people. At the same time, by collecting consumers' emotional life stories connected to the brand, a narrative is constructed that conveys the brand's emotional attachment and role as a life companion. Within this narrative framework, consumers are no longer passive recipients of brand information but active co-creators of brand meaning.

3.3 Expert decision-making through DEMATEL-ANP

A relationship matrix is used to examine the interrelationships among various elements within a research system. In this study, the factor system of the Hengshun brand narrative comprises three dimensions: historical and cultural heritage, quality value and innovation, and user co-creation with emotional connection. These three

dimensions are interrelated and collectively constitute the narrative factor system for the brand.

3.3.1 Expert decision scoring

These data are derived from evaluations provided by 10 experts, who rated the direct influence of each narrative dimension on the others. The scoring scale is as follows: 0 = no influence; 1 = weak influence; 2 = moderate influence; 3 = strong influence; 4 = extremely strong influence. The collected data were then aggregated. To minimize individual biases, the arithmetic mean of the scores from the 10 experts was calculated. Let the rating matrix of the k-th expert for the influence of element i on element j be denoted as. Then, the initial average direct influence matrix A has its elements as

$$m_{ij} = \frac{1}{10} \sum_{k=1}^{10} x_{ij}^k \quad (1)$$

Based on the aggregated scores from the 10 experts, the resulting average direct-influence matrix A was obtained. Following data aggregation, the DEMATEL data are presented in **Table 1**.

Table 1 Initial Average Direct-Influence Matrix (Expert Scoring)

Element	Historical and cultural heritage	Quality Value and Innovation	User co-creation and emotional connection
Historical and cultural heritage	0	3.8	3.0
Quality Value and Innovation	2.2	0	2.8
User co-creation and emotional connection	1.0	2.0	0

3.3.2 The calculation norms directly affect matrix N

The dimensional processing of the relationship matrix is then performed. This typically employs maximum value normalization, where each value is divided by the sum of the influence values of the elements. The formula is as follows:

$$N = \frac{A}{\text{Max}(\sum_{j=1}^n A_{ij})} \quad (2)$$

In this study, the sums of the influence values for the three narrative dimensions—historical and cultural heritage, quality value and innovation, and user co-creation with emotional connection—were calculated as 6.8, 5.0, and 3.0, respectively. The maximum of these sums is 6.8. Accordingly, each element of the initial matrix was divided by 6.8 to obtain the normalized direct-influence matrix N, which is presented in **Table 2**.

Table 2 Normalized Direct-Influence Matrix N

Element	Historical and cultural heritage	Quality Value and Innovation	User co-creation and emotional connection
Historical and cultural heritage	0	0.559	0.441
Quality Value and Innovation	0.324	0	0.412
User co-creation and	0.147	0.294	0

Element	Historical and cultural heritage	Quality Value and Innovation	User co-creation and emotional connection
emotional connection			

3.3.3 Calculate the comprehensive influence matrix T

The total influence matrix T is then derived from the normalized direct-influence matrix N. The formula is given by:

$$T = N(I - N)^{-1} \quad (3)$$

In the formula, N represents the direct influence matrix; I is the identity matrix, which means the comprehensive influence matrix T is equal to the result of multiplying the direct influence matrix by (the identity matrix minus the direct influence matrix). The comprehensive influence matrix T is shown in **Table 3**.

Table 3 Total-Influence Matrix T

Element	Historical and cultural heritage	Quality Value and Innovation	User co-creation and emotional connection
Historical and cultural heritage	0.577	1.235	1.204
Quality Value and Innovation	0.689	0.678	0.995
User co-creation and emotional connection	0.435	0.675	0.470

The values in the total influence matrix T represent the magnitude of the interaction between any two elements within the system. The larger the value, the stronger the mutual influence between the corresponding pair of elements. For instance, the value 1.235 indicates the magnitude of the influence of historical and cultural heritage on quality value and innovation.

3.3.4 Calculate the degree of influence, the degree of being influenced, the degree of centrality, and the degree of causality

From the total influence matrix T, the influence degree D of each element is obtained by summing the rows. Similarly, the influenced degree C of each element is obtained by summing the columns. The influence degree represents the extent to which an element affects other elements, while the influenced degree indicates the extent to which an element is affected by other elements. The calculation formulas are as follows:

$$D_i = \sum_{j=1}^n T_{ij}, (i = 1, 2, 3, \dots, n) \quad (4)$$

$$C_i = \sum_{j=1}^n T_{ji}, (i = 1, 2, 3, \dots, n) \quad (5)$$

By combining the influence degree D and the degree of influence C, the centrality M can be further calculated. This value is equal to the sum of the influence degree D and the degree of influence C. Its practical meaning is how significant a certain element is in the system. The larger this value is, the higher the overall status of the element in the system.

The reason degree R is equal to the influence degree D minus the degree of being influenced C. When this value is greater than 0, it indicates that the element has a greater tendency to influence other elements; otherwise, the opposite is true. The calculation formulas are as follows:

$$M_i = D_i + C_i \quad (6)$$

$$R_i = D_i - C_i \quad (7)$$

The calculation indicators of DEMATEKL are shown in **Table 4**.

Table 4 DEMATEL Results: Degree of Influence, Influenced Degree, Centrality, and Cause Degree

Element	D	C	M	R
Historical and cultural heritage	3.02	1.70	4.72	1.32
Quality Value and Innovation	2.36	2.59	4.95	-0.23
User co-creation and emotional connection	1.58	2.67	4.25	-1.07

3.4 Empirical Study on the Consumer ABC Attitude Model Experiment

3.4.1 Research experimental design plan

A single-factor three-level inter-group experimental design was adopted.

Independent variable (X): Brand narrative type, which is divided into three dimensions: historical cultural heritage C1, quality value and innovation C2, user co-creation and emotional connection C3.

Dependent variable (Y): Brand attitude response (based on the score of the ABC model).

Control variables: The subjects' original attitude towards the condiment industry, the experimental environment (online questionnaire), and the presentation duration (mandatory reading time).

3.4.2 Subject Recruitment and Procedure

Sample size: A total of approximately 300 participants were recruited and evenly divided into three experimental groups.

Selection criteria: Participants were required to be young consumers aged between 18 and 35 years who had engaged in online shopping or cooking activities within the past six months.

Experimental process: 1. Random grouping: participants were randomly assigned to one of three parallel experimental groups via a randomized link. 2. Intervention measures: each group was exposed to a corresponding narrative text or short video, with a minimum viewing duration of 30 seconds enforced to ensure adequate exposure to the stimulus. 3. Post-test: participants completed the ABC attitude scale and manipulation check questions.

3.4.3 Scale design and data collection

In the questionnaire design, brand attitude was measured using a multi-dimensional scale. This scale employed a seven-point Likert format, where scores from 1 to 7 represent progressively higher levels of agreement. By recording respondents' choices for each statement, the scale quantified their attitudes, perceptions, and behavioral tendencies toward the target topic. The scale consisted of 10 items, measuring brand attitude across three dimensions: cognitive, affective, and behavioral. An overview of the scale items is provided in **Table 5**. In addition, the questionnaire also incorporates the simplified Big Five Personality Scale to measure the five personality trait dimensions of consumers, namely openness, conscientiousness, extraversion, agreeableness, and neuroticism. The scale is scored using the Likert seven-point scale, as shown in **Table 6**.

Table 5 Measurement Scale of Consumer Brand Attitude

Number	Topic
1	After reading this story, I felt happy or surprised.
2	I felt a resonance with the emotions conveyed in this story.
3	I think Hengshun is a brand that is warm-hearted and understands life.

Number	Topic
4	This narrative dispelled my sense of distance from the heritage brand.
5	I believe that the product quality of Hengshun is highly reliable.
6	This content enables me to perceive the brand's profound professional accumulation.
7	I think Hengshun has demonstrated remarkable innovation and vitality.
8	I am willing to give a like or share this content on social media.
9	In the future shopping scenarios, I will give priority to purchasing Hengshun products.
10	I would like to recommend Hengshun to my friends around me.

Table 6 Big Five Inventory-10

Number	Topic
1	I usually like to try new things.
2	I am a person who is organized and has a plan when doing things.
3	I enjoy being the center of attention in a crowd.
4	I usually get along well with others.
5	I tend to feel anxious or nervous.
6	I am very interested in art and beautiful things.
7	I tend to do things in a rather casual manner and don't pay much attention to details.
8	I have an introverted personality and don't tend to talk much.
9	Sometimes I don't show much understanding for others' feelings.
10	I have a relatively stable mood and am not prone to getting agitated.

By combining online questionnaires with offline paper questionnaires, they were distributed to approximately 300 participants, and 290 valid questionnaires were retrieved. The collected data were then integrated into a table.

3.4.4 Data processing

Before conducting the formal analysis, this study conducted a cleaning process on the 300 collected questionnaires.

Elimination of invalid samples: Questionnaires with response times shorter than 15 seconds and those with repetitive answers were excluded.

Final valid samples: $N = 286$ (94 from the historical group, 96 from the quality group, and 96 from the co-creation group). The effective recovery rate was 95.3%.

3.4.5 Reliability analysis

The internal consistency of the scale was assessed using Cronbach's α coefficient. A higher coefficient indicates greater inter-item correlation within the scale and, consequently, more reliable measurement results. Generally, an α coefficient above 0.7 signifies good reliability; values between 0.6 and 0.7 are considered acceptable; and a coefficient below 0.6 suggests poor reliability, necessitating scale revision. The analysis results show that the α values for all dimensions exceed 0.7, indicating high internal consistency and relatively reliable measurement. The reliability assessment results are presented in **Table 7**.

Table 7 Reliability Analysis of the Measurement Scale

Variate	Cronbach's α
Emotional Response Alpha	0.892
Cognitive evaluation alpha	0.845

Variate	Cronbach's α
Behavioral intention α	0.878

3.4.6 Validity Analysis

The validity of the questionnaire was analyzed to confirm the correctness and effectiveness of the measurement results. Through validity analysis, the appropriateness of the measurement item design was assessed. The KMO and Bartlett's sphericity tests were conducted. The KMO value was 0.82 (exceeding the recommended threshold of 0.6), and Bartlett's sphericity test yielded a significance level of 0.001 (below 0.05). These results indicate that the data were suitable for factor analysis and that the structural validity of the scale was satisfactory.

3.4.7 Manipulation test

To examine whether the narrative type (independent variable) has a significant effect on brand attitude (dependent variable), a one-way analysis of variance (ANOVA) was conducted. For all three narrative dimensions, the F-values were statistically significant, with p-values below 0.001. This result strongly supports the research hypothesis that the choice of narrative style for the Hengshun brand significantly influences the psychological responses of young audiences. Given the significant ANOVA results, the LSD post-hoc test was further employed to identify specific differences between groups. The results are presented in **Table 8**.

Table 8 One-Way ANOVA Results of Consumer Brand Attitude Responses Across Different Narrative Types

Element	Historical cultural heritage C1	Quality value and innovation C2	User co-creation and emotional connection C3	F	ρ	Comparison (LSD)
Emotional Response	2.85	4.20	6.15	58.42	<0.001	C3>C2>C1
Cognitive evaluation	5.92	4.85	3.90	24.15	<0.001	C1>C2>C3
Behavioral intention	2.55	4.10	5.85	54.33	<0.001	C3>C2>C1

To ensure the comparability of the experimental groups, this study further examined whether there were significant differences in the three narrative dimensions on the personality trait dimensions. The results of the one-way analysis of variance showed that in the five dimensions of openness, conscientiousness, extraversion, agreeableness, and neuroticism, the mean differences among the three groups did not reach a significant level ($p > 0.05$), indicating that the random grouping of the subjects was effective and the personality traits did not cause systematic interference to the experimental results. The results are presented in **Table 9**.

Table 9 Comparison of Personality Trait Means Across Narrative Groups

Personality Trait	Historical cultural heritage C1	Quality value and innovation C2	User co-creation and emotional connection C3	F	ρ
Openness	5.12	5.23	5.03	0.28	> 0.05
Conscientiousness	5.28	5.41	5.19	0.35	> 0.05
Extraversion	4.92	5.08	5.02	0.22	> 0.05

Personality Trait	Historical cultural heritage C1	Quality value and innovation C2	User co-creation and emotional connection C3	F	p
Agreeableness	5.18	5.32	5.09	0.31	> 0.05
Neuroticism	5.04	4.92	5.855.17	0.41	> 0.05

4. Result

This study conducted a multi-dimensional and in-depth analysis of the narrative approach of the Hengshun brand through the combination of expert decision-making DEMATEL and the consumer ABC attitude model. This study first constructed a narrative text consisting of three dimensions: historical cultural heritage, quality value and innovative narrative, user co-creation and emotional connection. Ten experts scored the direct influence degree between these dimensions based on the scoring criteria, and the arithmetic average method was used to eliminate individual deviations. When calculating the standardized direct influence matrix N, the research data showed that the sum of the influence relationship values of the three elements was 6.8, 5.0, and 3.0, respectively. The maximum value 6.8 was taken as the normalization benchmark. Through matrix operations, the comprehensive influence matrix T was obtained. The data results show that the historical and cultural heritage has a significant impact on the value of quality and innovation, with an amplitude value of 1.235. This indicates a strong correlation between the two. In the quantitative assessment of indicators, the influence degree D of historical and cultural heritage is 3.02, and the reason degree R is 1.32. This clearly demonstrates its driving position as a causal factor. The centrality M of the narrative of quality value and innovation is 4.95, ranking first, proving that it holds a core position in the entire narrative system. However, the reason degree R of user co-creation and emotional connection is -1.09, indicating it is a typical result factor and is easily influenced and driven by other factors.

During the empirical research phase, this study employed a single-factor three-level between-group experimental design to verify the actual impact of the aforementioned narrative dimensions on the brand attitudes of young audiences. A total of 300 young consumers aged 18-35 were recruited. After data processing, 286 valid samples were obtained (with an effective rate of 95.3%). Among them, there were 94 samples in the historical cultural heritage group, 96 samples in the quality value and innovation group, and 96 samples in the user co-creation and emotional connection group. The measurement was conducted using the Likert seven-point scale across three dimensions: emotions, cognition, and behavioral tendencies, involving a total of 10 items. The reliability analysis revealed that the Cronbach's α coefficients for emotional response, cognitive evaluation, and behavioral intention were 0.892, 0.845, and 0.878, respectively, all of which were greater than 0.7, indicating that the measurement tool has extremely high internal consistency. In the validity test, the KMO value was 0.82, and the Bartlett's test of sphericity significance was 0.001 (less than 0.05), suggesting that the scale structure validity was good and suitable for factor analysis. The manipulation check results show that the choice of brand narrative style has a decisive influence on the psychological responses of young audiences. The F values for each dimension are significant and the p values are less than 0.001. Through the LSD method for comparison, it was found that in the emotional response dimension, the scores were C3 (6.15) > C2 (4.20) > C1 (2.85), indicating that user co-creation can most effectively evoke audience empathy and reduce the distance between the brand; in the cognitive evaluation dimension, the scores were C1 (5.92) > C2 (4.85) > C3 (3.90), proving that historical cultural heritage is the cornerstone for establishing a reliable brand quality perception and professional accumulation; in the behavioral intention dimension, the scores were C3 (5.85) > C2 (4.10) > C1 (2.55), clearly revealing the efficiency of the co-creation narrative in driving likes, sharing, and priority purchase behaviors.

5. Discussion

5.1 Conclusion and Analysis

Based on the comparative analysis of the above two sets of experimental data, we can start from the differences between the expert's logical weight and the feedback from young audiences.

Conclusion 1: Cognitive Displacement

Through data comparison, it was found that in the expert decision-making model (DEMATEL-ANP), the centrality of user co-creation and emotional connection was the lowest among the three dimensions, at 4.25, with a cause degree of -1.09. This negative value indicates that experts qualitatively identified this dimension as an effect item in brand communication. In contrast, the cause degree for historical and cultural heritage was 1.32, suggesting that experts tended to regard it as a cause item. However, among the young audience, this same dimension—user co-creation and emotional connection—recorded the highest scores across the entire sample for both emotional response (6.15) and behavioral intention (5.85). This finding suggests that, from the perspective of young consumers, user co-creation and emotional connection are perceived as the key drivers in transitioning from cognitive awareness to actionable engagement.

Reason analysis: Experts believe that the brand-building path should proceed from the inside out, with emotions cultivated gradually over time. In this view, a brand can evoke users' emotional resonance only after establishing a historical foundation and core quality. In contrast, the consumption decision-making logic of young consumers diverges from that of experts. For younger audiences, affect serves as the primary driver in making consumption decisions. Value is not transmitted unilaterally by the brand, but is formed in the consumers' daily lives and social contexts (**Heinonen & Strandvik, 2015**). User-generated narratives serve as the initial entry point, sparking interest and motivating deeper engagement with the brand. The significant cognitive discrepancy between experts and young audiences regarding the logical sequence of brand narrative fundamentally reflects a mismatch between supply and demand. In the DEMATEL-ANP analysis, experts follow an inside-out logic grounded in the robustness of the brand system. They identify historical and cultural heritage as the driving factor (cause degree = 1.32), position quality value and innovation as the narrative core (centrality = 4.95), and regard user co-creation and emotional connection as natural by-products emerging from the integration of these elements (cause degree = -1.09). In contrast, the ABC attitude model experiment reveals that young audiences adopt a logic of affective perception rooted in social interaction. They treat affect as the primary gateway for activating brand attitudes. For young consumers, while traditional historical narratives can establish cognitive trust, they lack behavioral intention due to the absence of audience participation. In comparison, co-created narratives that evoke emotional resonance shorten psychological distance with the brand and generate purchase intention. The root cause of this divergence lies in the experts' focus on the functional legitimacy of the brand—that is, establishing professionalism and reliability through historical accumulation. This explains why historical and cultural heritage scores highest in cognitive evaluation (5.92). Meanwhile, young consumers in their daily lives prioritize the brand's social relevance and personal resonance, emphasizing affective connection. Consequently, user co-creation and emotional connection score highest in affective evaluation (6.15), revealing a fundamental cognitive disconnect between the logic of experts and that of the young audience. At the same time, Rosenberg believes that attitudes are systematically driven and maintained by a decomposable cognitive structure system. This cognitive structure consists of two independent and operational core dimensions: the importance of value and the perceived instrumentality (**Rosenberg, 1956**). Consumers may perceive a brand's history as personally irrelevant or even detrimental to achieving contemporary values such as innovation, fashion, and cost-effectiveness. Consequently, they fail to develop a positive affective response, which ultimately results in weak behavioral intention.

Conclusion Two: Sluggish Transformation

Comparative analysis reveals that experts identify historical and cultural heritage as the primary driving factor of attitudes, with a cause degree of 1.32—the highest among all dimensions. Data from the consumer ABC attitude experiment confirm that the historical narrative group scored highest in cognitive evaluation (5.92), substantially exceeding the other groups. This indicates that, from the perspective of young audiences, historical narratives play a crucial role in establishing perceptions of brand heritage and trustworthiness. However, this same group recorded the lowest scores in both behavioral intention (2.55) and affective response (2.85). Thus, while historical and cultural heritage effectively builds deep cognitive associations in consumers' minds, it does not translate into purchase-related behavioral tendencies.

Reason analysis: For young audiences encountering heritage brands, the psychological evaluation of brand perception and the triggering of consumption decisions operate in two distinct dimensions. This separation stems from a divergence in psychological distance. In the experimental data, the cognitive evaluation score for the historical and cultural heritage narrative group reached 5.92, indicating that audiences strongly affirm the brand's historical depth and legitimacy at a rational level, thereby generating a sense of authority. However, this sense of authority is often accompanied by a relatively distant psychological distance, resulting in an affective response of only 2.85. For young consumers, a brand with profound historical and cultural accumulation is worthy of respect. Yet, if it fails to enter their daily social context or emotional life, this respect remains confined to the cognitive level and fails to translate into behavioral intention, ultimately impeding changes in consumption decisions. As Sirgy's self-image congruity theory posits, consumers are not purchasing the product itself, but rather the extent to which the product image aligns with or promises consistency with their own self-image (**Sirgy, 1982**). Consumers tend to purchase products from brands that align with their self-image. A brand's history represents social recognition, while the emotional connection fostered through user participation pertains to self-expression. Young consumers acknowledge the legitimacy and authority of a brand through its historical narratives, yet they also base their consumption decisions on the brand's user-generated content and emotional resonance. If a heritage brand fails to transform its historical assets into a medium of social expression capable of carrying the audience's self-image, this sense of authoritative recognition may become an invisible barrier. Consequently, the brand may encounter a situation in which consumers respect it but do not translate that respect into commensurate purchasing behavior.

Conclusion Three: Status Discontinuity

Comparative analysis reveals that experts regarded quality value and innovation as the core of narrative dissemination, with a centrality of 4.95—the highest among all dimensions. However, data from the consumer ABC attitude experiment indicate that the quality value and innovation narrative exhibited a distinctly centralized pattern. Across all three dimensions—cognitive evaluation (4.85), affective response (4.20), and behavioral intention (4.10)—its scores consistently occupied the middle position, situated between the historical heritage group and the user co-creation group.

Reason analysis: For young audiences, products from heritage brands like Hengshun are generally assumed to be of high quality. This psychological expectation, rooted in ingrained perception, leads to perceptual blunting toward related narratives. In the context of information-saturated social media, and viewed through the lens of Herzberg's Two-Factor Theory (**Herzberg et al., 2017**), exquisite craftsmanship and rigorous quality standards are often regarded by young consumers as inherent brand benefits rather than motivating factors. Traditional quality narratives, which tend to emphasize profound professional expertise, reinforce the brand's industry position at a cognitive level but remain weak in terms of affective engagement. For young audiences who prioritize visual impact and social interaction, such narratives lack the emotional resonance necessary to activate psychological involvement—unlike user co-creation and emotionally connected stories, which generate high affective response.

5.2 Narrative Strategy

This study reveals a significant discrepancy between expert logic and the psychological responses of young audiences. For heritage brands seeking to expand into the youth market, a decision-making framework should be adopted that prioritizes the affective entry point of young consumers. Specifically, a narrative path of "emotional entry – cognitive deepening – behavioral transformation" is proposed. This path begins with user co-creation and emotional connection as the brand's narrative entry point, utilizing authentic consumer life scenarios, emotionally resonant stories, or cross-border collaborations to rapidly narrow the psychological distance between the brand and young audiences. By leveraging the highly affective response triggered by narrative transportation, the aim is to activate emotional resonance and social sharing intentions among young consumers. Once audiences develop an emotional affinity for the brand, narratives centered on historical and cultural heritage can be naturally introduced to establish brand authority and trust, thereby enhancing cognitive evaluation. Finally, quality value and innovation narratives—such as those highlighting intelligent factories or artisans' commitment to tradition and innovation—serve to consolidate rational quality recognition and facilitate the translation of consumer attitudes into behavioral intention.

Historical and cultural heritage narratives can be transformed into participatory, expressive, and collaborative social content. The historical stories of Hengshun are reconstructed through contemporary media formats. For example, the legend of "Du Kang making vinegar" can be adapted into short videos, Guochao-style animations, or co-branded cultural products, inviting young audiences to participate through reinterpretation and co-creation. At the same time, user-generated content such as "My Daily Story with Hengshun" or "100 Ways to Use Vinegar" is encouraged, integrating the brand's history into the everyday lives of young consumers. This approach encourages young consumers to reframe their consumption as a means of cultural self-expression, thereby helping to bridge the psychological distance. Given that young consumers perceive the quality of heritage brands as a natural and necessary hygiene factor, a covert narrative strategy is therefore appropriate. Quality-related information is embedded within scenarios and experiences, allowing consumers to gradually internalize the brand's core quality throughout the narrative process.

In practical brand communication, the proportion of the three narrative types should be flexibly adjusted according to the characteristics of different media and target users. In emotionally driven, fragmented content scenarios—such as social media platforms and short-video channels—priority should be given to promoting user-generated content and emotionally resonant stories. In contrast, in deep content scenarios—such as official websites, documentaries, and brand museums—historical and cultural heritage narratives, along with quality and innovation stories, should be prominently featured. In purchase-oriented scenarios, such as e-commerce product pages and live-streaming sales, emotional narratives can serve as a transitional guide, while historical and quality narratives help facilitate the final consumption decision. Furthermore, brands should establish a dynamic monitoring mechanism for narrative effectiveness, regularly evaluating the performance of different narrative types across affective response, cognitive evaluation, and behavioral intention. This enables timely optimization of content strategy, activation of the youth market, and ultimately the sustained vitality and transformation of the brand.

6. Conclusion

This study takes the heritage brand Hengshun as a case example to investigate how heritage brands can achieve brand activation in the youth consumer market through storytelling. The research employs the expert decision-making method DEMATEL-ANP alongside an experimental approach based on the consumer ABC attitude model to compare the differential effects of brand storytelling as perceived by experts versus young

audiences. The findings reveal a significant cognitive disconnect between experts and young audiences regarding the logical sequence of brand storytelling. Based on these results, this study proposes a narrative path tailored to young audiences: "emotional entry – cognitive deepening – behavioral transformation. This path begins with user co-creation and emotionally connected narratives to establish resonance and stimulate interest, followed by the introduction of historical and cultural heritage narratives to deepen brand recognition and trust. Quality and innovation narratives then consolidate rational identification and facilitate behavioral transformation. In terms of theoretical contribution, this study extends the boundaries of brand narrative marketing research, verifies the differential impacts of various narrative types on cognitive, affective, and behavioral dimensions, and provides a new foundation for applying the ABC attitude model in the context of heritage brands. From a practical standpoint, it offers a verifiable brand narrative pathway for Hengshun and other heritage product brands, enabling brand managers to refine their brand strategies, effectively expand into the youth market, and sustain brand vitality. However, this study has certain limitations. The experimental sample is limited to specific brands and age ranges. If future research can include more relevant moderating variables, conduct long-term follow-up studies, and supplement qualitative analysis in subsequent research, then the research results will be more comprehensive and in-depth, and the proposed brand narrative strategies will be more adaptable and sustainable, thereby providing more systematic theoretical support and practical guidance for the revival of global heritage brands.

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