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Research on Spatial Color Design and Enhancement Strategies in the Revitalization of Wuhan Tongxing Lane: A K-means Cluster Analysis-Based Approach

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Abstract: In recent years, Wuhan's traditional alleyway neighborhoods ("Lifen") have gradually shifted from residential units to commercialized development, inevitably leading to weakened residential functions and fading cultural characteristics. This study takes Tongxing Lane as its research object, examining how color design can introduce commercial vitality while preserving the cultural essence of these historic alleyways. It explores the critical role of color design in revitalizing traditional residential units—balancing urban development with historical continuity through synergistic approaches with commerce—where the dual demands of cultural representation and commercial vibrancy pose urgent challenges for urban regeneration and planning. The paper is structured in three parts: First, it investigates the cultural values embedded in Jing-Chu regional color traditions and early modern architectural palettes. Next, it analyzes the significance of spatial color in historic streetscapes for both cultural preservation and commercial appeal. Finally, employing quantitative methods such as cluster analysis, the study visualizes Tongxing Lane's chromatic profile and cross-references it with cultural color benchmarks. This systematic evaluation reveals gaps in the current color scheme's efficacy for cultural symbolism and commercial functionality, elevating color from mere aesthetics to a mediatory tool reconciling culture and commerce. Grounded in urban renewal principles, the research concludes with color optimization strategies for Tongxing Lane's public spaces.

Key words: Color geography; Historic streets; Spatial optimization; Jing-chu culture

1 Introduction

Against the accelerating tide of global urbanization, urban regeneration has emerged as an inevitable trajectory for metropolitan development worldwide. Far beyond mere physical and spatial transformation, this process profoundly

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engages cultural, social, and economic dimensions, striving to elevate urban quality and enhance competitiveness in response to humanity's escalating aspirations for better living. In Wuhan, the distinctive Lilong-style residential architecture embodies historical memory, cultural traditions, and regional identity, serving as a vital vessel of vernacular heritage. Yet rapid urbanization has increasingly commercialized these neighborhoods, risking irreversible damage to historic structures and cultural continuity during redevelopment. Within this context, color proves uniquely significant—simultaneously encoding deep cultural DNA while directly shaping commercial ambiance and consumer psychology. This dual capacity positions chromatic strategies as a critical medium for reconciling cultural representation with commercial vitality in Lilong revitalization efforts.

Scholars widely acknowledge that the most distinctive morphological characteristics of Lilong reside in its East-meets-West architectural style and neighborhood unit spatial layout. Zhang Na (2023) and Zhou Hong et al. (2010) conducted detailed analyses of Lilong's brick-wood structures, decorative moldings, and courtyard designs, revealing how their natural material textures collectively form the district's understated and harmonious chromatic foundation. From a socio-cultural perspective, Wang Jing et al. (2023) established theoretical grounding for extracting the cultural base color by emphasizing a deep comprehension of cultural genes. As tangible embodiments of Wuhan's regional identity, Lilong neighborhoods necessitate that any chromatic intervention be rooted in cultural authenticity. However, accelerating commercialization has triggered visual clutter and cultural erosion, raising urgent concerns. Chen Kang et al. (2025) argued from a living heritage standpoint that applying such approaches to Hankou Lilong's revitalization demonstrates both necessity and applicability, proposing a regeneration framework centered on dynamic heritage preservation. Case studies by Ning Linyuan (2023) and Wang Minghao (2022) further exposed systemic challenges in historic district conservation, including inadequate prioritization and encroaching modernity. While existing research has delineated Lilong's spatial-cultural attributes and core preservation dilemmas while introducing advanced methodologies, targeted strategies leveraging spatial color as a mediator between cultural signification and commercial vitality remain underexplored. This gap constitutes the present study's innovative focus.

Centering on Wuhan's Tongxingli district, this research investigates how chromatic design can synergize cultural continuity with commercial revitalization in historic urban renewal. Integrating theories from color geography and color psychology with quantitative analysis, it systematically evaluates Tongxingli's existing chromatic patterns to derive optimized design strategies. The findings aim to establish generalized chromatic principles for historic districts, offering theoretical and practical insights for Lilong's regeneration and analogous contexts globally.

2 Theoretical Foundations of Color Design

2.1 The Theory of Place Identity in Color Geography

The Color Geography as an Interdisciplinary Discipline Developed in the 1960s by French chromatologist and design master Jean-Philippe Lenclos, color geography is grounded in systematically categorizing regional color specimens to extract localized chromatic characteristics, thereby providing a theoretical foundation for design practice. The theory seeks to uncover intrinsic connections between geographic environments and color phenomena, with its methodological innovation lying in integrating color-space interactions into its analytical framework—wherein "space" encompasses both the materiality of physical entities and the cognitive dimensions of cultural perception (Zhang

et al., 2025). Ethnochromatic geography employs methodological practices such as field surveys, chromatographic documentation, specimen collection, data synthesis, genealogical classification, and regional chromatic analysis to study localized color traits. Its findings supply crucial color reference systems for urban planning, architectural and environmental landscape design, and modern industrial production. Comparatively, color geography as a theoretical construct elucidating the dynamic interplay between color, regional environments, culture, and social dynamics emphasizes interpreting color as an intrinsic attribute of geographic milieus. Moving beyond traditional aesthetics-focused color studies, this paradigm situates color within "local identity," positing that regional hues emerge from the interplay of natural surroundings, cultural heritage, and human activity, thereby forming irreplaceable cultural markers. Consequently, color geography encompasses a broad scope, investigating both natural chromatic expressions (e.g., sky, soil, rocks, water systems, and vegetation) and cultural manifestations (including architectural, sculptural, decorative artifacts, and culturally embedded color systems). Through in-depth data analysis and interpretation, the discipline seeks to reveal spatial distribution patterns, evolutionary trends, and sociocultural connotations embedded within geographic color schemes(Xu, 2024).

Within the context of urban renewal, chromatology's significance resides in its capacity to identify and preserve a locale's "color DNA." These chromatic signatures stem from indigenous environmental conditions and cultural traditions, crystallizing over prolonged historical settlement to become integral components of regional cultural identity. Scholar Wang-Heng Chen posits in environmental aesthetics research that ecosystems fundamentally constitute symbiotic habitats merging human and natural elements, with color serving as this coexistence's most immediate visual manifestation.

2.2 The Role of Color in Commercial Environments

Research in color psychology demonstrates that specific hues can significantly influence emotional responses and cognitive states. Red tones evoke a sense of vitality, while colors with higher saturation and brightness tend to induce excitement. Furthermore, the combinatorial characteristics of multiple colors can trigger diverse perceptual experiences (Song & Xiao, 2025). Color extends far beyond aesthetics—it serves as a potent medium for information transmission, profoundly affecting individuals' emotional conditions, cognitive processes, and behavioral tendencies(Elliot & Maier, 2014).

In the commercial revitalization of historic districts, the appropriate application of color not only enhances spatial attractiveness but also boosts commercial vitality while preserving cultural heritage. This characteristic makes color a crucial design element in shaping commercial environments. From an environmental perspective, integrating color with surroundings helps beautify and unify architectural styles while enhancing the atmosphere of commercial spaces. From a consumer psychology standpoint, different hues evoke distinct emotional responses. Warm tones like red, orange, and yellow typically stimulate excitement and urgency in consumers and, when used judiciously in dining and retail spaces, can effectively drive purchasing behavior. Conversely, cool tones such as blue and green foster tranquility and trustworthiness, making them particularly suitable for cultural exhibitions and leisure-focused commercial settings. It is important to note that both saturation and brightness exert significant psychological effects. While highly saturated colors capture more visual attention, excessive use may cause eye fatigue. Conversely, low-brightness colors convey sophistication and elegance. As contemporary lifestyles grow increasingly diverse and quality-oriented, consumers are placing greater emphasis on the ambiance of commercial spaces beyond mere product functionality, seeking comfort and emotional fulfillment during their purchasing experiences(Jiang, 2019).

3 Analysis of Jingchu Cultural Colors and Modern Architectural Color Schemes

3.1 Modern Architectural Color Analysis

The establishment of the Modern Chinese Architectural History Committee under the Architectural History Society of China in August 1977 marked a significant milestone in the academic recognition of modern architecture as an independent research field. This institutionalization trajectory signified the transition of related scholarship into standardized and systematic development(Li, 2004). During China's modern period, architectural styles maintained classical traditions while profoundly absorbing Western architectural philosophies. A prevailing European architectural form emerged, characterized by innovative wall construction techniques including extensive application of fair-faced brickwork and polychromatic decorative treatments. These stylistic innovations stimulated advancements in brickmaking technology, ultimately leading to the proliferation of European-style red bricks while preserving traditional blue-gray brick techniques(Sha, n.d.). Such buildings became prevalent during the 1880s, with late 19th-century facades predominantly featuring blue-gray brickwork accented with red elements. The majority exhibited light-colored finishes in pale yellow, green, and pink tones. Subsequently, from the late 19th century to the early to mid-20th century, China's brick industry experienced rapid development, primarily producing blue-gray and red bricks.

China possesses a vast territory with abundant resources, a large population, and a profound cultural heritage. Diverse physiographic conditions have shaped distinct lifestyles and resultant aesthetic paradigms. Such variations manifest not only in architecture but also in attire and linguistics. By the 21st century, increased academic and societal attention to regional architecture has fostered critical conceptual developments. Regional architecture serves as the primary embodiment of critical regionalism theory. Grounded in specific locales and cultural contexts, this approach traces authentic trajectories of daily life while maintaining enduring connections between architectural works and their socio-environmental milieus. Significantly, critical regionalism achieves vernacular adaptation through experiential learning—encompassing restoration, refinement, compromise, and innovation—thereby responding to local distinctiveness. Its theoretical and practical foundations derive from multifaceted elements, including local history, geographical contexts, humanistic values, economic circumstances, technological traditions, and cultural practices, all of which collectively constitute the phenomenological spatial authenticity perceived by users (Slessor C, 2001).

3.2 Regional Architectural Color Characteristics

3.2.1 Traditional Chinese Five Colors System

The "Rites of Zhou·Artificers' Record" documents: "In painting and dyeing, the five colors are skillfully blended. The eastern orientation is designated cyan, southern vermilion, western white, and northern black. Heaven is termed profound (dark blue), while earth is referred to as yellow." Traditional Chinese chromatic application developed an indigenous color system employing red, yellow, cyan, white, and black as its fundamental scheme(Xu J, 2024). Urban vernacular architecture eschewed ornamental display of "five-color brilliance", preserving natural grayish-blue hues through construction materials like grayish-blue tiles and gray bricks characteristic of courtyard dwellings and alleyways. Notably, chromatic transitions radiate progressively from urban centers to peripheries, manifesting systematic

shifts from primary to composite hues, high to low saturation, and high to low lightness. This chromatic configuration emerges not arbitrarily but rather through deep-rooted hierarchical conventions—wherein color functionally demarcates architectural purposes and denotes stratified social status—thereby engendering an urban color system distinguished by contextual clarity and integrative harmony (Yi, 2023).

3.2.2 Analysis of Color Characteristics in Jingchu Culture

Within the Jingchu cultural context, the characteristic colors commonly employed by Chu people—ochre, pale yellow, dark red, purple, and emerald green—were systematically derived through modulation of the orthodox color system. These adjacent or analogous hues exhibit minimal differentiation, presenting soft contrasts that readily coalesce into unified chromatic tonalities (Yang, 2025).

Analysis of Jingchu material culture reveals the following color spectrum:Textiles: Red, brown, yellow, purple, blue, umber, greenEmbroidery: Red (red, crimson, vermilion, scarlet), brown (brown, reddish-brown, dark brown), yellow (yellow, light yellow, ochre, golden, yellow-green)Lacquerware: Red (red, crimson, vermilion, scarlet), yellow (yellow, light yellow, ochre)Others: Brown-umber, gold, silver, white, blue, cyan, ochre, gray (Cai, 2014). The data demonstrate predominant utilization of warm hues—particularly reds, yellows, and browns—within Jingchu material culture. As the principal cultural tradition of southern China, Chu culture manifests through Wuhan's urban morphology via rigorously symmetrical and orthogonal spatial configurations.

4 Quantitative Analysis of Chromatic Status in Tongxingli

4.1 Acquisition and Processing Pipeline of Chromatic Data in Tongxingli

Based on preliminary research, Tongxingli was categorized into three fundamental typologies: "commercial operation zones," "residential living quarters," and "external street facades."

In the data processing phase, the K-means clustering algorithm was employed to systematically categorize and analyze the color data. After multiple trials, the optimal cluster count was determined to be K=15. Street view image pixels were converted from the RGB color space to the more perceptually uniform Lab color space for clustering computations. This process identified color proportions, dominant colors, secondary colors, and accent colors. Analytical results revealed distinct hierarchical characteristics in Tongxingli's chromatic composition:

Figure 1 Part I: Business operation zones

Figure 2 Part II: Business operation zones

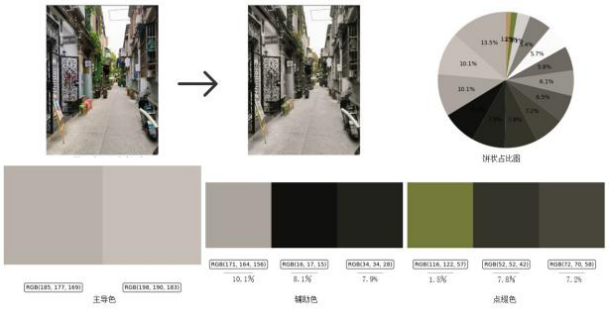

Figure 3 Part II: Business operation zones

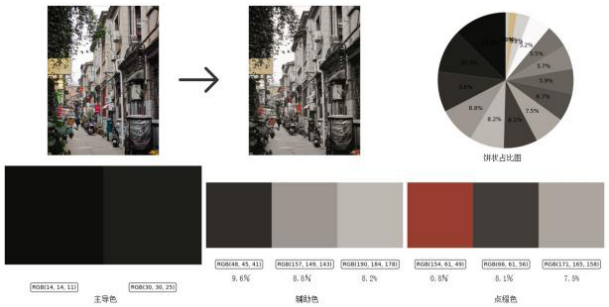

Figure 4 Part IV: Business operation zones

The commercial districts primarily feature warm gray tones with low brightness and saturation levels, including RGB(28,26,20) and RGB(42,40,31), collectively accounting for approximately 30.6% of the color scheme. These hues predominantly originate from the blue-gray bricks, gray tiles, and stone foundations of building facades. Secondary colors encompass medium-brightness warm tones such as RGB(57,53,49), representing about 19.1% of the palette and reflecting the chromatic characteristics of traditional timber structures and partial wall surfaces. Accent colors demonstrate higher saturation levels, exemplified by ochre-red shades like RGB(121,50,25), which constitute roughly 13.2% of the spectrum and mainly derive from commercial signage and decorative elements.

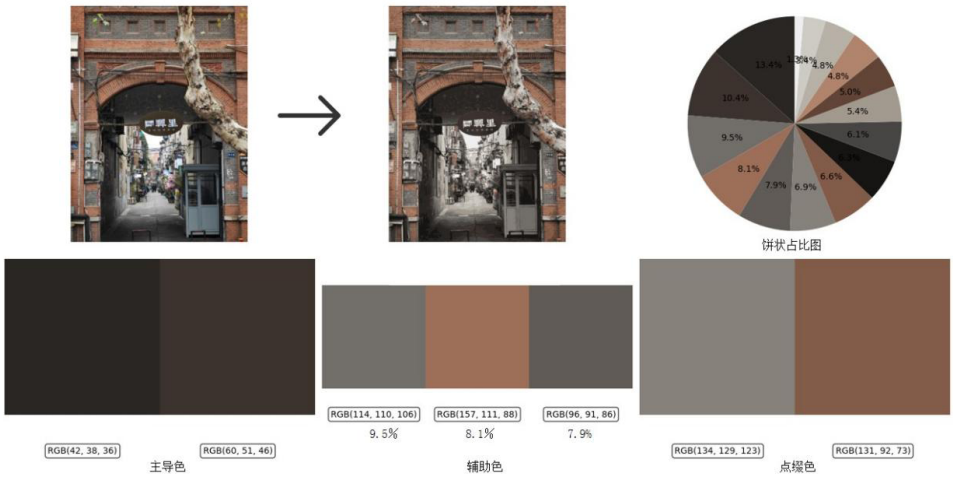

Figure 5 Commercial district quantitative analysis chart

The dominant hue in exterior streets presents as a light gray tone (RGB: 114,110,106), constituting approximately 9.5% of the chromatic distribution. Excluding shadowed areas, this establishes the neutral foundation for facade coloration. Secondary chromatic elements include warm ochre (RGB: 157,111,88) at 8.1% and medium gray (RGB: 96,91,86) at 7.9%, complemented by light gray (RGB: 134,129,123) and reddish ochre (RGB: 131,92,73). The overall palette demonstrates low saturation with medium-to-low brightness, primarily featuring warm ochres and light grays. Warm tonalities manifest principally through reddish-ochre hues, serving crucial balancing functions within the facade composition. The chromatic brightness range remains relatively concentrated, generating harmonious visual cohesion. Notably absent are high-saturation colors, aligning with traditional neighborhood color characteristics.

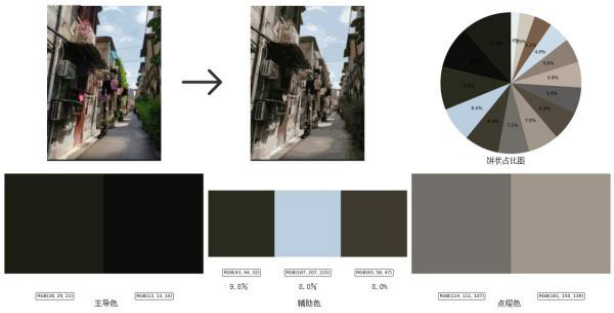

Figure 6 Part I: Residential living area

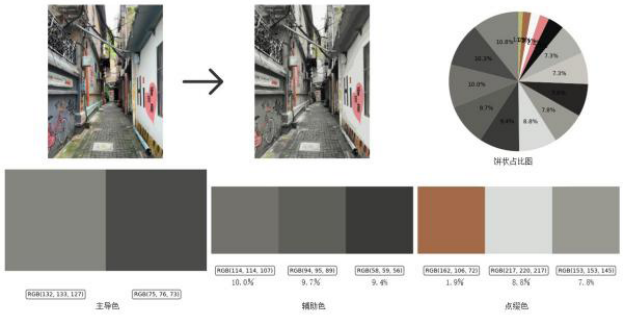

Figure 7 Part II: Residential living area

The residential quarter's color system predominantly features low-saturation grays concentrated within the yellow-gray spectrum range. The moderate brightness levels create smooth visual transitions, with warm tones minimally represented by ochre (RGB: 162,106,72). The limited chromatic presence and absence of high-saturation hues align with the zone's functional requirements for tranquility and restraint.

Quantitative analysis of chromatic distribution across functional zones reveals that the commercial district exhibits markedly higher proportions of accent colors with dispersed hue distribution. Residential areas maintain traditional tonal consistency through dominant hues, while public thoroughfares demonstrate transitional characteristics intermediate between the two zones.

4.2 Summary of Color Characteristics in Tongxingli

The infiltration of commercial elements exacerbates the lack of unified street planning. Merchants freely design storefronts and alter building facades to enhance the visual identity of "internet-famous alleys," yet these practices often compromise historic building preservation(Zhou, 2023). Based on K-means clustering results, this study successfully extracted Tongxing Lane's color clusters, revealing three distinctive spatial-color characteristics.

First, regarding overall chromatic structure, Tongxing Lane exhibits a "warm-gray base with colored accents" pattern. Data analysis shows cluster C1 (light warm gray, RGB[215,210,202]) dominates at 42.7%, primarily from plastered walls and natural stone; cluster C2 (deep brick-red, RGB[145,85,72]) accounts for 18.3%, seen in traditional brickwork and architectural details—together forming the base tones. Clusters C3 (high-saturation red, RGB[154,61,49]) and C4 (blue, RGB[95,151,209]) serve as accents (31.5% combined), appearing predominantly in modern commercial elements like store signs.

Second, functional zones show clear chromatic differentiation. Commercial areas feature more accent colors (C3–C4) with dispersed hues, creating high visual activity but poor harmony. Residential areas retain traditional tones, where base colors (C1–C2) dominate with unified harmony. Transitional corridors display intermediate characteristics but suffer strong commercial color infiltration.

Finally, cultural analysis reveals a complex relationship between current colors and traditional Jing-Chu chromatic genes. Comparing clusters with Jing-Chu heritage shows base colors (C1–C2) maintain strong hue/value continuity with historic gray-brick roofing and warm wood tones, whereas commercial accents (C3–C4) deviate markedly in hue/saturation from traditional palettes.

Two critical issues emerge: (1) High-saturation commercial colors visually overwhelm traditional tones, disrupting

streetscape harmony; (2) Disordered color application erodes cultural distinctiveness, rendering Tongxing Lane visually generic and failing to express its unique historic value through chromatic language.

5 Discussion on Optimization of Chromatic Coordination Design Strategies

5.1 Current Issues of Tongxingli Under the Jing-Chu Color Context

In the ancient Jing-Chu region of China, vermilion was widely revered as an aesthetic preference, with this chromatic inclination prominently manifested in traditional architectural designs. Specifically, architectural components, including roof ridges, doors/windows, structural columns, and wall carvings, were systematically adorned with vermilion hues, thereby establishing a distinctive visual chromatic identity. However, contemporary architectural applications risk causing visual disharmony when employing vermilion extensively, potentially disrupting the overall coherence of structural compositions. Thus, judicious incorporation of vermilion accents is recommended—such as in eaves, window frames, and balcony columns—to preserve traditional chromatic aesthetics while enriching architectural layering. These strategic applications enhance vitality without inducing excessive visual dissonance (Liu, 2018). Within the Tongxingli district, vermilion has been selectively adopted in eaves, door frames, windows, and commercial façades as ornamental elements. Yet, excessive design autonomy among merchants has led to the adoption of hyper-saturated hues, which frequently undermine the planned cultural and historical integrity of the streetscape.

5.2 Optimization Strategies for Chromatic Planning in Commercial Districts

In commercial district color planning, priority should be given to employing low-saturation red hues while implementing unified color schemes for storefront accents and streetscape embellishments. This involves restricting the color varieties of detailing elements to maintain harmony with the overall palette. To address current issues of chromatic overstimulation and cultural identity dilution, a rigorous chromatic management system must be established. First, the traditional “cinnabar red” requires contemporary reinterpretation through saturation reduction to create a standardized “ochre-cinnabar” color spectrum (RGB range: ochre [150,80,70] to cinnabar [200,70,60]), with strict application limited to commercial elements like signage and awnings. Concurrently, building facades should maintain a blue-gray base tone (RGB: 120,120,110). Leveraging the classic red-gray chromatic relationship ensures visual vibrancy while reinforcing the distinctive color characteristics of Jing-Chu culture. This approach offers dual advantages:(1) Unified color standards prevent disruptive commercial hues from compromising historical aesthetics. (2)Merchants retain sufficient creative latitude, achieving dynamic equilibrium between cultural preservation and commercial vitality.

5.3 Optimization Strategies for Chromatic Planning in Residential Areas

To address the issues of chromatic monotony and spatial hierarchy deficiency in residential areas, we recommend adopting an overall low-brightness color scheme while retaining the original wall hues. Under the strict preservation of buildings’ foundational bluish-gray wall coloration (RGB: 114,114,107), improvements can be achieved through the introduction of low-brightness, low-saturation complementary color systems. Specifically, professionally calibrated warm ochre tones (RGB: 162,106,72) with saturation precisely controlled within 20%-30% and brightness maintained at 40%-60% may be applied to window/door components, railing systems, and architectural details. This chromatic

intervention strategy can achieve three optimization objectives:

(1) Preserving the unique sense of place, security, and visual comfort intrinsic to historic architecture.

(2) Enhancing spatial aesthetic quality through subtle chromatic gradation.

(3) Improving residents' living environment quality while progressively maintaining regional architectural characteristics, ultimately achieving synergy between heritage conservation and contemporary residential needs.

5.4 Optimization and Summary of External Street Color Strategies

Functioning as a critical transitional zone linking retail districts, the chromatic planning of street facades should prioritize preserving original wall hues while employing adjacent complementary tones to mitigate direct clashes between dominant color schemes. Maintaining the foundational blue-gray base color (RGB: 114,114,107)—which embodies the neighborhood's historical identity—paired with meticulously calibrated complementary tones such as warm sienna (RGB: 162,106,72) and pale gray (RGB: 217,220,217) can enhance visual stratification without compromising harmony. A gradient zoning control strategy proves effective in intensifying transitional effects. By implementing a well-defined chromatic gradient management system, natural transitions between commercial and residential areas can be achieved. This approach simultaneously preserves the cohesive historical streetscape while ensuring visual continuity across functionally distinct zones. In summarizing the chromatic strategies for Tongxingli district, the following recommendations emerge:

(1) Employ low-saturation crimson tones while systematically coordinating accent colors across storefronts and streetscape elements.

(2) Implement low-luminance color schemes district-wide to enhance perceptions of security and pleasantness, maintaining alignment with historic architecture.

(3) Constrain chromatic diversity in detailed fixtures (e.g., seating, waste receptacles, informational panels) to achieve systemic coherence.

(4) Preserve original wall pigmentation, utilizing adjacent complementary hues to prevent discord between dominant colors.

This approach transcends simplistic constraints on commercial vibrancy. Through scientific chromatic guidance, it carves innovative expressive space for businesses while safeguarding historical cultural heritage, ultimately achieving symbiotic advancement of cultural preservation and commercial development.

6 Conclusion

Urban chromatic identity constitutes a city's visual signature. While natural environments establish foundational tones, anthropogenic design ultimately shapes distinctive characteristics. Effective urban color planning necessitates integration of regional landscapes, ethnic cultural elements, and sociocultural contexts to authentically manifest intrinsic urban qualities. With economic development driving escalating demands for environmental aesthetics, strategic planning, design, and implementation of urban color schemes have emerged as critical endeavors in cultivating culturally distinctive metropolitan landscapes (Sha, n.d.).

This study situates itself within the macro-context of "urban renewal," focusing specifically on "spatial color" within historic districts, with chromatic coordination design as its central investigation. Examining Wuhan's

Tongxingli—a lane neighborhood possessing both cultural heritage value and commercial development potential—the research employs theories from color geography and color psychology, combining quantitative analysis with empirical investigation. It systematically analyzes chromatic imbalances encountered during Tongxingli's commercial transformation, proposing the innovative color coordination strategy "Cultural Foundation, Commercial Accentuation" as its core concept.

Through this case study of Tongxingli, the author aims to establish replicable color design paradigms applicable to Wuhan's other lane neighborhoods and comparable historic districts. Beyond providing theoretical support and practical references for historic districts' color planning, this research fundamentally demonstrates color's unique mediating value in reconciling preservation-development tensions. By investigating chromatic design strategies, we can better perpetuate historical continuity during urban modernization, preserve collective memory, and mold distinctive urban spaces that simultaneously honor history and embrace futurity.

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