Mapping Living Heritage: Integrating Pattern Language and Urban MorphoMetrics for Socio-Cultural Resilience

Mapiranje živog nasljeđa: Integracija jezika obrazaca i urbane morfometričnosti za socio-kulturnu otpornost

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Abstract Urban heritage conservation amidst rapid city transformation frequently prioritises the preservation of tangible structures over the continuity of daily life. In Chengdu, a southwestern Chinese city, which is experiencing intense redevelopment of its historic districts, the built environment has been meticulously preserved, while numerous collective socio-cultural practices have diminished. This research advocates for a synthesised approach to heritage assessment, bridging form-based and life-based evaluations through a dual analytical framework. This framework integrates qualitative pattern-based interpretation with quantitative Urban MorphoMetric modelling—a Python-based geospatial analytical approach. We examine six historic neighbourhoods—Shaocheng, Caoshijie, Ma'an, Jianshe Rd., Zhiminlu, and Fuqin—to investigate how varied urban morphologies either facilitate or impede the persistence of quotidian cultural practices. Ethnographic fieldwork identified recurrent spatial patterns, such as open-air markets, communal dancing, gardening, and teahouses. These patterns were subsequently correlated with 296 MorphoMetric descriptors that capture aspects of enclosure, density, and connectivity. MorphoMetric clustering delineated thirty-two distinct urban typologies, each associated with varying intensities of social interaction and place attachment. Our findings elucidate how concrete spatial configurations underpin intangible cultural resilience and how computational metrics can augment qualitative insights in identifying the living dimensions of heritage. By integrating behavioural observation with spatial measurement, this paper introduces a reproducible framework for assessing living heritage as a hybrid material and social system, thereby charting new pathways for sustainable heritage planning in rapidly urbanising Chinese metropolises and potential extensions to the international sphere.

Keywords societal values; historic neighbourhoods; pattern Language; urban morphometrics

Sažetak Očuvanje urbane baštine usred brze transformacije gradova često daje prioritet očuvanju fizičkih struktura nad kontinuitetom svakodnevnog života. U Čengdu-u, gradu na jugozapadu Kine, koji doživljava intenzivnu obnovu svojih historijskih četvrti, izgrađeno okruženje je pažljivo očuvano, dok su brojne kolektivne socio-kulturne aktivnosti smanjene. Ovo istraživanje zagovara sintetizirani pristup procjeni baštine, povezujući evaluacije zasnovane na formama i životnom stilu kroz dvostruki analitički okvir. Ovaj okvir integriše kvalitativnu interpretaciju zasnovanu na obrascima sa kvantitativnim urbanim morfometrijskim modeliranjem – geoprostornim analitičkim pristupom zasnovanim na Pythonu. Analizirano je šest historijskih naselja - Shaocheng, Caoshijie, Ma'an, Jianshe Rd., Zhiminlu i Fuqin - kako bi se istražilo kako različite urbane morfologije olakšavaju ili ometaju opstanak svakodnevnih kulturnih praksi. Etnografskim terenskim istraživanjem identificirani su prostorni obrasci koji se ponavljaju, kao što su tržnice na otvorenom, zajednički ples, vrtlarenje i čajdžinice. Identificirane su veze između ovih obrazaca i 296 morfometrijskih opisa koji obuhvataju aspekte zatvorenosti, gustine i povezanosti. Morfometrijsko grupiranje je ocrtalo trideset dvije različite urbane tipologije; svaka je povezana s različitim intenzitetom društvene interakcije i vezanosti za mjesto. Naši nalazi objašnjavaju kako konkretne prostorne konfiguracije podržavaju nematerijalne socio-kulturne aktivnosti i kako računarske metrike mogu proširiti kvalitativne uvide u identifikovanju živih dimenzija baštine. Integracijom posmatranja socio-kulturnih aktivnosti sa prostornim mjerenjem, ovaj rad predstavlja okvir za procjenu žive baštine kao hibridnog materijalnog i društvenog sistema, čime se trasiraju novi putevi za održivo planiranje baštine u brzo urbanizirajućim kineskim metropolama i potencijalno proširenje primjene ovog okvira na međunarodnom nivou.

Ključne riječi društvene vrijednosti; historijska naselja; jezik obrazaca; urbana morfometrika

1 Introduction

Historic urban districts in rapidly transforming cities face growing pressure to reconcile urban renewal with the preservation of socio-cultural continuity (Kalman & Létourneau, 2020). While traditional heritage conservation has prioritised material fabric—such as façades, street alignments, and architectural ensembles—research increasingly demonstrates that neighbourhood identity and social well-being are sustained through everyday cultural routines embedded in public space (Gehl, 2010; Whyte, 1980). Despite this shift, many restoration and regeneration initiatives continue to privilege built form, often at the expense of the socio-cultural practices that animate historic environments (Chen et al., 2024; Liang, Ahmad, & Mohidin, 2023).

The UNESCO Recommendation on the Historic Urban Landscape (HUL) responds to this limitation by reconceptualising urban heritage as the "historic layering of cultural and natural values," explicitly recognising intangible practices, daily routines, and experiential meanings alongside physical attributes (UNESCO, 2011). Subsequent UNESCO policy documents further emphasise the "social value of place" as a core dimension of urban heritage (UNESCO, 2016). Nevertheless, despite these conceptual advances, urban planning practice remains dominated by form-centric evaluation tools that struggle to detect, quantify, or spatially represent intangible socio-cultural values (Meissner, 2021; Pendlebury, 2013).

A key methodological challenge lies in the separation between spatial analysis approaches that focus primarily on built form and those that examine social activity, with few frameworks able to integrate both dimensions. Urban MorphoMetrics (UMM) enables high-resolution, comparative analysis of urban form through extensive MorphoMetric descriptors capturing shape, density, enclosure, and connectivity (Fleischmann et al., 2020). However, UMM alone cannot explain how specific socio-cultural practices are enabled, constrained, or transformed by these morphological conditions. Conversely, Pattern Language approaches, drawing on Alexander's work (Alexander, Ishikawa, & Silverstein, 1977), offer interpretive tools to describe how spatial configurations support social behaviour and everyday practices, but lack quantitative rigour and cross-neighbourhood comparability (Zhang & Dimitrijevic, 2025). As a result, existing heritage assessment frameworks remain limited in explaining where socio-cultural practices occur, how they are spatially structured, and why certain historic fabrics sustain cultural vitality while others do not.

This study addresses this gap by operationalising the HUL framework through an integrated methodology combining Urban MorphoMetrics, historical morphogenetic analysis, and Pattern Language validation. Using Chengdu—a rapidly transforming regional capital in southwestern China—as a case study, the research applies UMM to classify six historic neighbourhoods into distinct urban typologies and to assess their spatial affordances at neighbourhood scale, including enclosure, density, grain, and street connectivity. These typologies are then interpreted through Chengdu's historical development phases to identify how morphogenetic trajectories shape opportunities and vulnerabilities for socio-cultural practices (Jiao et al., 2023; Zhang, Dimitrijevic, & Romice, 2025). Building on this analysis, the study infers likely spatial conditions for practices such as Mahjong socialisation and open-air dancing, which are subsequently verified and formalised through a Pattern Language framework derived from empirical field observation.

The study is guided by three research questions:

1. How can Urban MorphoMetrics classify historic neighbourhoods into meaningful urban types and elucidate their spatial affordances for socio-cultural activity at neighbourhood scale?
2. How can these MorphoMetric typologies be correlated with Chengdu's historical layers and developmental cycles to identify zones of cultural vitality or vulnerability?
3. How can a Pattern Language model validate and translate these inferred socio-cultural practices into practical planning and design guidance within the HUL paradigm?

The remainder of the paper is structured as follows. Section 2 reviews relevant literature on living heritage, socio-cultural practices, and urban morphology. Section 3 outlines the integrated methodological framework. Section 4 presents the empirical findings from the six Chengdu neighbourhoods, and Section 5 discusses their implications for heritage planning, urban planning polices, and the operationalisation of the HUL framework; and Section 6 concludes with reflections on limitations and avenues for broader applicability.

2 Literature Review

2.1 Living Heritage and the Historic Urban Landscape (HUL) Framework

Over the past two decades, heritage discourse has expanded from a monument-centred focus toward a broader understanding of urban environments as dynamic systems shaped by both material form and intangible socio-cultural processes (Sun, Jigyasu, & Nakajima, 2025). The UNESCO Recommendation on the Historic Urban Landscape (HUL) conceptualises heritage as a layered assemblage of cultural, social, and natural values, explicitly recognising everyday practices, spatial morphology, and collective meaning alongside architectural fabric (UNESCO, 2011). Through tools such as spatial mapping, impact assessment, and integration into urban planning, the HUL extends heritage management from individual sites to wider urban systems (Veldpaus, Pereira Roders, & Colenbrander, 2013).

Despite this conceptual advancement, a persistent challenge lies in translating the recognition of living heritage into operational and spatially grounded methodologies. Everyday practices—such as markets, communal rituals, and informal uses of public space—are central to social cohesion, identity, and urban resilience, yet they remain difficult to capture within planning frameworks that prioritise fixed spatial typologies and formal designation (Poulios, 2014). This difficulty is further compounded by a mismatch between the fine-

grained, transient nature of socio-cultural practices and the relatively coarse spatial units typically employed in urban analysis and governance (Tarrafa Silva et al., 2023). Although intangible heritage is increasingly framed as a global public good linked to cultural diversity and continuity (Nebot-Gomez de Salazar et al., 2023), its integration into planning instruments remains underdeveloped (Deacon, 2018). As a result, expert-driven inventories and authorised heritage discourse often fail to capture the community-negotiated values embedded in everyday urban life (Poulios, 2014).

Recent scholarship has increasingly positioned cultural heritage as a key component of socio-cultural resilience, highlighting its role in sustaining community continuity, social cohesion, and adaptive capacity in the face of urban transformation (Fabbricatti, Boissenin, & Citoni, 2020). However, much of this work remains conceptually oriented, with limited translation into spatially explicit and operational planning tools (Deacon, 2018). These challenges become particularly visible in rapidly transforming urban contexts such as Chinese cities, where historic neighbourhoods embody complex socio-spatial systems shaped by long-term interactions between built form and daily practices. Fine-grained street–alley networks, courtyard structures, and mixed-use frontages support diverse forms of social interaction and informal economic activity, forming an integral part of living heritage (He & Wu, 2009; Song et al., 2024; Zhang & Dimitrijevic, 2025). However, large-scale redevelopment and standardised planning approaches frequently disrupt these systems, leading to the erosion of socio-cultural practices despite the formal preservation of physical fabric (Jian et al., 2025; Li, Li, & Ma, 2024). While existing studies have examined either urban form or socio-cultural resilience, there remains a lack of methodological approaches capable of systematically linking measurable spatial structures with observed cultural practices.

Within this context, the HUL framework's call to integrate tangible and intangible attributes presents not only a conceptual ambition but a methodological imperative. To effectively inform planning and governance, socio-cultural practices must be integrated into spatial analysis alongside urban form. Responding to this gap, this study proposes a dual methodological framework that combines quantitative Urban MorphoMetrics with qualitative socio-cultural interpretation. By aligning these approaches within the HUL management cycle, the research seeks to operationalise living heritage at the neighbourhood scale and provide a spatially explicit basis for heritage-informed urban planning.

2.2 UMM and the Quantification of Historic Urban Space

The historic urban landscape is defined by spatial configurations or urban morphology that have developed over extensive periods (Rodwell, 2009), with classical theories highlighting how the arrangement of built and open spaces, public-private interfaces, and connectivity networks impact the spatial allocation of daily urban functions (Alexander, Ishikawa, & Silverstein, 1977; Hillier & Hanson, 1984; Sim & Gehl, 2019; Trancik, 1986). Although these frameworks clarify cultural and experiential facets of urban form, they possess limited capacity for systematic cross-neighbourhood spatial comparison or for assessing form-driven socio-cultural practices.

Typomorphology offers an intermediate analytical layer by classifying urban tissues (Kropf, 2009) based on their morphological lineage, such as street network configurations, plot patterns, block geometries, and building typologies (Moudon, 1994). Applied to Chengdu's historic districts—such as Ma'an neighbourhood, this approach uncovers recurring public-space typologies shaped by layered urbanism: street frontage zones, public open squares, green spaces, semi-private courtyards, and alley corridors where socio-cultural activities occur (Zhang, Dimitrijevic, & Romice, 2025). Each typology exhibits distinct spatial structures and degrees of openness, which influence potential social interactions, informal economic activities, and communal rituals (ibid.). Building on Typomorphology theory, UMM offers a systematic, multi-scale measurement framework to quantify the geometric and spatial configuration of urban morphology (Fleischmann et al., 2020; Porta & Romice, 2014). It deconstructs the urban morphology into coherent morphological components, independent of the conventional "plot" paradigm, emphasising "tessellation cells" as the fundamental urban spatial units, and extends this approach within quantitative MorphoMetrics through standardised mathematical descriptors (Fleischmann et al., 2020).

While precedents in using UMM with historical, behavioural or social datasets remain limited, they still effectively reveal the influence of morphological conditions on territorial evolution, urban types variation (Fleischmann et al., 2021; Venerandi et al., 2021), and also cultural traditions within these urban types (Zhang, Dimitrijevic, & Romice, 2025). For instance, in old Chinese neighbourhoods, narrow alley corridors with high enclosure ratios and low vehicular permeability are correlated with informal social activities such as tea gatherings or children's play areas (ibid.).

In this context, UMM functions not solely as a descriptive instrument but as a diagnostic methodology capable of revealing the spatial affordances embedded within diverse public-space typologies. Quantifying physical spatial quality in relation to street frontages, courtyards, squares, and alleys through MorphoMetric descriptors facilitates the identification of material conditions that sustain specific socio-cultural patterns. This analytical foundation underpins subsequent Pattern Language analyses, which interpret how these spatial affordances are culturally enacted and maintained.

2.3 Pattern Language and the Socio-Cultural Complexity of Everyday Urban Practices

Research on intangible cultural heritage increasingly illustrates the inseparability of socio-cultural practices from the spatial conditions that host and reproduce them (Motonaka, 2025; Nie et al., 2023). Pattern Language, developed by Alexander, Ishikawa and Silverstein (1977), offers a conceptual model for analysing this relationship by identifying recurrent socio-spatial configurations—patterns—that emerge from stable interactions between the built environment, collective routines, and cultural semantics. This approach reframes space and behaviour

not as discrete but as interconnected categories, elucidating how specific spatial formations, e.g., corners, edges, thresholds, clusters, and enclosures (Gehl, 2010; Low & Smith, 2003; Mehta, 2014; Rapoport, 1990; Whyte, 1980) correspond with particular modes of quotidian activity. Seamon (1979) study focuses on "body-ballets" and "place-ballets," exploring how rhythmic movement and encounter patterns generate socio-spatial fields that foster familiarity, place-attachment, social cohesion, and communal identity. This echoes the Pattern Language theory that a complex socio-cultural behaviour is combined with many smaller patterns that demonstrate the spatial quality of space.

Empirical research across Chinese urban settings reveals how informal food markets favour permeable street frontages with significant pedestrian throughput (Xu, 2014; Zhang & Dimitrijevic, 2025); how communal dance forms (Martin & Chen, 2020) gravitate toward open, paved corners or courtyards that optimise visibility and acoustic dissemination (Duan, 2016); how routine gardening emerges along residual green strips, setbacks, and fence-lined micro-spaces (Zhang & Xin, 2023); and how social activities such as Mahjong and teahouse gatherings are situated in semi-enclosed threshold environments that support prolonged interaction through enclosure and outward orientation (Wang, 2008). These scenarios resonate with spatial motifs from Pattern Language, e.g., "activity nodes," "edge conditions," "outdoor rooms," and "intimacy gradients" (Alexander, Ishikawa, & Silverstein, 1977), demonstrating that socio-cultural practices are systematically embedded within specific spatial configurations.

This interpretive framework aligns with UNESCO's HUL guidelines, which emphasise heritage emergence from layered tangible and intangible attributes within dynamic urban systems (UNESCO, 2011). Although the HUL provides a broad conceptual basis, it lacks detailed procedures for embedding intangible practices in specific spatial contexts. Pattern Language operationalises this, illustrating how socio-cultural activities such as informal markets, social dance, community gardening, and Mahjong gatherings are facilitated by unique morphological settings. This enhances the spatial legibility of cultural practices and supports their integration into urban conservation and design. In historic neighbourhoods, disrupting micro-scale spatial logic may threaten the preservation of these practices, highlighting the need for systematic methods to connect everyday activities with their sustaining material structures.

2.4 Towards an Integrated Socio-Spatial Analytical Framework

In response to these methodological limitations, this study adopts an integrated analytical framework that combines MorphoMetric quantification with pattern-based socio-spatial interpretation. By linking Urban MorphoMetrics with a Pattern Language approach, the framework enables both the systematic classification of urban form and the spatial interpretation of everyday socio-cultural practices. This integration provides the methodological foundation for the empirical workflow presented in Section 3.

3 Methodology

The case study city, Chengdu, is the capital of Sichuan Province in Southwest China; it functions as a significant metropolitan hub with a population surpassing 21.47 million (Cities, 2024) and an administrative jurisdiction covering approximately 14,355 km2 (ibid.). Located within the fertile Chengdu Plain, this urban centre has experienced uninterrupted spatial expansion for over three millennia (Chengdu Municipal Bureau of Statistics, 2023), resulting in a complex, stratified urban morphology. Its old historic centre, primarily corresponding to the area bounded by today's Second Ring Road (Fig.1), exhibits the highest density of traditional neighbourhoods—pre-reform communities in 1949—and early socialist housing complexes, whereas subsequent developments extending beyond the Second Ring reflect rapid post-1978 urbanisation processes. This multilayered spatial configuration renders Chengdu an ideal case for applying the HUL paradigm, especially its focus on synthesising tangible urban fabric, intangible socio-cultural practices, and long-term urban transformation (UNESCO, 2011). In addition, Chengdu is on the UNESCO "Creative Cities Network" and was designated as a "City of Gastronomy" (UNESCO, 2010).

To encompass the complete morphological diversity of the city, six neighbourhoods were selected along Chengdu's chronological and spatial trajectory: Shaocheng (A) and Caoshijie (B) as embodiments of traditional alleyway networks; Ma'an (C) representing an organic settlement in the early socialist era (from 1949 to 1955) (Wang & Su, 2016)—the Jiefang model; Jianshe Road (D) exemplifying socialist-era Danwei compounds (from 1956 to 1978) (ibid.); Zhiminlu (E) as a high-rise gated residential complex developed post-2005; and Fuqin (F), illustrating early Xiaoqu models emerging after the 1978 economic reforms. These neighbourhoods collectively offer a cross-sectional perspective on Chengdu's urban evolution, facilitating a comparative analysis of how divergent morphological logics influence spatial openness, enclosure, permeability, and socio-cultural routines.

This study integrates Urban MorphoMetrics (UMM) and Pattern Language into a unified analytical framework designed to link urban form, everyday socio-cultural practices, and heritage-informed planning guidance. The methodological sequence proceeds as follows: first, UMM is applied to compute MorphoMetric descriptors (Fleischmann et al., 2020) and generate Urban Types through clustering analysis, capturing structural variations in Chengdu's historic neighbourhoods. This will utilise Geospatial data (Street & Building shapefiles) accessed from the Amap Open Access Platform. Second, archival analysis and historical interpretation (with historic maps accessed through Google Earth (2025)) are used to situate these Urban Types within Chengdu's layered morphogenesis. Third, fieldwork is undertaken to document the socio-cultural activities occurring within each neighbourhood through photographic documentation (Gehl & Svarre, 2013). Using Pattern Language as a structured observation protocol, these activities

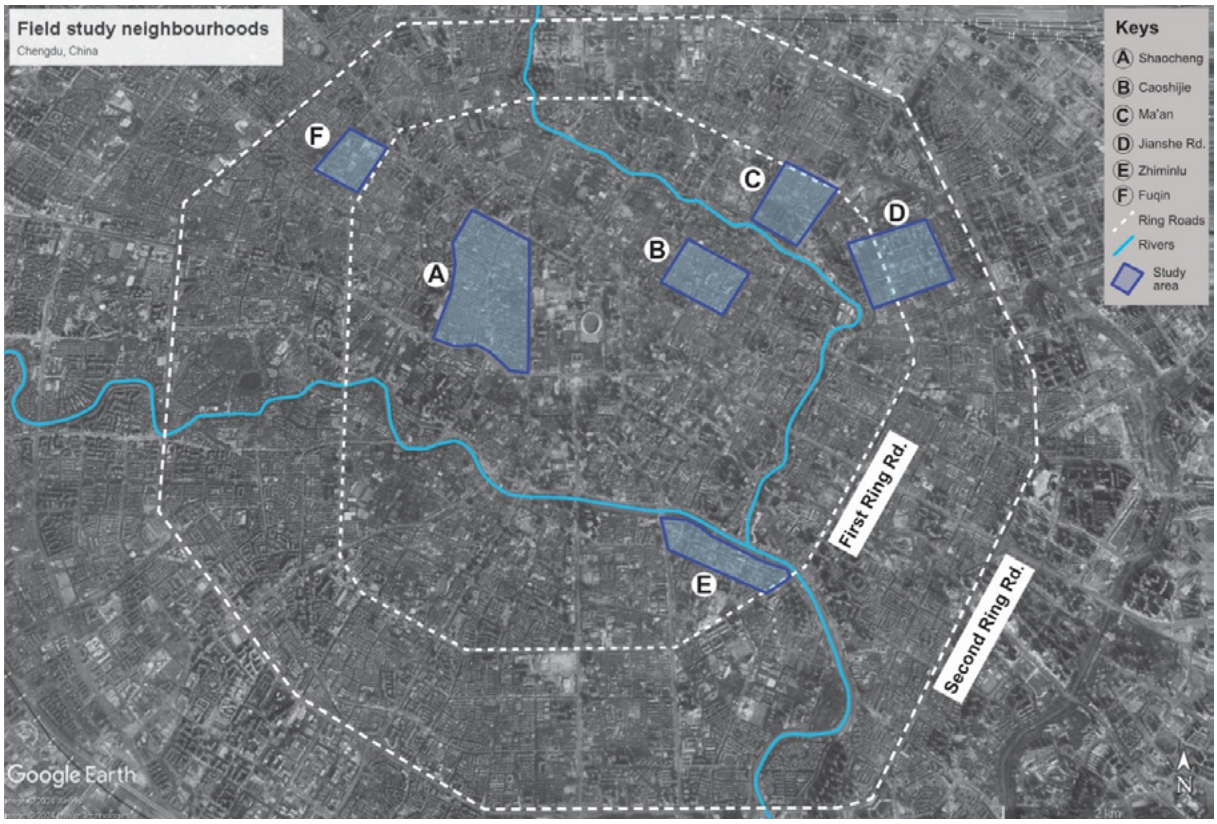

Figure 1 Location of the six study neighbourhoods within Chengdu's historic urban core. Source: Authors, 2026.

are systematically examined and disaggregated into recurrent spatial patterns and their underlying spatial requirements, allowing everyday practices to be interpreted in relation to the physical configurations that enable or constrain them. Through this sequential process, the framework progresses from urban form to social behaviour and subsequently to the assessment and validation of planning rationales within the Historic Urban Landscape approach, thereby establishing an evidence-based link between everyday practices and heritage-informed urban governance.

3.1 Urban MorphoMetrics

Urban MorphoMetrics (UMM) provides a quantitative, multi-scalar approach for analysing the spatial configuration of the built environment by systematically measuring buildings, parcels, blocks, and street networks (Fleischmann et al., 2021). It is particularly suitable for historic urban contexts, where subtle variations in enclosure, permeability, grain, and connectivity strongly influence everyday socio-cultural practices.

In this study, UMM is operationalised within a Python-based geospatial analysis environment, primarily using the open-source library momepy (Morphological Measuring in Python), which is part of the PySAL ecosystem for spatial analysis (Fleischmann, 2019; Rey, Arribas-Bel, & Wolf, 2023). The analytical workflow was implemented in a reproducible computational setting (e.g., Jupyter Notebook), relying on a standard geospatial stack including GeoPandas for vector data processing (Jordahl, 2014), NetworkX for street network analysis (Hagberg, Swart, & Schult, 2008), and auxiliary libraries such as NumPy (Harris et al., 2020) for numerical computation and Matplotlib (Hunter, 2007) for visualisation. The momepy toolkit enables the systematic computation of morphometric descriptors—such as shape, density, spatial distribution, and network connectivity—across multiple urban elements, as well as the construction of relational units (e.g., morphological tessellation and street-based metrics) (Fleischmann, 2019). The analysis was conducted in Python (version 3.x) within a managed environment (e.g., Conda), ensuring library compatibility and reproducibility. Preprocessing steps included the cleaning and standardisation of building and street geometries, coordinate reference system (CRS) harmonisation, and the generation of morphological tessellations and network representations required for momepy-based analysis. These steps were implemented through scripted procedures to ensure consistency and replicability across all study areas.

All analytical steps, including data preprocessing, feature extraction, and descriptor calculation, were conducted through scripted workflows to ensure transparency and replicability. This includes the use of custom Python scripts[1] to standardise input datasets (e.g., building footprints and street networks), compute UMM indicators, and aggregate them into higher-

1 The Python Script for each descriptor's calculation can be found in https://docs.momepy.org/en/stable/user_guide/intro.html.

level morphological units. Explicitly specifying the software environment, analytical libraries, and scripted procedures is essential for reproducibility, enabling other researchers to replicate or extend the analysis in comparable urban contexts.

Within this framework, UMM is employed not as an end in itself, but as a classificatory tool to generate Urban Types that capture structurally distinct urban fabrics across Chengdu. The UMM workflow begins with the construction of a consistent morphological base model comprising building footprints, parcel-based tessellations, urban blocks, and street networks. MorphoMetric descriptors are computed across these scales to quantify geometric and configurational properties of the urban fabric. In total, 296 MorphoMetric descriptors required by this method (Fleischmann et al., 2020) (the whole list of factors can be found through the link in footnote 1) were calculated for the study areas within Chengdu's Second Ring Road, ensuring a statistically robust representation of urban form. A subset of representative morphometric descriptors—covering key dimensions such as enclosure (e.g., sdbAre, building area), density (e.g., sicFAR, floor area ratio), and street network structure (e.g., mtdDeg, node degree)—was selected to enable comparative analysis between neighbourhoods, with the full list of abbreviations and corresponding definitions provided in Appendix Table 2a.

These descriptors were subsequently subjected to clustering analysis, resulting in the classification of 32 distinct Urban Types, which were further organised into four higher-order morphological groups. Rather than interpreting individual descriptors in isolation, the analysis focuses on how combinations of MorphoMetric properties, such as shape, spatial distribution, density and network structure, cohere into recognisable urban typologies. This typological output provides a legible, comparative framework for examining spatial variation across neighbourhoods shaped by different historical and planning trajectories. In this way, UMM functions as the initial step in translating complex urban form into analytically meaningful categories that can be linked to everyday practices and heritage-informed planning guidance.

3.2 Historic Cartographic & Morphogenetic Analysis

To contextualise the quantitative outputs of the UMM Analysis, this study applies a lightweight morphogenetic interpretive framework to the six Chengdu neighbourhoods. This interpretive layer does not introduce additional analytical procedures; rather, it links present-day morphological performance to historically accumulated spatial structures, allowing UMM descriptors to be read as products of long-term urban development trajectories.

Five temporal points—1947, 1965, 1982, 2001 and 2025—were selected based on the availability of comparable cartographic records from Google Earth (2025) and their correspondence to key phases of urban transformation in China, including the pre-1949 period, the socialist era, the post-socialist transition, housing privatisation, and the contemporary condition.

- 1947 represents the pre-1949 urban condition;
- 1965 captures the socialist era (1949–1978) of Danwei-led spatial organisation;
- 1982 marks the immediate post-socialist transition;
- 2001 reflects the restructuring following the 1998 housing privatisation reform;
- 2025 provides the current morphological baseline.

Existing research highlights the path-dependent nature of Chinese residential environments, in which street alignments, block shapes, and parcel structures persist through successive architectural renewals and policy phases (Chen & Thwaites, 2013; Lu, 2006; Zhang, Dimitrijevic, & Romice, 2025). Building on this principle, the historical typologies summarised in Appendix Table 1a are used solely as an explanatory framework for interpreting why each neighbourhood exhibits specific UMM characteristics across the five descriptor themes outlined in Section 3.1.

Neighbourhoods rooted in traditional fine-grain urban fabrics, such as Shaocheng (Hutong morphology) and Caoshijie (Linli morphology), demonstrate strong enclosure, articulated frontages, and high granularity, consistent with narrow alley networks, dense block subdivisions, and porous building-street interfaces inherited from pre-reform planning logics (Zhang, Dimitrijevic, & Romice, 2025).

In contrast, socialist-era Ma'an (Jiefang morphology) and Jianshe Rd. (Danwei compound morphology) display regularised block geometries, controlled spatial depths, and reduced permeability, reflecting the administrative and production-oriented planning ideals of the 1950s–1970s. Post-1978 fabric, such as Fuqin (early Xiaoqu typology), exhibits smaller-sized parcels, increased setbacks from streets, and moderate reductions in granularity, shaped by the proliferation of 6–7 storey building blocks with no lifts installed. Meanwhile, Zhiminlu, representing the post-2005 high-rise tower model, is characterised by large consolidated parcels, extensive open spaces, simplified frontage conditions, and strong verticality.

This morphogenetic interpretation clarifies how the five UMM descriptor themes—Enclosure & Spatial Configuration, Permeability & Frontage Dynamics, Granularity & Density, Street Network Topology, and Contextual Morphology—emerge as consequences of historically embedded spatial logics rather than isolated numerical variations. It provides a typology-sensitive foundation for Section 3.3, where these morphological configurations are further integrated with socio-cultural practices through a Pattern Language analytical framework.

3.3 Pattern Language Approach

To enhance the structural analysis derived from UMM, this research employs a Pattern Language methodology to systematically document the integration and adaptation of socio-cultural activities within urban neighbourhoods. Utilising the validated pattern catalogue established by Zhang and Dimitrijevic (2025) (Appendix, Table 1b), thirteen patterns were identified that span four domains, representing essential socio-cultural activities (intangible cultural heritage) in old Chengdu neighbourhoods. These activities are

Traditional Markets (with subtypes: M1–M4), Square Dance (D1–D3), Socialisation in Community Gardens (G1–G3), and Teahouses for Playing Mahjong (T1–T3). Each socio-cultural activity encompasses multiple patterns delineating specific spatial behaviours. Spatial data were geo-referenced through site cartography and recorded via a binary Yes (Y) /No (N) protocol across six delineated neighbourhoods (A–F), facilitating direct linkage of activity instances to UMM-defined spatial units, such as parcels, tessellation cells, and street profiles. This methodological approach allows for a comparative spatial analysis of activity distribution and its correlation with underlying morphological configurations. Rather than focusing on quantitative measurement of behaviours, the pattern-based approach provides an interpretive layer as an observational prototal elucidating how conditions mapped from UMM, such as enclosure, permeability, adjacency, and openness, are expressed through lived socio-cultural routines. Consequently, the Pattern Language framework functions as a triangulation tool, integrating historic morphological tendencies (Section 3.2) with quantitative spatial analyses (Section 3.1), thereby yielding a comprehensive understanding of the co-production processes linking built form and cultural practices in fostering neighbourhood vitality.

4 Results

4.1 Urban MorphoMetrics Findings

The Urban MorphoMetrics analysis provides a multi-scale spatial characterisation of six Chengdu neighbourhoods, drawing on building footprint and street network data from Amap (Gaode), a publicly accessible national geospatial platform. These datasets were used to construct a consistent MorphoMetric framework comprising buildings, parcel-based tessellations, urban blocks, and street networks. In total, 296 MorphoMetric variables were computed.

The results are presented in three stages. Section 4.1.1 establishes the morphological baseline through visualisation of the four foundational spatial layers. Section 4.1.2 reports the agglomerative hierarchical clustering results, identifying distinct Urban Types and their higher-order morphological groupings. Section 4.1.3 then interprets the differentiation of these types across the six neighbourhoods and relates them to existing typological classifications.

4.1.1 Multi-Scale Morphological Characteristics of the Six Neighbourhoods

The multi-scale spatial data derived from Urban MorphoMetrics reveal a clear gradient of morphological granularity across the six study neighbourhoods, observable consistently across building footprints, tessellation parcels, block structures, and street networks (Table 1). Together, these layers delineate a spectrum ranging from highly compact, fine-grained urban fabrics to coarse-scale, consolidated morphologies, with several transitional conditions in between.

Figure 2 Multi-scale morphological characteristics of the six study neighbourhoods: a) building footprints; b) parcel-based tessellation; c) block structure; and d) street network.Source: Authors, 2026.

At one end of the spectrum, Shaocheng (A) and Caoshijie (B) exhibit fine-grained configurations characterised by small building footprints, dense parcel subdivisions, small block sizes, and highly permeable street networks (Fig.2). Ma'an (C) and Jianshe Road (D) occupy intermediate positions, where fine-grain elements coexist with more regularised block structures and clearer street hierarchies, reflecting hybrid and transitional morphologies (Fig.2). At the coarser end, Zhiminlu (E) and Fuqin (F) display large-scale spatial structures with larger parcels and blocks, simplified street networks, and reduced internal permeability, although Fuqin retains a more articulated internal structure than the more consolidated morphology of Zhiminlu (Fig.2).

This multi-scale continuum provides the spatial foundation for the subsequent MorphoMetric and clustering analyses, enabling systematic comparison across neighbourhoods shaped by different historical development trajectories.

4.1.2 Clustering and Grouping of MorphoMetric Descriptors

Cluster analysis of the MorphoMetric descriptors classified Chengdu's urban fabric into 32 Urban Types (UTs). Their spatial distribution across the Second Ring Road area is illustrated in the Urban MorphoMetric Map (Fig.3), which reveals a structured pattern of morphological differentiation corresponding to distinct phases of urban development.

The dendrogram (Fig.4) organises these 32 Urban Types into five higher-order morphological groups, each representing a broadly shared spatial logic. By taking reference from Fig.5 on the presentation of descriptor values, at one extreme, we have Group I (UT 11, 18, 25 & 31), which corresponds to fine-grained, low-rise, and low-intensity street-block fabrics typically associated with traditional or early urban forms. Group II (0, 1, 3, 4, 5, 6, 8, 9, 10, 12, 13 & 29) comprises middle-density residential morphologies characterised by moderate

Table 1 Findings from the basic morphological factors analysis.

Neighborhood	Building footprints	Tessellation cells (parcels)	Block structure	Street network
A	• Very small footprints • Irregular shapes • Tightly packed with minimal spacing	• Very small cells • Highly irregular outlines • Compact cell arrangement	• Very small blocks • Curving/angled boundaries	• Dense, fine-grain alleys • Many short segments and junctions
B	• Small footprints • More rectilinear • Continuous frontage	• Small cells with moderate regularity • Closely aligned with the grid	• Small–medium blocks • More orthogonal edges	• Dense network • Mix of alleys and short streets
C	• Mix of small + medium footprints • Distinct contrast between finer and coarser areas	• Coexistence of small, irregular cells + larger, regular cells	• Combination of very small blocks + very large ones	• Mixed network: fine-grain in one part, straighter/ longer streets in another
D	• Medium-sized, rectilinear footprints • Buildings aligned to internal roads	• Mostly rectangular parcels • Similar size and highly regular	• Medium–large blocks • Closed perimeters with limited openings	• Clear street hierarchy • Fewer intersections than in A–C
E	• Large, repetitive footprints • Very regular shapes	• Large parcels • Simple geometry • Low internal subdivision	• Large, continuous blocks	• Sparse network • Movement channelled through main streets
F	• Medium-sized slab-like footprints • Short gaps between buildings	• Medium-sized parcels • Moderate regularity with small local variations	• Medium blocks • Several internal passages	• Moderate intersection density • Mix of internal streets and connectors

Table 2 Urban Types existing in the studied neighbourhoods.

Neighborhood	Urban Types
A – Shaocheng	UT 10 only
B – Caoshijie	UT 6 (dominant), with a small part of UT 3
C – Ma'an	UT 1 and UT 6
D – Jianshe Rd.	UT 1 only
E – Zhiminlu	UT 9 (dominant) with a small part of UT 4
F – Fuqin	UT 0 only

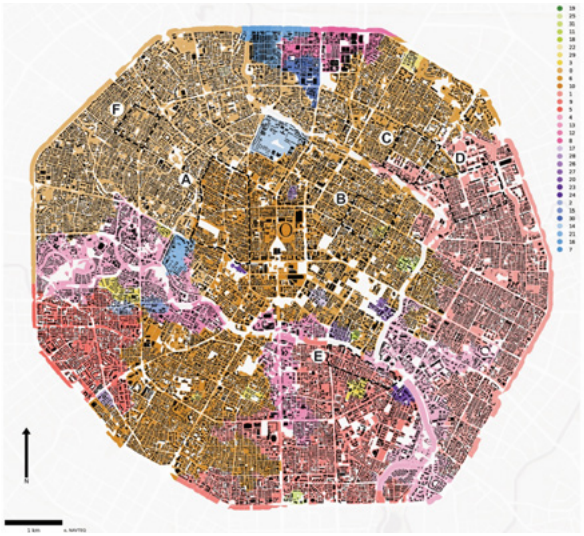

Figure 3 Spatial distribution of the 32 Urban Types (UTs) generated through Urban MorphoMetric clustering within Chengdu's Second Ring Road area.Source: Authors, 2026.

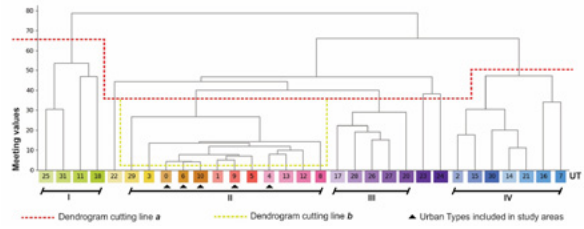

Figure 4 Hierarchical clustering dendrogram showing relationships among the 32 Urban Types and their higher-order morphological groupings. Source: Authors, 2026.

building intensity, regularised parcel structures, and relatively stable street networks. Group III (17, 20, 26, 27 & 28) is distinguished by heightened street-network connectivity and centrality, indicating circulation-intensive fabrics shaped more by movement structures than by building mass. Group IV (2, 7, 14, 15, 16, 21 & 30) represents the most intensive redevelopment typologies, marked by large parcels, high building volumes, and strong verticality, while Group V consists of a small number of outlier types with highly specific or uncommon MorphoMetric signatures.

When the analysis is restricted to the six selected historic neighbourhoods, the citywide typology resolves into a much smaller, neighbourhood-specific set of Urban Types (Table 2). Shaocheng (A) is composed exclusively of UT 10, Caoshijie (B) is dominated by UT 6 with a minor presence of UT 3, and Ma'an (C) comprises UT 1 and UT 6, reflecting a transitional morphology. Jianshe Road (D) consists solely of UT 1, while Zhiminlu (E) is primarily defined by UT 9 with a small proportion of UT 4. Fuqin (F) is entirely composed of UT 0.

Although all Urban Types present in the six neighbourhoods fall within the broadly middle-density residential family (Group II), their relative positions within the dendrogram indicate meaningful internal differentiation shaped by distinct historical and planning trajectories. This structure provides the conceptual bridge between MorphoMetric classification and the historical interpretation developed in Section 3.2 and elaborated further in Section 4.2.

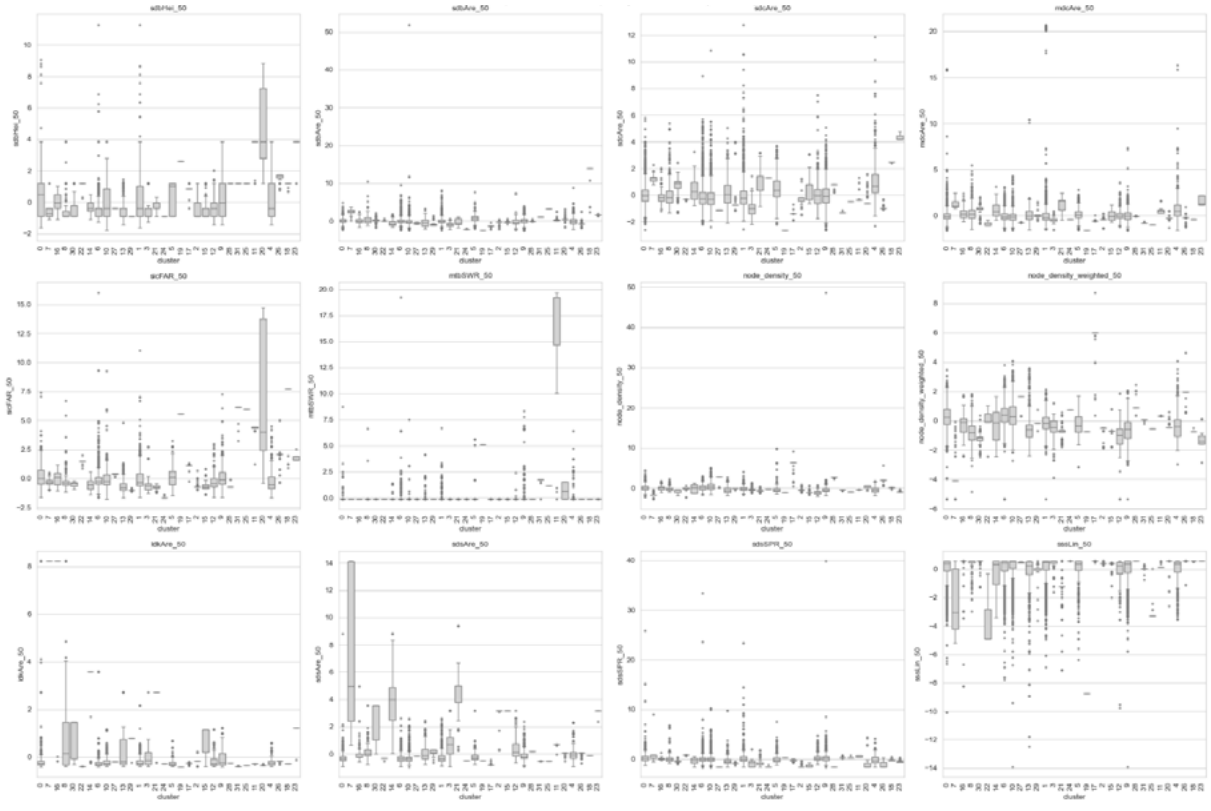

Figure 5 Distribution of representative MorphoMetric descriptors across Urban Types, illustrating variations in enclosure, density, and network structure. Source: Authors, 2026.

4.1.3 Cross-Neighbourhood Differentiation and Typological Interpretation

Although all major Urban Types (UT 0, 1, 6, 9, and 10) present in the six studied neighbourhoods fall within the broadly middle-density residential family (Group II), their MorphoMetric profiles reveal clear internal differentiation across enclosure, density, and street-network characteristics (Fig. 6; Table 3).

UT 0 represents the most fine-grained morphology within the group. It is characterised by very small building footprints, low Floor Area Ratio (FAR), and minimal inter-building distances, producing compact, low-rise fabrics with narrow passageways and strong spatial enclosure. This configuration reflects human-scale environments with limited vertical intensity and dense micro-spatial articulation.

UT 10 retains a traditional morphogenetic structure but exhibits moderate densification. Compared to UT 0, it shows increased building footprint area and FAR, alongside more coherent frontage conditions. These shifts indicate incremental consolidation while preserving elements of earlier block structures, resulting in a denser yet still historically legible urban fabric.

UT 6 marks a transition toward planned modern residential forms. Its profile combines moderate FAR and coverage with higher intersection density and improved network integration, signalling regularised parcel structures, widened internal roads, and rationalised circulation systems. This morphology reflects a balance between redevelopment and retained fine-grain elements.

UT 1 constitutes the most intensive redevelopment trajectory within Group II. It is distinguished by high building volume, compact footprints, and peak FAR values, together with highly regular parcel geometries. These characteristics correspond to consolidated block forms and high-rise or perimeter-block redevelopment, prioritising land efficiency and volumetric intensity.

UT 9 occupies a hybrid position between densification and permeability. While its FAR and coverage exceed those of UT 0 and UT 10, its defining feature lies in strong street-network performance, with high connectivity and detour efficiency. This combination produces morphologies where moderately dense building forms coexist with fine-grained, highly permeable circulation systems.

Taken together, these Urban Type profiles demonstrate that even within a shared middle-density morphological family, the six neighbourhoods occupy distinct MorphoMetric positions shaped by different redevelopment intensities and spatial logics. This differentiation provides the quantitative foundation for the historical interpretation in Section 4.2 and the subsequent analysis of how specific spatial configurations condition socio-cultural practices.

4.2 Historic Cartographic & Morphogenetic Analysis

The MorphoMetric signatures identified in Section 4.1—fine-grain enclosure, variable permeability, shifting grain sizes, and restructured networks—reflect the layered morphogenesis of the six Chengdu neighbourhoods rather than isolated spatial outputs. This section synthesises archival cartography from 1947, 1965, 1982, 2001 and 2025 (Fig.7) to explain how each neighbourhood acquired its present-day morphological form and why their UMM values diverge across enclosure, density, and network dimensions.

4.2.1 Morphogenetic Foundations (1947–2025)

The historical layering (Fig.7) of Chengdu's urban form provides a crucial explanatory foundation for understanding the differentiated Urban Types (UTs) identified in the MorphoMetric analysis. Although the six neighbourhoods broadly fall within the same dendrogram family (Group II), their present morphologies reflect distinct morphogenetic pathways. Shaocheng (A), for example, preserves the fine-grained logic of its pre-1949 courtyard—or hutong fabric—but has been progressively densified since the 1980s. The replacement of single-storey courtyards with 6–7 storey residential buildings has increased their Standard Building Area (sdbAre), raised Floor Area Ratio (sicFR) and produced more coherent frontage lines, features that define the UT 10 profile of "densified traditional morphology." A similar but more transitional condition exists in Caoshijie (B) and northern parts of Ma'an

Table 3 Urban form features of the Urban Types (UTs) within the studied neighbourhoods.

Urban Type	General Characterisation	MorphoMetric Signature
UT 0	fine-grain historic fabric	lowest Floor Area Ratio (FAR), smallest parcels, tight spacing
UT 10	densified traditional morphology	moderately higher FAR, larger footprints, semi-continuous frontages
UT 6	planned mid-rise blocks	higher coverage, moderate FAR, regular and integrated networks
UT 1	high-density consolidation	highest FAR, high volume, large footprint blocks
UT 9	hybrid dense-permeable grid	moderate FAR + highly permeable, fine network

Figure 6 Standardised MorphoMetric profiles of Urban Types: a) enclosure and spatial configuration; b) permeability and frontage dynamics; c) granularity and density; d) street network topology; and e) contextual morphology. Source: Authors, 2026.

(C). Originally traditional, both underwent systematic redevelopment in the 1990s–2000s that introduced mid-rise slab blocks, widened internal roads and rationalised the street network. These interventions resulted in higher Coverage Area Ratio (sicCAR), increased mean Node Degree (mtdDeg) and Closeness Centrality (lcnClo), and moderate Floor Area Ratio (sicFAR), matching the UT 6 signature of early planned modern blocks.

In contrast, Jianshe Rd. (D) and the consolidated southern sections of Ma'an (C) originated as socialist work-unit compounds, whose planned geometry, enclosed courts and post-2000 introduced tower-form (UT 1) insertions created the highest Building Volumes (sdbVol), compactness values reagrding Courtyard Area (sdbCoA) and Floor Area Ratio (sicFAR) among the six areas. Their elongated, regular parcel forms implied by the tessellation cell Equivalent Rectangular Index (sscERI) further define the UT 1 condition of high-density consolidation. Zhiminlu (E) represents a different lineage: once an informal riverside settlement, it underwent selective high-rise redevelopment after the 2000s but retained much of its alley-based circulation system. The coexistence of medium-density blocks with a permeable, historically rooted network explains its elevated mtdDeg, higher Meschedness (lcdMes) and strong Square Clustering Index (xenSCI), which together characterise UT 9 as a "dense–permeable hybrid grid."

Fuqin (F) completes this spectrum through its early post-1980s Xiaoqu morphology. Although formally planned, it still rests on a fine alley geometry inherited from earlier settlements, producing small, closely spaced footprints with low Standard Building Area (sdbAre), short Mean Inter-Building Distance (ltbIBD) and low Floor Area Ratio (sicFAR). These elements correspond directly to the UT 0 profile of compact but low-rise structures. Taken together, these differentiated morphogenetic trajectories clarify why the six neighbourhoods, despite their shared classification within a "middle-density residential" family, occupy distinct MorphoMetric positions. This historical interpretation anchors the transition from the quantitative UMM results in Section 4.1 to the behavioural and socio-cultural analysis undertaken in Section 4.2.2 and provides the structural foundation for pattern verification in Section 4.3.

4.2.2 Interpretive Link Between Morphogenesis, UMM Signatures, and Behavioural Patterns

The morphogenetic layers described above provide an interpretive foundation for understanding why the six neighbourhoods are predisposed to distinct socio-cultural practices, as evidenced in previous empirical work in decoding complex socio-cultural activities by using a Pattern Language approach (Zhang & Dimitrijevic, 2025). Although this article does not reproduce full observational protocols, the spatial logics embedded in each Urban Type (UT) closely correspond to the behavioural patterns (Table 4) documented in earlier fieldwork across markets, dance activities, gardening practices and teahouse cultures.

Traditional courtyard-based morphologies, clearly expressed in Shaocheng (A) and Caoshijie (B), and sharing key features with the early-1980s Xiaoqu

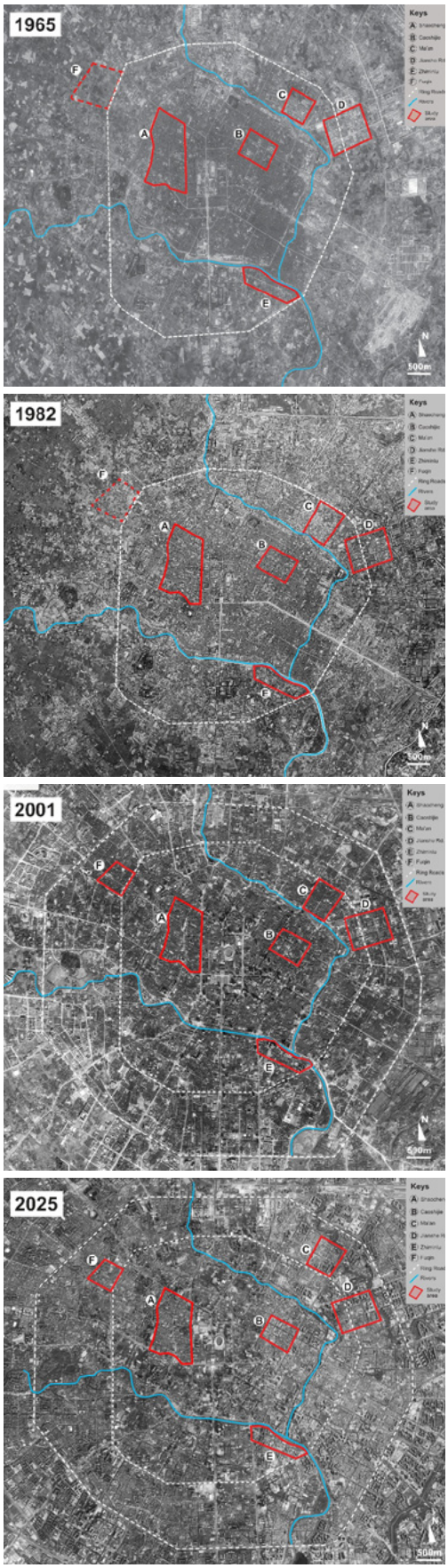

Figure 7 Morphogenetic evolution of the six study neighbourhoods from 1965 to 2025. Source: Authors, 2026.

neighbourhood of Fuqin (F), combine narrow corridors, continuous frontages, short inter-building distances, and highly permeable street networks. These fine-grain structures generate intense street–threshold interfaces and frequent micro-encounters. Such conditions align with socio-cultural patterns reliant on short visibility lines, rhythmic pedestrian flows, and porous edges, including informal food markets and threshold-based retail (M1–M2), home-based teahouses (T1), and informal community gardening (G2). At the MorphoMetric level, small building footprints, compact parcels, close spacing, and dense networks reinforce the capacity of these fabrics to sustain edge-dependent practices.

Planned socialist-era Jiefang and Danwei compounds, represented by Ma'an (C) and Jianshe Road (D), introduce a more internally structured spatial order. Rectilinear blocks, semi-enclosed circulation loops, and centrally positioned communal courts form stable, legible, and well-lit nodes suitable for patterned collective movement. These conditions support coupled and matrix-based dancing (D1–D2), circled dancing in larger plazas (D3), planned community gardens (G1), and certain forms of retail-based teahouses (T2). Corresponding MorphoMetric indicators, such as moderate building intensity, regularised parcel geometry, and relatively integrated street networks, reinforce these behavioural affordances.

Hybrid grid–alley systems and transitional riverfront morphologies, most notably in Zhiminlu (E) and parts of Ma'an (C), combine medium-rise building forms with varied visibility conditions, partially retained alley networks, and permeable circulation structures. These environments accommodate semi-structured and flexible practices, including large open-air markets and residential-to-commercial conversions (M3–M4), outdoor teahouses (T3), and vertical gardening (G3). MorphoMetrically, these areas, especially those characterised by UT 9, exhibit strong network integration and spatial adaptability, supporting both movement intensity and functional flexibility.

Post-2000 tower-form estates, present in parts of Ma'an (C), Zhiminlu (E), and Jianshe Road (D), provide fewer micro-scale interaction interfaces due to large parcels and simplified frontages. However, expansive plazas, linear open spaces, and peripheral seating zones support organised and highly visible activities, including circled dancing (D3), managed gardening (G1), and some retail-oriented teahouses (T2). These characteristics correspond to the consolidated block patterns associated with UT 1.

Taken together, these correspondences establish an intermediate analytical layer between the MorphoMetric typologies identified in Section 4.1 and the empirical pattern-mapping results presented in Section 4.3. Rather than constituting observational evidence, this layer formulates a set of spatial expectations regarding where specific socio-cultural patterns (M1–T3) are most likely to emerge based on the affordances embedded in each Urban Type. In summary, UT 0 and UT 10 are expected to sustain edge-dependent practices; UT 6 to support organised collective activities centred on internal courts; UT 9 to enable hybrid and semi-structured uses requiring both permeability and visibility; and UT 1 to

Table 4 Empirical work on exploration of subtypes of four socio-cultural activities in old Chengdu neighbourhoods.

a. Traditional Food Market				
Types	Informal stalls by boundary walls (M1)	Ground floor retail unit (M2)	Large open-air markets under the tent (M3)	Market converted from the former residential units (M4)
Photos				
b. Elderly Square Dance				
Types	Coupled dance (D1)	Dance in a matrix (D2)	Circled dance (D3)	
Photos				
c. Socialisation in Community Garden				
Types	Planned plantation garden (G1)	Informal plantation garden (G2)	Vertical plantation garden (G3)	
Photos				
d. Teahouse for Playing Mahjong				
Types	Ground floor family unit converted into a teahouse (T1)	Original ground floor retail Teahouse (T2)	Outdoor Teahouse (T3)	
Photos				

concentrate formalised activities within plazas and linear open spaces. These expectations provide the analytical scaffold for the pattern verification undertaken in Section 4.3.

4.3 Pattern Language Findings Across Six Neighbourhoods

Building on the morphogenetic expectations established in Section 4.2.2, this section reports the empirical verification of socio-cultural patterns across the six neighbourhoods through Pattern Language-based observational mapping (Fig.8). Four major activity domains: markets, elderly square dance, community gardening, and teahouse practices, were examined using the spatial attributes defined in the observation protocol (Table 1b), including visibility, enclosure, frontage adaptability, circulation rhythm, seating edges, and degrees of openness. Rather than treating socio-cultural activities as isolated events, the analysis evaluates how specific spatial features required by each pattern are supported or constrained by different Urban Types (UTs). The resulting distribution (Fig. 8; Table 5) confirms that socio-cultural practices cluster selectively within morphological niches where these spatial features align.

Across the six neighbourhoods (A–F), fine-grain morphologies (UT 0 and UT 10) consistently supported socio-cultural practices dependent on short visibility lines, porous thresholds, and frequent edge encounters. Small building footprints, narrow inter-building distances, continuous frontages, and dense street networks produced highly articulated street–building interfaces. These conditions sustained informal and hybrid market activities organised along pedestrian corridors, home-based teahouses where domestic interiors blended acoustically and visually with the street, and informal community gardening through self-organised edge planting and low-intervention appropriation of residual spaces. The recurrent co-occurrence of these practices confirms that fine-grain fabrics structurally favour edge-dependent and threshold-based socio-cultural activity.

Planned mid-rise morphologies (UT 6), associated with socialist-era and early post-reform redevelopment, generated a contrasting constellation of practices. Rectilinear blocks, semi-enclosed circulation loops, and centrally positioned communal courts produced stable, legible spatial nodes with moderate enclosure and consistent lighting. These environments supported organised elderly dance practices reliant on predictable movement fields, repeated edge reoccupation, and surrounding seating surfaces. Planned community gardens also emerged in these settings, enabled by defined plots, circulation paths, and the possibility of local management oversight. Regularised frontage conditions further sustained ground-floor retail and retail-oriented teahouses, indicating that UT 6 environments are particularly suited to repetitive, organised collective routines rather than highly permeable informal uses.

Hybrid and transitional morphologies (UT 9) exhibited the greatest functional elasticity. Medium-rise buildings combined with retained alley networks created varied visibility fields, permeable circulation, and flexible semi-open spaces. These conditions accommodated

Figure 8 Pattern Language verification of socio-cultural activities across the six neighbourhoods. Source: Authors, 2026.

Table 5 Availability of socio-cultural activity subtypes in each neighbourhood.

Neighbourhood	M1	M2	M3	M4	D1	D2	D3	G1	G2	G3	T1	T2	T3
A – Shaocheng	N	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y
B – Caoshijie	N	Y	N	N	N	Y	N	N	Y	N	Y	Y	N
C – Ma'an	N	Y	N	N	Y	Y	N	N	Y	N	Y	Y	Y
D – Jianshe Rd.	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
E – Zhiminlu	N	Y	N	N	N	Y	Y	N	Y	N	Y	Y	N
F – Fuqin	N	Y	Y	Y	N	Y	N	N	Y	N	Y	Y	Y

large open-air markets, residential-to-commercial conversions, and outdoor teahouses that rely on adaptive reuse, emergent clustering, and seasonal open-air sociability. Circled dance practices also appeared in expansive, well-lit plazas that allowed unobstructed collective movement. The concentration of these activities demonstrates that UT 9 morphologies function as spatial mediators, enabling semi-structured practices that require both openness and adaptability.

High-rise and consolidated block morphologies (UT 1) displayed a narrower but clearly defined socio-cultural profile. Large parcels, simplified frontages, and reduced micro-scale interfaces constrained informal and edge-based practices. However, these environments consistently supported activities benefiting from high exposure, long sightlines, and extensive open surfaces, including circled dancing, planned gardening, and retail-oriented teahouses. Expansive plazas, linear open spaces, and predictable circulation corridors facilitated organised and highly visible routines, indicating a restructuring of socio-cultural activity toward formalised expressions rather than its elimination.

Taken together, the verified pattern distributions reveal a strong correspondence between morphological affordances and socio-cultural practice requirements as defined in the observation protocol. Fine-grain fabrics favour informal and domestic practices; structured mid-rise compounds support organised collective routines; hybrid morphologies enable adaptive and semi-structured uses; and high-rise estates concentrate formalised, high-visibility activities. These findings confirm that socio-cultural patterns are spatially conditioned behaviours rather than incidental appropriations. By demonstrating that the spatial features specified in Table 1b systematically align with UT-based morphologies, this section completes the empirical validation of the Pattern Language framework and provides a direct bridge between MorphoMetric classification, historical morphogenesis, and the policy discussion in Section 5.

5 Discussion

5.1 Answering the Research Questions

The findings presented in Sections 4.1–4.3 enable a direct and structured response to the three research questions guiding this study, clarifying how Urban MorphoMetrics, historical morphogenesis, and pattern-based behavioural analysis can be integrated to interpret and support socio-cultural practices in historic neighbourhoods.

5.1.1 How can UMM classify historic neighbourhoods into meaningful urban types and elucidate their spatial affordances relative to socio-cultural activity at neighbourhood scale?

The MorphoMetric analysis identifies distinct dominant Urban Types (UTs) across the six case-study neighbourhoods—most prominently UT 10 in Shaocheng (A), UT 6 in Caoshijie (B), UT 1 and UT 6 in Ma'an (C), UT 1 in Jianshe Rd. (D), UT 9 in Zhiminlu (E), and UT 0 in Fuqin (F), with minor subsidiary types appearing locally. Each UT expresses measurable differences in enclosure, frontage continuity, permeability, grain, street-node configuration, and internal court structure.

These physical differences align closely with the empirically observed distribution of socio-cultural activities summarised in Table 5. Neighbourhoods characterised by fine-grained street–alley fabrics (A and B) consistently support threshold-based retail, home-based teahouses, and informal gardening practices. Transitional neighbourhoods containing hybrid UT 1 and UT 6 fabrics (C) accommodate the widest range of socio-cultural activities, including multiple market forms, dance routines, and gardening types, reflecting their mixed enclosure and circulation structures. More formal UT 1 neighbourhoods (D) reliably support organised collective activities such as dancing and planned gardening, while constraining informal or edge-dependent practices. High-rise neighbourhoods dominated by UT 9 (E) accommodate only a limited subset of large-scale collective activities, most notably circled dancing, indicating reduced socio-cultural

diversity. Early reform-era UT 0 Xiaoqu neighbourhoods (F) support a narrower but still legible mix of activities anchored in low-rise, domestic-scaled environments.

Through these correspondences, Urban MorphoMetrics demonstrates not only that historic neighbourhoods can be classified into meaningful urban types, but also that each type possesses a distinct socio-spatial affordance profile arising from its morphological structure.

5.1.2 How can these MorphoMetric typologies be correlated with Chengdu's historical layers and developmental cycles to identify zones of cultural vitality or vulnerability?

The spatial differentiation of UTs across the six neighbourhoods mirrors Chengdu's historical cycles of urban development, revealing how morphogenetic trajectories condition present-day cultural vitality. Shaocheng (A) and Caoshijie (B), shaped by pre-1949 and early socialist street–alley assemblies, retain fine-grained, permeable urban forms that continue to support edge-based and threshold-dependent practices. However, the absence of informal markets in both neighbourhoods—despite their morphological suitability—demonstrates how contemporary governance and conservation-oriented regulation can override historic spatial affordances.

Ma'an (C) and Jianshe Rd. (D), whose UT 1 and UT 6 morphologies derive from socialist and transitional Danwei structures, exhibit robust clustering around activities that depend on semi-enclosed communal interiors, predictable circulation loops, and mid-sized courts. These include coupled and matrix dancing as well as planned gardening practices. Zhiminlu (E), representing post-2005 high-rise redevelopment, supports only a limited range of socio-cultural activities and displays diminished functional diversity, marking it as a zone of reduced cultural vitality. Fuqin (F), developed during the early reform era, represents an intermediate condition in Chengdu's morphogenetic sequence, sustaining some, but not all, historic socio-cultural routines.

The alignment between UT distributions and socio-cultural practices therefore reflects the city's layered historical development, clarifying where living heritage remains resilient, where it has partially eroded, and where it is most vulnerable to further transformation.

5.1.3 How can a Pattern Language model validate, detail and translate these inferred socio-cultural practices into practical planning and design guidance within the HUL paradigm?

Building on established empirical studies of socio-cultural activities, the Pattern Language framework in this study operates as a translational layer that substantiates and refines the spatial expectations emerging from UT classifications. The thirteen verified socio-cultural activity subtypes (M1–M4, D1–D3, G1–G3, T1–T3) provide fine-grained mechanisms that anchor intangible practices to concrete spatial configurations. Informal markets cluster along permeable transitional alleys; open-air markets stabilise within semi-enclosed courtyards; coupled and matrix dances depend on stable mid-scale courts; circled dances require large, evenly lit open plazas; informal gardens colonise lightly managed edges; planned gardens remain confined to formal internal courts; and teahouse practices anchor themselves in shaded, semi-enclosed thresholds.

These spatially explicit configurations demonstrate that socio-cultural practices are not abstract cultural tendencies, but behaviours tightly coupled to specific morphological features. The Pattern Language framework translates these relationships into operational parameters—such as enclosure depth, threshold continuity, court proportions, façade articulation, and edge permeability—that can be mobilised by planners and designers at neighbourhood and block scales. Rather than treating intangible heritage as diffuse or symbolic, the framework renders it spatially legible, analytically verifiable, and applicable within future heritage-sensitive planning and design interventions under the Historic Urban Landscape approach.

5.2 Corroborating the Findings with Existing Literature

The convergence between MorphoMetric affordances identified through UMM and the empirically verified socio-cultural sub-patterns corroborates and extends existing scholarship on sociospatial practices in historic urban environments. In particular, the observed alignment between fine-grained street–building interfaces and threshold-oriented activities supports well-established arguments that intimate, human-scale streetscapes foster informal commerce and everyday social interaction (Gehl & Svarre, 2013; Whyte, 1980). In Shaocheng (A) and Caoshijie (B), the persistence of home-based teahouses, informal gardening, and micro-retailing exemplifies this relationship. At the same time, the absence of informal food markets in these neighbourhoods, despite clear morphological suitability, highlights the mediating role of regulatory and governance frameworks. This finding reinforces the view that spatial affordances interact with sociopolitical conditions rather than determining behaviour unilaterally.

The exceptional socio-cultural vitality observed in Ma'an (C) further substantiates research emphasising the importance of medium-scale enclosure, semi-open courtyards, and stable circulation structures in sustaining collective routines and everyday sociability (Carmona et al., 2010; Gehl & Svarre, 2013). The hybrid UT 1/UT 6 morphology of Ma'an provides precisely these conditions, enabling the full manifestation of all thirteen validated socio-cultural patterns. The coexistence of informal, planned, and vertical gardening practices extends existing discussions by demonstrating how adaptable communal interiors can support layered and hybrid forms of social production that transcend rigid typological categories.

In contrast, Zhiminlu (E) exhibits a markedly restricted range of practices, consistent with broader findings that large, open plazas and high-rise redevelopment tend to privilege formalised, collective activities while discouraging informal, resident-driven uses (Carmona et al., 2010). The exclusive presence of circled dancing (D3) in E aligns with this spatial logic. The absence of informal markets, gardening, and alley-based social interaction reflects patterns identified in international literature on superblock redevelopment, which has

been shown to erode fine-grained socio-cultural ecologies historically embedded in older urban fabrics (Jian et al., 2025; Song et al., 2024).

The intermediate outcomes observed in Jianshe Rd. (D) and Fuqin (F) add further nuance. In Jianshe Rd., the socialist-era block structure supports organised collective activities reliant on predictable movement and enclosed courts, while simultaneously constraining informal practices such as street vending or ad hoc gardening—an outcome consistent with studies of Danwei-derived morphologies. Fuqin, representing an early reform-era Xiaoqu morphology, retains a degree of socio-cultural flexibility through its moderate scale and semi-open thresholds, echoing findings that early Xiaoqu developments preserve residual capacities for everyday social practices despite subsequent densification pressures.

Taken together, these results confirm that the distribution of socio-cultural practices across Chengdu's historic neighbourhoods cannot be attributed solely to cultural preference or community agency. Instead, they substantiate a growing body of literature arguing that socio-cultural vitality emerges from the interaction between spatial affordances, governance conditions, and historically layered urban form. By demonstrating how distinct Urban Types facilitate, inhibit, or transform specific socio-cultural sub-patterns, this study provides empirical support for the Historic Urban Landscape approach, reinforcing the proposition that living heritage is inseparable from the spatial configurations that enable its continued reproduction.

5.3 Broader Applicability Across Global and Regional Contexts

Building upon the empirical findings, the framework proposed in this study synthesises and extends three established components of research (section 3)—quantitative urban morphology, historical morphogenesis, and socio-spatial observation—into a structured and transferable analytical sequence (Fig. 9). Unlike conventional linear approaches, the framework introduces intermediate interpretative and participatory mechanisms that enable the translation of spatial analysis into socio-cultural resilience-oriented planning insights.

First, Urban MorphoMetrics (UMM) is applied to compute a comprehensive set of spatial descriptors and generate Urban Types through clustering analysis, following recent developments in the numerical taxonomy of urban form (Fleischmann et al., 2020; Fleischmann et al., 2021). This step provides a systematic and comparable representation of structural variations across urban neighbourhoods, allowing complex urban fabrics to be classified into measurable typologies. Second, these morphometric outputs are situated within a morphogenetic perspective through archival analysis and historical interpretation, drawing on traditions in urban morphology that emphasise historical layering and the evolutionary logic of urban form (Conzen, 1960; Whitehand, 2001). At this stage, a behaviour-related protocol is formulated, translating historically grounded spatial configurations into expectations of potential socio-cultural practices. This intermediate step establishes a critical bridge between morphological classification and

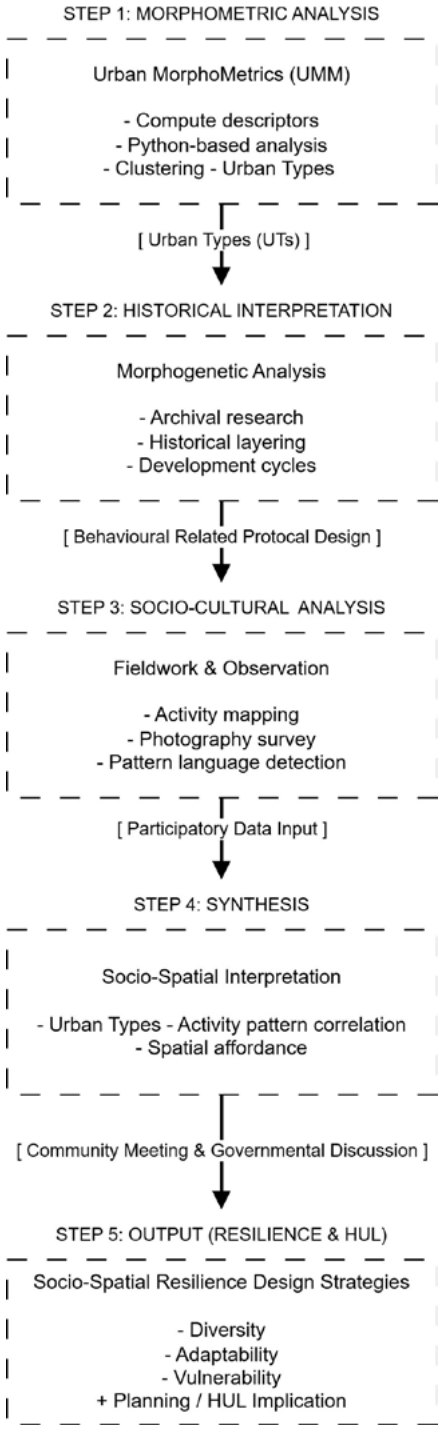

Figure 9 Integrated framework linking Urban MorphoMetrics, historical interpretation, and socio-cultural analysis. Source: Authors, 2026.

behavioural interpretation. Third, socio-cultural analysis is conducted through fieldwork, including activity mapping and photographic documentation, following established approaches in public life studies (Gehl & Svarre, 2013; Whyte, 1980). The observed practices are structured through a Pattern Language approach (Alexander, Ishikawa, & Silverstein, 1977), enabling recurring behavioural configurations to be systematically identified. In addition, participatory data input is incorporated

to capture local knowledge and lived experience, reinforcing the framework's alignment with community-oriented planning principles. Fourth, a synthetic step integrates these analytical layers through socio-spatial interpretation. Urban Types are correlated with observed activity patterns, allowing spatial affordances to be inferred from measurable morphological characteristics. This step is further extended through community consultation and governmental discussion, ensuring that analytical findings are translated into socially grounded and policy-relevant interpretations. Finally, the framework produces outputs oriented toward socio-cultural resilience and planning applications. By evaluating the diversity, adaptability, and vulnerability of socio-cultural practices across different urban conditions, it supports the formulation of resilience-informed design strategies within the Historic Urban Landscape (HUL) framework (Fabbricatti, Boissenin, & Citoni, 2020; UNESCO, 2011).

Although developed through the case of Chengdu, this framework addresses a set of challenges widely recognised across historic urban environments globally. In rapidly urbanising contexts, historic neighbourhoods are frequently subject to redevelopment pressures that transform or displace everyday socio-cultural practices embedded in fine-grained urban fabrics. Existing studies have shown that while such practices are closely related to spatial configurations, planning approaches often lack systematic tools to connect measurable urban form with lived cultural activities (Carmona et al., 2010; Gehl & Svarre, 2013).

At the same time, in European contexts, particularly in cities characterised by historically layered urban forms, the key challenge lies not only in preservation, but in the operationalisation of heritage within contemporary planning processes. The Historic Urban Landscape approach has been widely adopted as a conceptual framework for integrating tangible and intangible heritage (UNESCO, 2011), yet its implementation often remains at a strategic level, with limited methodological instruments for analysing how spatial structures support or constrain everyday practices. This gap is particularly evident in Southeast European contexts such as Sarajevo, Bosnia and Herzegovina, where the historic urban core reflects multiple historical layers (Ottoman period, Austro-Hungarian period and Socialist Yugoslav period) and complex socio-cultural dynamics. While the HUL has been introduced as a guiding framework, studies have highlighted the need for more practice-oriented and analytically grounded approaches to support its implementation in planning and design (Ibrisimbegovic & Tatlic, 2025; Kudumović, 2024). In such contexts, the framework would help identify how specific morphological configurations, such as courtyard-based structures or compact street networks, can support or constrain everyday practices including informal gatherings, small-scale commerce, or community-based social interaction. For instance, in the historic commercial core of Baščaršija in Sarajevo, the urban fabric is characterised by low-rise structures of Ottoman origin arranged in an organic spatial configuration. Within this setting, both residents and visitors frequently occupy the building frontages to consume Bosnian coffee, a practice that extends beyond mere consumption to function as a form of everyday social interaction. In contrast, areas developed during the Austro-Hungarian period exhibit more formalised urban layouts, including Western-style gardens and planned green spaces, where activities such as reading and strolling are more prevalent. These examples, occurring across distinct morphological zones within the same city, illustrate how different spatial configurations afford varied patterns of use. They provide a basis to further examine how specific urban features can be integrated into the proposed model to reveal the interrelationship between spatial form and socio-cultural practices.

In this regard, the framework proposed in this study offers a transferable methodological pathway. By systematically linking MorphoMetric analysis, historical interpretation, behavioural observation, and participatory input, it enables the identification of spatial conditions that support or constrain locally embedded practices. Although the specific socio-cultural activities differ between Chengdu and Sarajevo and beyond, the analytical logic, connecting morphology, affordance, and practice, remains applicable. As such, the framework provides an operational bridge between theory and practice, supporting the implementation of the HUL approach in diverse urban settings.

6 Conclusion

This study set out to demonstrate how Urban MorphoMetrics, combined with a Pattern Language approach, can make the lived dimensions of Chengdu's historic neighbourhoods spatially legible and operational within a Historic Urban Landscape (HUL) framework. By integrating quantitative MorphoMetric types with empirically verified socio-cultural sub-patterns, the research clarifies how distinct spatial fabrics afford, constrain, or reconfigure the everyday cultural practices that constitute living heritage at neighbourhood scale.

The findings demonstrate that MorphoMetric classification is not merely an abstract typological exercise, but a reliable predictor of socio-cultural vitality. Fine-grained, pre-1949 morphologies retain strong affordances for threshold-based sociability, despite regulatory pressures that suppress informal vending. Transitional UT 1/6 neighbourhoods sustain the highest cultural density, supporting markets, dancing, gardening, and teahouse practices through balanced enclosure, adaptable courts, and permeable frontage conditions. Socialist-era blocks, while more regulated, continue to anchor choreographed collective activities and planned gardens. Conversely, post-2005 redevelopment forms exhibit sharply reduced socio-cultural diversity, underscoring their vulnerability in sustaining living heritage. These differentiated relationships demonstrate that long-term morphogenetic processes, rather than isolated design elements, play a decisive role in shaping the persistence, transformation, or erosion of socio-cultural practices.

The corroboration with the Pattern Language model further strengthens these interpretations. The thirteen sub-patterns validated through field evidence translate cultural routines into concrete spatial parameters, including threshold depth, court proportion, vertical articulation, visibility corridors, and circulation rhythms.

Their distribution confirms that socio-cultural expressions are not diffuse or purely symbolic phenomena, but spatially contingent practices rooted in the micro-configuration of urban form. In this sense, the integrated UMM–pattern framework provides a methodological basis for interpreting spatial affordances and linking them directly to culturally embedded behaviours.

Crucially, this relationship allows socio-cultural resilience to be interpreted in spatial terms. Within this study, resilience is understood as the capacity of urban environments to sustain, adapt, and reproduce everyday cultural practices over time in response to morphological and socio-institutional change. The results show that resilience is not evenly distributed, but varies systematically across different Urban Types, depending on their capacity to support diverse, adaptable, and socially embedded practices. By making this relationship explicit, the framework moves beyond abstract discussions of cultural resilience and provides a means to identify where living heritage is robust, where it is transforming, and where it is most vulnerable.

There are, however, several limitations that define the scope of this work. Field validation was conducted within a specific temporal window, meaning that seasonal or time-dependent practices may not have been fully captured. The analysis remains primarily morphology-driven; while governance conditions and demographic change were acknowledged, they were not systematically measured. Furthermore, the study focuses on six neighbourhoods within a single city, which, although morphologically diverse, do not represent the full spectrum of urban conditions. These limitations point towards future research directions, including longitudinal observation, comparative cross-cultural studies, and the integration of governance and socio-economic variables. Despite these constraints, the study offers a coherent methodological and conceptual contribution. It demonstrates that living heritage can be spatially modelled, empirically validated, and translated into design-relevant knowledge through the systematic integration of MorphoMetrics and pattern language. More broadly, the framework contributes to the operationalisation of the HUL approach by providing a replicable pathway for linking urban form, socio-cultural practices, and planning intervention.

For rapidly transforming cities worldwide, where redevelopment risks disconnecting cultural practices from their enabling environments, this approach offers a grounded and transferable method to interpret, protect, and enhance everyday urban life. In doing so, it reinforces the contemporary relevance of the HUL: safeguarding cultural vitality not through the preservation of form alone, but through the sustained support of the socio-spatial systems within which heritage continues to be lived.

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+ Appendices

Table 1a The literature-informed neighbourhood morphology and spatial context.

Neighbourhood	A. Enclosure & Spatial Configuration	B. Permeability & Frontage Dynamics	C. Granularity & Density	D. Street Network Topology	E. Contextual Morphology
A – Shaocheng	High enclosure; compact block forms; narrow alleys producing strong edge definition	Highly permeable frontages; shallow setbacks; rhythmic façade articulation	Very fine grain; small plots; dense spatial texture	Organic, interconnected network with multiple short segments	Strong historical persistence; continuous alignment with pre-1949 morphology
B – Caoshijie	Moderate-to-high enclosure; rectangular parcels shaping semi-enclosed alleyways	High permeability; frequent door–window rhythm; active street edges	Fine grain but slightly more regular than Shaocheng	Orthogonal but intricate alley grid; high local connectivity	Southern pre-year-reform morphology still strongly legible
C – Ma'an	Mixed enclosure; combination of narrow lanes and wider retrofitted streets	Moderate permeability; retained active interfaces; some later infilled frontages	Transitional grain—fine in older areas, coarser in later insertions	Hybrid network; organic base with rationalised interventions	Reflects incremental growth during early socialist urbanisation
D – Jianshe Rd.	Lower enclosure; open building spacing; controlled spatial hierarchy	Lower permeability; organised frontages; planned setbacks	Coarser grain; larger blocks; internally oriented layout	Highly structured network with hierarchy; clear primary axes	Strongly administrative spatial logic; work-unit morphology
E – Zhiminlu	Low enclosure at ground level; large open spaces; tower-separated forms	Very low permeability; deep setbacks; minimal active edges	Very coarse grain; large parcels; vertical, high-density typology	Low internal street connectivity; perimeter-based movement	Modern gated compound morphology; privatised spatial organisation
F – Fuqin	Moderate enclosure; wider distances between buildings	Reduced frontage complexity; deeper setbacks; regular façades	Medium-to-coarse grain; repetitive 6–7 floors block structure	More uniform grid; moderate connectivity	Early reform-era mass housing logic; limited organic layering

Table 1b The literature-informed neighbourhood morphology and spatial context.

Pattern	Sub-pattern Code	Sub-patterns to be observed	A	B	C	D	E	F
M1 Informal food market	M1-1 M1-2 M1-3 M1-4	Densely clustered informal stalls lining pedestrian corridors Intermittent vendor positioning High visibility along pedestrian desire lines Social permeability shaped by rhythmic pedestrian flows	(Document the presence or absence of specific socio-cultural activity subtypes within the neighbourhood and characterise the spatial qualities of their sub-patterns.)					
M2 Ground-floor retail unit	M2-1 M2-2	Threshold-based interactions at neighbourhood edges Transitional boundaries between private/public						
M3 Large open-air markets	M3-1 M3-2 M3-3	Hybridised use of courtyards or garages Co-existence of sales + storage/production Adaptive reuse and emergent clustering						
M4 Markets converted from residential units	M4-1 M4-2 M4-3	Commercial rhythm along internal roads Clearer frontage and longer visibility lines Territorial clarity & legibility						
D1 Coupled dance	D1-1 D1-2 D1-3	Ambient lighting enabling evening activities Convergence of movement & sociability Repeated reoccupation of peripheral edges						
D2 Dance in a matrix	D2-1 D2-2 D2-3	Flexible use of internal access roads/courtyards Spontaneous evening occupation Seating edges surrounding dance nodes						
D3 Circled dance	D3-1 D3-2 D3-3	Large multifunctional plazas High exposure and natural brightness Embodied collective access rituals						
G1 Planned garden	G1-1 G1-2 G1-3 G1-4	Defined plots and circulation paths Supported by local management Structured yet open layout Intergenerational visibility						
G2 Informal gardens	G2-1 G2-2 G2-3 G2-4	Self-organised edge gardens Vines and recycled planters Makeshift seating Low-intervention appropriation						
G3 Vertical garden	G3-1 G3-2 G3-3 G3-4	Vertical gardens on façades and balconies High observability Creative container/railing uses Domestic identity in shared streetscape						
T1 Home-based teahouse	T1-1 T1-2	Blending of home and street Acoustic and visual permeability						
T2 Retail teahouse	T2-1 T2-2 T2-3	Extended social stays Familiar hosts and repeated users Public-yet-intimate ambiance						
T3 Outdoor teahouse	T3-1 T3-2 T3-3 T3-4	Seasonal outdoor setups Shaded sidewalks or squares Portable furniture Open-air sociability						

Table 2a Abbreviation and full name of UMM descriptors.

a) Enclosure & Spatial Configuration	
sdbAre	Standard Building Area
sdcAre	Standard Cell Area
sdbVol	Building Volume
sdbPer	Standard Building Perimeter
sdbCoA	Courtyard Area
sscCCo	Cell Circular Compactness
sscERI	Cell Equivalent Rectangular Index
sdcLAL	Longest Axis Length
mdcAre	Area Covered (tessellation cells)
midAre	Area Covered (nodes/M)
sddAre	Area Covered (nodes/S)
midRea	Reached Cells
b) Permeability & Frontage Dynamics	
ssbFoF	Form Factor
stbOri	Building Orientation
stcOri	Cell Orientation
stbSAl	Street Alignment (building)
stcSAl	Street Alignment (tessellation cells)
ssbVFR	Volume Façade Ratio
ssbCCo	Building Circular Compactness
ssbCor	Number of Corners
ssbSqu	Squareness
ssbERI	Building Equivalent Rectangular Index
ssbElo	Elongation
ssbCCM	Centroid-Corner Mean Distance
ssbCCD	Centroid-Corner Distance Deviation
sdsSPW	Street Profile Width
sdsSPR	Street Profile
sdsSWD	Setback Deviation
c) Granularity & Density	
sicFAR	Floor Area Ratio
sicCAR	Coverage Area Ratio
ltbIBD	Mean Interbuilding Distance
libNCo	Number of Courtyards
ldbPWL	Perimeter Wall Length
d) Street Network Typology	
mtdDeg	Node Degree
mtdMDi	Mean Distance to Nodes
linWID	Weighted Intersection Density
linPDE	Proportion of Dead-Ends
linP3W	Proportion of 3-Way Intersections
linP4W	Proportion of 4-Way Intersections
lcnClo	Local Closeness Centrality
lcdMes	Meshedness
xenSCI	Sqaure Clustering
e) Contextual Morphology	
mdsAre	Area Covered (tessellation cell/M)
misRea	Reached cells (M)
ldkAre	Block Area
ldkPer	Block Perimeter
ldsMSL	Mean Segment Length
ldsCDL	Cul-de-sac Length
ldsRea	Reached cells (L)
likWBB	Weighted Buildings (block)
lskERI	Block Equivalent
lskCCo	Block Circular Compactness
lskCWA	Compactness Weighted Axis
ltkOri	Block Solar Orientation
ltkWNB	Weighted Neighbours (block)
sssLin	Linearity
sdsAre	Area Covered (tessellation cell/S)
sdsSHD	Height Deviation (street)
sdsSPH	Street Profile Height
sdsSPO	Street Openness