International Journal of Geo-Information

MDPI

Article

A Multi-Dimensional Evaluation of Street Vitality in a Historic Neighborhood Using Multi-Source Geo-Data: A Case Study of Shuitingmen, Quzhou

Guoquan Zheng *, Lingli Ding and Jiehui Zheng

Faculty of Landscape Architecture, Zhejiang Agriculture and Forestry University, Hangzhou 311300, China; dinglingli@stu.zafu.edu.cn (L.D.); zhengjiehui1111@163.com (J.Z.)
* Correspondence: zhenggq@zafu.edu.cn

Abstract

Territorial tourism has brought new development opportunities for historic and cultural neighborhoods. However, an insufficient understanding of the spatial distribution and influencing mechanisms of neighborhood vitality continues to constrain effective revitalization strategies. This study takes the Shuitingmen Historical and Cultural Neighborhood in Quzhou, China, as a case study and develops a multi-dimensional vitality evaluation framework incorporating point-of-interest (POI) data, location-based service (LBS) heatmaps, street network data, historical resources, and environmental perception indicators. The Analytic Hierarchy Process (AHP) is applied to assign indicator weights and calculate composite vitality scores across 19 streets. The results reveal that (1) comprehensive evaluation corrects the bias of single indicators and highlights the value of integrated assessment; (2) vitality is higher on rest days than on weekdays, with clear temporal patterns and two types of daily fluctuation trends—similar and differential; and (3) vitality levels are spatially uneven, with higher vitality in central and western areas and lower performance in the southeast, often related to low accessibility and functional monotony. This study confirms a strong positive correlation between street vitality and objective spatial factors, offering strategic insights for the micro-scale renewal and sustainable revitalization of historic neighborhoods.

Keywords: spatial vitality; multi-source geo-data; analytic hierarchy process (AHP); urban renewal strategies; historic neighborhoods

check for updates

Academic Editors: Wolfgang Kainz and Godwin Yeboah

Received: 17 April 2025
Revised: 18 June 2025
Accepted: 23 June 2025
Published: 24 June 2025

Citation: Zheng, G.; Ding, L.; Zheng, J. A Multi-Dimensional Evaluation of Street Vitality in a Historic Neighborhood Using Multi-Source Geo-Data: A Case Study of Shuitingmen, Quzhou. *ISPRS Int. J. Geo-Inf.* **2025**, *14*, 240. https://doi.org/10.3390/ijgi14070240

Copyright: © 2025 by the authors. Published by MDPI on behalf of the International Society for Photogrammetry and Remote Sensing. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Historic and cultural neighborhoods are essential carriers of urban memory, spatial diversity, and cultural identity. In the context of China's accelerated urbanization, these heritage-rich areas face increasing pressures from redevelopment, tourism commercialization, and functional decline [1–3]. Although many of them have gained renewed attention due to their historical significance and tourism potential, challenges such as environmental degradation, social fragmentation, and homogenized land use continue to threaten their vitality [4–7]. Meanwhile, the rise in experiential tourism, spatial consumption, and the demand for meaningful places has reactivated interest in the street-level vitality of such districts. This "renewed" focus highlights their evolving role as drivers of urban vitality, moving beyond static preservation to become dynamic hubs that offer authentic cultural experiences and human-scaled environments, which are increasingly valued in

contemporary urban life and actively fostered through new approaches to heritage-led regeneration. Within this regeneration process, tourism frequently emerges as a significant factor influencing, and being influenced by, urban vitality. Well-managed tourism can enhance the vibrancy of historic neighborhoods by attracting diverse visitors, stimulating local economies that support heritage upkeep, and creating demand for lively public spaces and cultural programming. Conversely, the unique identity and sense of community within these neighborhoods, aspects crucial for their sustained vitality and social sustainability [8], can also shape the nature and success of tourism development. However, effectively harnessing this potential requires a deeper and more nuanced understanding of street-level vitality, especially as these historic neighborhoods grapple with the pressures of rapid urbanization and evolving socio-economic demands, an understanding that, as highlighted in the abstract, remains insufficient in many contexts.

Urban vitality, as a core concept in assessing the quality and liveliness of public spaces, has attracted wide academic attention from seminal figures in urban studies who have profoundly shaped our understanding of what makes cities thrive. Jane Jacobs [9] emphasized that mixed land uses, short blocks, diverse building ages, and high pedestrian activity are essential to vibrant urban life, highlighting the importance of fine-grained urban fabric and organic, diverse human interactions. These elements highlighted by Jacobs are not only crucial for vibrancy but also foundational for fostering social interaction, community cohesion, and a sense of belonging, all of which are key components of social sustainability in urban neighborhoods. Similarly, William H. Whyte's [10] meticulous observations of social life in small urban spaces underscored how subtle design features can dramatically impact human behavior and the use of public areas, thereby influencing their perceived vitality. Kevin Lynch [11] underlined the importance of legibility, while Ian Bentley [12] contributed insights into spatial richness and permeability. Extending these people-centered approaches, Jan Gehl [13] has consistently advocated for human-scaled environments that prioritize pedestrian and cyclist experiences, emphasizing the critical role of walkability—underpinned by supportive urban design features such as active frontages, comfortable pathways, and a permeable street network—in fostering social activities and, consequently, urban vitality. His work, and that of others associated with organizations like Project for Public Spaces, emphasizes that vitality is not merely about the frequency of interactions but also encompasses the quality, diversity, and inclusivity of such interactions and their positive impact on community life and the local economy. Drawing from these foundations, scholars have increasingly turned to quantitative approaches to analyze spatial vitality, using indicators such as pedestrian flow, POI density, land use mix, and environmental comfort [14–20]. Recent works in China have further demonstrated the temporal dimension of vitality and its relationship with human behaviors such as lingering, walking, and gathering [14,15], offering new empirical insights in rapidly urbanizing contexts.

The evaluation of vitality in historical and cultural districts typically involves multiple dimensions—material (e.g., spatial structure, street layout), social (e.g., functional mix, accessibility), and cultural (e.g., historical resource density, visual atmosphere) [2,21–26]. With the growing availability of big data and spatial analytics, sources such as LBS heatmaps [27], POI data [28], street view imagery [29], and mobile signaling [30] now enable more refined, dynamic assessments [15]. These tools, when used in combination, have proven effective in revealing spatial patterns and diagnosing problems in heritage preservation and urban design [5,31–33]. However, it is also important to acknowledge the context within which much of these dynamic geo-data are generated. The rise in 'surveillance capitalism,' where personal data become a commodity, means that many LBS and POI datasets are collected by commercial entities with profit-driven motives. While these data sources offer

unprecedented insights for urban research, their use also raises critical questions regarding individual privacy, data security, algorithmic bias, and the potential for such pervasive data collection to subtly alter public behavior or impact the sense of safety and freedom within urban spaces. Therefore, researchers and planners leveraging these new data streams must remain mindful of such ethical considerations and societal impacts, ensuring that the pursuit of data-driven insights does not compromise community well-being or exacerbate inequalities. Indeed, the increasing digitization of urban life and the tools for visualizing and analyzing urban space are not neutral instruments; they actively shape how cities are experienced, understood, and governed—a critical focus within fields like the digital sociologies of cities [34,35]. Acknowledging this broader context is important for future research aiming to integrate digital methods with deeper understandings of urban social dynamics and vitality.

While the foundational works of scholars like Jacobs, Lynch, and Gehl laid crucial groundwork for understanding urban vitality and people-centric public spaces, and contemporary research has advanced quantitative methods and data sources as reviewed above, the application and refinement of these insights in specific contexts, particularly with the advent of new data possibilities and pressing urban challenges, reveal several areas ripe for further investigation. Despite these advancements, three notable gaps remain in the current body of research: First, many existing studies focus on macro-scale city or district-level analysis and lack attention to micro-scale street-level dynamics, which are crucial in heritage neighborhoods where fine-grained space use patterns dominate [15,36], especially leveraging new multi-source geo-data to capture these nuances in rapidly evolving urban contexts like those in China. Second, evaluation frameworks often rely on single data types or partial indicators, limiting the capacity to uncover multi-dimensional patterns of vitality and their underlying mechanisms in a holistic and replicable manner [14,37]. Third, the integration of objective spatial data (e.g., street structure, building form) with dynamic human activity data (e.g., LBS heatmaps) and historical–cultural attributes to form comprehensive, operationalizable vitality models is still underdeveloped in both the Chinese and international literature [15,20,26].

Moreover, while theoretical understandings of urban vitality have evolved, there is a lack of application-oriented frameworks specifically tailored to historic and cultural blocks, particularly in the Chinese urban context where street morphology and cultural layers, and the rapid pace of change, present unique challenges and data opportunities, including the need to understand and enhance vitality and walkability within dense, historically layered pedestrian environments often interacting with intense commercial pressures and evolving community needs. A more nuanced and operationalized model is needed to assess vitality holistically and guide targeted micro-renewal in these specific settings.

This study addresses the above research gaps by developing a multi-source, multi-dimensional street vitality evaluation framework. By integrating POI data, LBS-based heatmaps, vector road network data, building attributes, and environmental perception indicators, we construct a composite vitality index using the Analytic Hierarchy Process (AHP). This study takes the Shuitingmen Historical and Cultural Neighborhood in Quzhou, China, as a case site—an area known for its preserved Huizhou-style buildings, cultural landmarks, and mixed commercial–tourism functions. The choice of Shuitingmen as a case study is deliberate; it is not only an exemplary site embodying Quzhou's profound historical and cultural heritage, having received national and provincial accolades for its significance (e.g., "National 4A Level Tourist Attraction," "Provincial Historical and Cultural Block"), but it also reflects the common challenges and opportunities encountered by many similar heritage districts across China during their urban renewal processes. These include the imperative to balance heritage conservation with contemporary development needs,

address potential issues like over-commercialization or the erosion of local distinctiveness, and continuously work towards enhancing public engagement and socio-economic vibrancy. Thus, an in-depth analysis of its street vitality can offer valuable insights for both local planning interventions and broader heritage revitalization practices. Given Shuitingmen's prominent role as a tourist destination and its mixed commercial–tourism functions, understanding its street vitality inherently involves considering how tourism activities and related amenities contribute to or shape its spatial and temporal vitality patterns. This perspective informs our research focus.

This research seeks to answer two key questions:

1. What are the temporal variations in neighborhood vitality?
2. How do functional diversity and accessibility influence street-level vitality?

To guide the empirical investigation, we propose the following hypothesis:

Streets with higher levels of functional diversity, pedestrian accessibility, and historical–cultural richness exhibit significantly higher vitality scores, as measured by integrated geo-spatial indicators.

This research contributes both theoretically and practically. Theoretically, it offers a refined model of spatial vitality applicable to heritage urban settings. Practically, it provides a data-driven basis for informing micro-scale renewal strategies that respect cultural integrity while enhancing everyday usability.

2. Data and Methods

This section details the methodological framework designed to address the research questions outlined in the Introduction, specifically concerning the spatiotemporal evaluation of street vitality in the Shuitingmen Historical and Cultural Neighborhood and the identification of its influencing factors. The approach adopted is multi-faceted, beginning with a thorough contextualization of the study area (Section 2.1) to highlight its relevance and specific characteristics that inform the vitality assessment. Subsequently, the diverse data sources (Section 2.2) utilized in this research are described, emphasizing the need for multi-source geo-data to capture the complex and dynamic nature of urban vitality. Finally, the core methods (Section 2.3) for constructing the vitality evaluation framework are presented. This includes the systematic selection of evaluation indicators based on the existing literature (Section 2.3.1), the crucial step of quantifying these indicators (Section 2.3.2) to transform observable urban phenomena and abstract concepts into measurable variables suitable for objective analysis, and the subsequent assignment of weights to these indicators using the Analytic Hierarchy Process (AHP) (Section 2.3.3) to derive a composite vitality index. Each component of this methodology is integral to achieving a robust, data-driven, and replicable assessment of street vitality, ultimately aiming to provide actionable insights for the sustainable revitalization of historic neighborhoods.

2.1. Study Area

Located in the core area of the ancient city of Quzhou, the Shuitingmen Historical and Cultural Block has the highest concentration of traditional-style buildings and the richest collection of historical and cultural relics in the city. Covering approximately 100,000 m^2, the neighborhood is well known for its profound cultural heritage and distinctive urban character. Shuitingmen's identity is deeply interwoven with Quzhou's history, reflecting, for example, its 'outward shipping merchant culture' and the 'legacy of traditional Chinese medicine'—aspects that contribute to its unique 'cultural fabric' as explored in heritage studies of the area [38]. The block also stands as a poignant historical witness to the War of Resistance, an element that adds to its layered historical significance. Figure 1 illustrates the location of this significant historical block. As shown in the figure, two related but

distinct boundaries are used in this study: the official boundary of the core conservation zone, which defines the overall heritage area, and a more generalized analytical boundary defined by the network of the 19 selected streets and their immediate surroundings. This analytical boundary is used for all subsequent spatial evaluations to ensure that our analysis is precisely focused on the street spaces themselves and their direct interfaces, which are the primary carriers of public life and vitality. The block's strategic location within the core of Quzhou's ancient city, a city known as a thoroughfare for four provinces (Min, Zhe, Gan, and Wan) and a tourist distribution center for surrounding national 5A scenic spots, naturally establishes it as a significant point of attraction. This inherent appeal draws both local citizens and incoming tourists, providing a foundational pedestrian flow essential for street vitality. Furthermore, its convenient accessibility, supported by multiple bus stops within 100 m and nearby parking facilities, is a crucial prerequisite for attracting diverse visitors and fostering a vibrant street life.

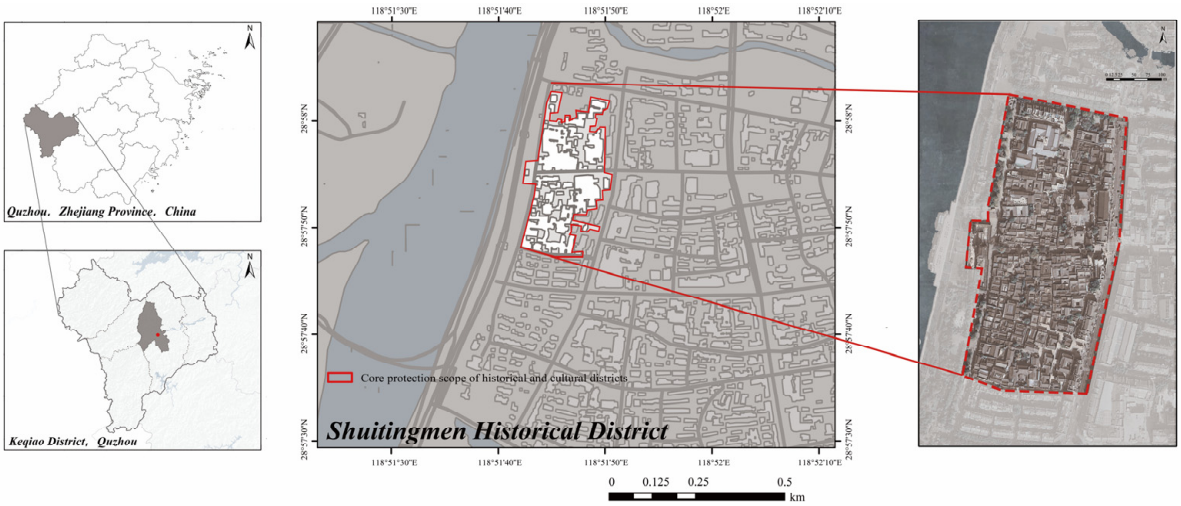


Figure 1. Shuitingmen Historical and Cultural Neighborhood area. Source: Base map from Gaode Map (2025), with authors' additions.

The neighborhood retains the classic spatial layout of "three main streets and seven major alleys," with various architectural styles and well-preserved street textures, showcasing the typical features of residential communities in western Zhejiang. Figure 2 provides a visual impression of the area's characteristic streetscape and architectural style. It integrates cultural experiences, tourism, catering, leisure and entertainment, education, performing arts, and accommodation. Currently, the area houses over 301 businesses, including 102 cultural and creative shops, 130 restaurants, 32 leisure and entertainment venues, 30 cultural exhibition sites, and 11 hotels and guesthouses. In addition, the neighborhood features 9 time-honored Chinese brands and intangible cultural heritage projects at the national, provincial, and municipal levels (9, 4, and 2, respectively), reflecting its deep cultural roots and commercial vitality. Emphasizing integrated development, the area supports various business types to meet various market needs. To provide a clearer overview of the neighborhood's functional layout, the spatial distribution of its primary functions is illustrated in Figure 3. As the map shows, commercial and dining activities are heavily concentrated along Shuiting Street (Street 1) and Jinshi Lane (Street 3), forming the commercial core of the neighborhood. In contrast, cultural experience and heritage sites—including exhibition halls, former residences of famous people, and temples—are more dispersed throughout the block's various streets and alleys, acting as key cultural nodes rather than forming a single contiguous zone. Hospitality services, such as guesthouses, are few and scattered. A notable characteristic is the presence of original residential buildings;

however, many of these are now vacant, indicating a significantly weakened residential function. This distinct functional layout provides an essential backdrop for understanding the vitality patterns analyzed later in this study. The Shuitingmen Historical and Cultural Block's role as a significant tourist destination is evident in its capacity to attract a large volume of visitors annually, with notable peaks in attendance during public holidays and festival periods. This consistent tourist interest, alongside local patronage, underscores the area's public appeal and its function as a key leisure and cultural hub within Quzhou.



Figure 2. Typical streetscapes and the architectural atmosphere of the Shuitingmen Historical and Cultural Block. The area is characterized by its well-preserved Huizhou-style buildings and traditional street textures. Source: Photographs by authors (2025).

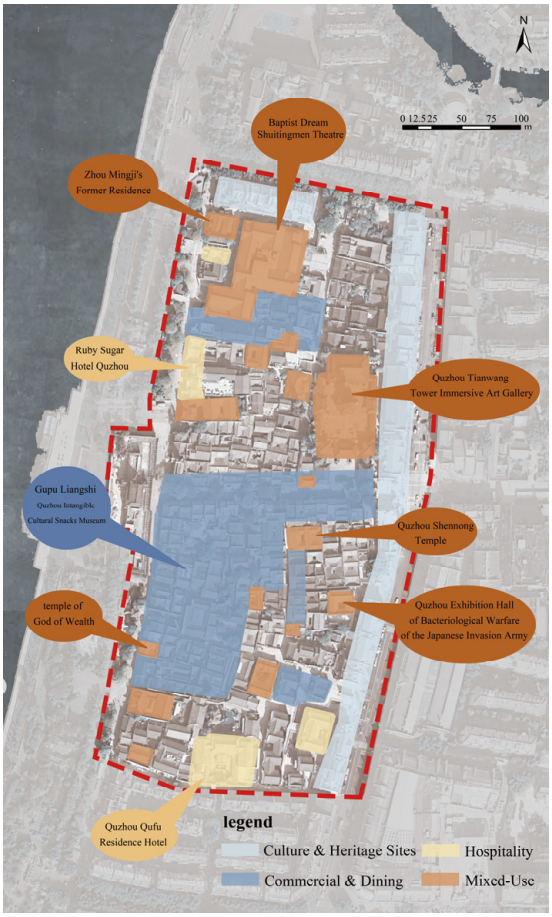


Figure 3. Spatial Distribution of Dominant Functions in the Shuitingmen Neighborhood. Source: Authors' elaboration based on POI data and field surveys.

The Shuitingmen Historical and Cultural Street area contains 14 key cultural heritage units and 36 historical buildings. The architectural style and street texture have been carefully preserved, following the Huizhou style. Restoration work adheres to the principle of "repairing the old as old," ensuring historical continuity through precise reconstruction and conservation. The neighborhood has embraced industrial integration, responding to new trends by introducing varied industries and enriching its functions in commerce, education, art, and creativity. These efforts support Shuitingmen's transformation into a hub of urban tourism and cultural–creative commerce. Reflecting its diverse offerings, the Shuitingmen Historical and Cultural Block attracts a mixed population of users, including local residents enjoying daily life and the cultural atmosphere, tourists drawn to its historical character and amenities, and individuals working within its numerous commercial and cultural establishments. The commercial value of the area is also reflected in its shop rental market. For instance, based on publicly available information from 2023, three-year lease rights for some shops within the block varied, with reported figures such as CNY 49,600 for a property at No. 4 Jinshi Lane, CNY 59,000 for No. 11 Luohan Jing, CNY 84,800 for No. 3 Ningshao Lane, and CNY 18,000 for No. 28 Zhaijia Lane, indicating differences in market value based on location and other conditions. While specific rental rates per unit area are not detailed here, these figures provide some insight into the commercial attractiveness of different locations within the block. The block itself primarily features commercial–residential mixed-use properties, with original inhabitants and renters, rather than newly developed large-scale residential zones. The cost of housing in the immediate vicinity also reflects its prime location within the historic core. For example, second-hand apartment prices in nearby residential compounds ranged approximately from CNY 10,700 per square meter (e.g., Wutong Lane Residential Area) to CNY 18,300 per square meter (e.g., Fudi Jingyuan). Rental prices in these surrounding areas also varied, with a 130 m^2 apartment in Meisufang reportedly leasing for around CNY 1800 per month, a 60 m^2 unit on Xianxi Street for about CNY 1180 per month, and a 97 m^2 apartment in Fudi Jingyuan for approximately CNY 2300 per month, illustrating the combined influence of location, size, and condition on housing costs. While tourism significantly contributes to the area's vibrancy and economic activity, it is also acknowledged in broader urban studies that intensive tourism in historic neighborhoods can present complex challenges. These may include pressures on local residential life, the authenticity of cultural experiences, and the overall livability, often creating tensions that require careful management to ensure sustainable vitality [39,40]. Understanding and navigating these dynamics is pertinent for heritage areas like Shuitingmen that aim to balance tourism development with community well-being and cultural integrity.

This study focuses on evaluating the vitality of street spaces within the Shuitingmen Historical and Cultural Block. These spaces comprise the network of primary streets and alleys, along with key public space nodes. The study area is defined as the core conservation zone, extending from Xianxi Street in the east to Shangying Street and the western city gate in the west and from Soapwood Lane in the south to Xinheyan in the north, covering a total of 15.5 hectares. This research concentrates on 19 primary streets and alleys, which serve as essential carriers of spatial vitality and cultural heritage within the neighborhood. The specific layout and names of these studied streets and alleys are detailed in Figure 4. Understanding these specific physical, cultural, and functional characteristics of the Shuitingmen block is foundational for the subsequent vitality evaluation, as these attributes are hypothesized to directly influence its vitality patterns and levels.

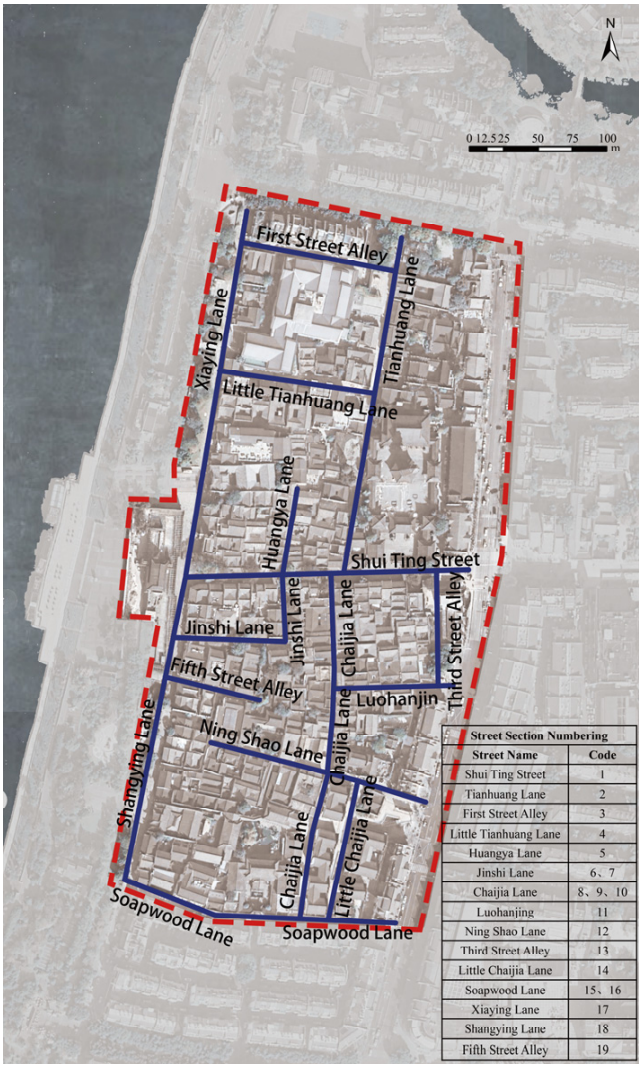


Figure 4. Streets and alleys studied. Source: Base map from Google Earth (2025), with authors' additions.

2.2. Data Sources

To comprehensively analyze the spatial vitality and its influencing factors in the Shuitingmen neighborhood, thereby addressing our research questions, this study utilizes several key sets of multi-source geo-data. Each data type provides unique insights into different facets of urban life and the built environment pertinent to vitality assessment: The first set of geospatial data captures crowd distribution and urban vitality through LBS positioning data (e.g., Baidu heat map) [23], POI data provide geographic location information of food and beverage, retail, and other businesses, and vector road network data supplement information such as names, lengths, and grades of roads [24], which together outline the spatial structure and functional layout of the area. The second group of architectural and infrastructure data analyzes building contours, attributes, and historical element points, describing architectural features and historical and cultural resources in detail. The third group of urban visual and environmental data records the street environment and building layouts through streetscape images. It assesses the proportion of street elements using image recognition technology to provide a basis for assessing the vitality of public space.

2.3. Methods

To systematically evaluate street vitality based on the collected data and to directly address the research objectives, the following methodological procedures for indicator construction, quantification, and weighting were implemented.

2.3.1. Construction of Evaluation Indicators

This study's selection of evaluation indicators is primarily based on a literature review. Drawing on relevant research in China and abroad over the past 40 years, we summarized the objective factors commonly used by scholars to assess spatial vitality. Among these, functional mixing and traffic accessibility are the most frequently cited indicators, followed by functional density, street width-to-height ratio, and green visibility. Indicators related to historical elements also appear frequently in studies of historical and cultural neighborhoods and are therefore used as important references in this study. A summary of these factors, drawn from a literature review spanning 1971–2024 and commonly used by scholars to assess spatial vitality, is provided in Table 1.

Considering data availability, we selected vitality indicators that are both widely used and representative, including functional diversity, historical richness, environmental comfort, spatial scale, and pedestrian accessibility. LBS data reflects the spatial distribution of people within the neighborhood, forming six primary criteria layers for quantification. Based on these layers and the specific characteristics of historical and cultural neighborhoods, ten evaluation factors are identified—such as the proportion of old buildings, density of historical elements, integration, and selectivity—to construct a comprehensive indicator system for assessing neighborhood vitality. The structure of this indicator system, outlining the relationship between LBS location data, POI data, traffic accessibility, spatial scale, environmental comfort, historic resource attractiveness, and the overall neighborhood vitality assessment, is depicted in Figure 5.

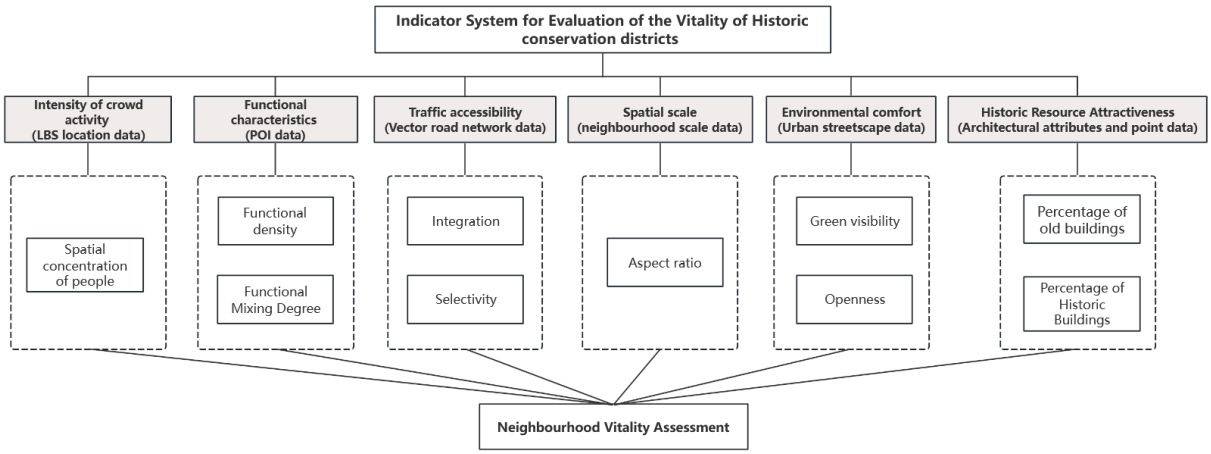


Figure 5. Neighborhood vitality evaluation indicator system model. Source: Authors' elaboration.

Table 1. A summary of the selection of factors for the vitality evaluation indicator (1971–2024). Source: Compiled by the authors based on the literature review (references as cited in the main text and table content).

Author	Development Intensity	Accessibility	Spatial Form and Scale	Site Classification	Functionality	Historic Resource Elements	Neighbor-Hood Amenity	Other Elements
Jan Geier [13] (1971)	/	slow traffic	Open block	/	/	/	/	Diversity of space activities
Jacobs [9] (1992)	neighborhood scale	accessibility and continuity	Macro -block	/	Functional mix	Mixed building age	/	Spatial richness
KatzP [25] (1994)	construction density	/	Walking Scale	/	Functional mix	/	/	/
Mont-goMery [26] (1998)	/	street connectivity	Street scale, building texture	Land mix	Functional mix	/	Green/ water spaces	Open space
Siavash (2011)	neighborhood scale	/	/	/	functional density	/	/	/
Zarin [36] (2015)	/	accessibility	/	/	/	/	/	Cultural atmosphere
Long Y [37] (2016)	development intensity	accessibility	Interface continuity	Nature of the plot	Functional density, degree of mixing	Iconic building	/	/
Hao X H [41] (2016)	/	accessibility	Street length, road texture	/	Functional density, degree of mixing	/	/	/

Table 1. *Cont.*

Author	Development Intensity	Accessibility	Spatial Form and Scale	Site Classification	Functionality	Historic Resource Elements	Neighbor-Hood Amenity	Other Elements
Ye Y [42] (2017)	construction density	accessibility	/	/	Functional mix	/	/	/
Dan H [43] (2018)	/	/	Pavement width	/	Functional density, degree of mixing	/	Green rating	Public service density
Niu X Y [14] (2019)	/	accessibility	Minor street code	/	Functional mix	Old building	/	/
Zhang Y Y [44] (2019)	/	accessibility	/	/	/	Attractive-ness of historical resources	/	Commercial attraction
Mao Z R [45] (2021)	/	accessibility	Neighborhood scale (aspect ratio, enclosure, openness)	/	Functional density, degree of mixing	/	Street green visibility	Situation of public facilities
Zhou D L [46] (2021)	/	accessibility	/	/	Functional mix	/	Green Configuration	Facility Functional Configuration
Li W [47] (2024)	/	integration, selectivity	Comprehensibility	/	Functional density, degree of mixing	Historic building density	/	/

2.3.2. Quantification of Indicators

This paper quantitatively analyzes the spatial vitality of historical and cultural neighborhoods by selecting key indicators, including pedestrian density, POI density and mixing, the proportion of old buildings, the density of historical elements, green visibility, sky openness, street width-to-height ratio, and intersection density. By integrating and analyzing multiple sources of big data, these indicators reflect various dimensions—ranging from crowd activities and functional facilities to historical architecture and street environmental characteristics—enabling a comprehensive assessment of neighborhood vitality. Table 2 summarizes the data sources, quantitative models, formulas, and descriptions for each selected indicator.

The quantification of indicators, as detailed by the specific formulas and models presented in Table 2, is a critical methodological step that translates the conceptual dimensions of urban vitality—such as functional diversity (RQ2, Hypothesis), pedestrian accessibility (RQ2, Hypothesis), spatial scale, environmental comfort, and historical-cultural richness (Hypothesis)—into objective, measurable variables. This rigorous quantification process is essential for fulfilling our research objectives in several ways:

Enabling Objective Assessment: It allows for a systematic and replicable evaluation of these diverse factors across all 19 studied streets, moving beyond subjective impressions to provide a consistent basis for comparison.

Facilitating Analysis of Influencing Factors: By generating precise numerical values for each indicator (e.g., POI density, road network integration, green visibility), we can subsequently analyze their statistical relationship with the overall street vitality scores. This directly supports our aim to investigate how these built environment characteristics influence vitality (addressing Research Question 2) and allows for the empirical testing of our proposed hypothesis.

Providing a Foundation for the Composite Index: These quantified indicators are the necessary inputs for the Analytic Hierarchy Process (AHP) used in assigning weights (Section 2.3.3) and for the subsequent calculation of the composite vitality index (Section 3.3). Without this initial quantification, a weighted, multi-dimensional assessment of vitality would not be possible. Therefore, the formulas and quantification procedures outlined in Table 2 are instrumental in systematically measuring the attributes hypothesized to shape street vitality, enabling a data-driven approach to understanding its spatiotemporal patterns and underlying mechanisms in the Shuitingmen historic neighborhood.

To standardize the diverse range of raw indicator values for subsequent comparative analysis and weighted summation in the Analytic Hierarchy Process (AHP) model, each of the ten evaluation factors was classified into five levels. This classification was primarily performed using the Jenks Natural Breaks method within ArcGIS 10.2 software. The Natural Breaks method is a data clustering approach that identifies natural groupings inherent in the data by seeking to minimize variance within each class while maximizing variance between classes. A five-level classification (scored 1 to 5, corresponding to Level 1 to Level 5, respectively) was chosen as it provides a balanced and interpretable scale, facilitating the normalization of different indicators prior to calculating the composite vitality index. While the specific value ranges (thresholds) for each indicator's five levels are detailed in the legends of their respective thematic maps in the Results Section where applicable, a consolidated table summarizing these thresholds for all evaluation factors is provided in Appendix B for comprehensive reference.

Table 2. Summary of data sources and quantification of indicators. Source: Authors' elaboration.

Dimension	Category	Indicator	Source of Data	Quantitative Model	Formula	Formula Description
multi-source big data	LBS location data	Spatial concentration of people	Baidu Heat	Data overlay, vectorization	/	/
	POI data	Functional density	Gaode Map	Information entropy	$Density = \frac{POI_{NUM}}{Road_{length}}$	The number of POI functions refers to the number of functional business POIs.
		Functional mix		Shannon Entropy Index [48]	$Diversity = -\sum P_i \times lnP_i (i = 1, 2, \cdots, n)$	i denotes the POI category and P_i denotes the ratio of the number of POIs in category i to the total number of POIs in the neighborhood.
	Vector road network data	Integration	Baidu Map	Depthmap integration, selectivity calculation	/	/
		selectivity			/	/
	Neighborhood-scale data	Street height and width	Actual Test	Data overlay, vectorization	$\frac{D}{H} = \frac{D_i}{3 \times F_i} (i = 1, 2, \cdots, n)$	D_i is the width of the street and F_i is the number of stories of building i within the street buffer, and n average floor height of 3 m per story is assumed for calculating building height.

Table 2. *Cont.*

Dimension	Category	Indicator	Source of Data	Quantitative Model	Formula	Formula Description
multi-source big data	Building attribute and point data	Percentage of old floor space	Gaode Maps	nuclear density method	$Old = \frac{S_{oldi}}{S_t}$ $(i = 1, 2, \cdots, n)$	S_{oldi} represents the floor area of the old buildings in street buffer zone i, and S_t represents the total floor area of the buildings in zone i.
		Density of historical elements			$Densityi = \frac{HPOI_{numi}}{road_{lengthi}}$	The historical number of POIs means the number of historical element POIs.
	City streetscape data	Green visibility [49]	Baidu Street View	Semantic segmentation, data overlay	$GV_I = \frac{G_i}{V_i}$	G_i denotes the sum of pixels occupied by the greenery in image i, and V_i denotes the sum of the ith facet domains.
		Openness to the sky [50]			$SVF_I = \frac{S_i}{v_i}$	S_i denotes the sum of the pixels of the sky in image i, and V_i denotes the sum of the ith field.

2.3.3. Assignment of Evaluation Indicators

This study combines expert consultation and the Analytic Hierarchy Process (AHP) to assign weights to the evaluation indicators. The expert consultation method ranks the relative importance of indicators based on professional experience, while AHP quantitatively determines the weights by constructing a hierarchical structure and pairwise comparison matrices. This approach ensures scientific and accurate weight assignment. The AHP framework includes three levels: the target level, the criterion level, and the factor level. Each level is scored using pairwise comparisons, with values ranging from 1 to 9 representing relative importance. To ensure the validity of the evaluation, 20 experts in urban planning—mainly those in university faculties specializing in urban and rural planning—were invited to participate. By calculating the maximum eigenvalue (λMax) and the consistency index (CI) of the judgment matrices and applying the consistency ratio formula (CR = CI/RI), this study confirms that six judgment matrices passed the consistency test, validating the weight results. Table 2 provides a detailed summary of the data sources, quantitative models, formulas, and descriptions for each of these selected indicators, including pedestrian density, POI density and mixing, and others.

According to the assigned weights shown in Table 3, pedestrian density received the highest weight, indicating its dominant influence on neighborhood vitality. Vector road network data received the lowest weight. The weight of POI mixing exceeds that of POI density, suggesting that functional diversity plays a more critical role than sheer density. Similarly, the weight of road network integration is higher than that of selectivity, highlighting the importance of connectivity to destinations. The street width-to-height ratio also holds a relatively high weight, underlining its impact on vitality. The density of historical elements carries more weight than the proportion of old buildings, suggesting that concentrated historical features are more effective in attracting people. Green visibility and sky openness are assigned equal weights, indicating that both contribute significantly to neighborhood vitality.

Table 3. Neighborhood vitality evaluation indicator weights. Source: Authors' calculation based on AHP analysis and expert consultation.

Target Level	Standardized Layer	Weights	Factor Level	Weights	Combined Weights
Neighborhood Vitality Evaluation Indicator System (A)	LBS thermal data (B1)	0.3826	Spatial concentration of people (C1)	1	0.3826
	POI data (B2)	0.2518	POI mixing (C2) POI density (C3)	0.6667 0.3333	0.1679 0.0839
	Vector road network data (B3)	0.0486	Road network integration (C4) Road network selectivity (C5)	0.6667 0.3333	0.0324 0.0162
	Neighborhood scale data (B4)	0.067	Street aspect ratio (C6)	1	0.067

Table 3. *Cont.*

Target Level	Standardized Layer	Weights	Factor Level	Weights	Combined Weights
Neighborhood Vitality Evaluation Indicator System (A)	Urban streetscape data (B6)	0.0958	Green vision (C7)	0.5	0.0479
			Sky opening (C8)	0.5	0.0479
	Building outline and attribute data (B5)	0.1543	Percentage of old buildings (C9)	0.25	0.0386
			Density of historic elements (C10)	0.75	0.1157

3. Results

This section presents the empirical results of the study, structured to systematically address the research questions outlined in the Introduction. First, to answer RQ1, the spatiotemporal characteristics of vitality are analyzed based on LBS data (Section 3.1). Next, to provide the foundational analysis for RQ2 and the hypothesis, the multiple built-environment factors—including functional diversity and accessibility—are quantitatively assessed (Section 3.2). Finally, a composite vitality evaluation is conducted (Section 3.3), and the characteristics of streets at different vitality levels are summarized to synthesize the findings (Section 3.4).

3.1. Characteristics of Temporal and Spatial Vigor Distribution

To address the first research question (RQ1) regarding the temporal variations in neighborhood vitality, this section begins by analyzing the spatiotemporal distribution of crowd activity based on Baidu heat map data from April 19 (weekday) and April 21 (rest day) in 2024, this study identifies clear daily fluctuations in the vitality of the Shuitingmen Historical and Cultural Neighborhood in Quzhou. Figure 6, now presented as a line graph, visually summarizes these daily variations, where the Y-axis represents the Average Relative Crowd Heat Index (e.g., scale: 200–1000, with higher values indicating greater crowd density) and the X-axis shows the time of day; distinct lines identify working days and rest days. On weekdays, as the line graph in Figure 6 depicts, the vitality follows a pattern of "slow rise–smooth fluctuation–rapid fall." After low activity levels before 10:00 a.m., likely due to work and commuting schedules, vitality gradually increases in the morning, peaking around 12:00 p.m. This midday peak is particularly prominent on working days and is presumed to be associated with lunchtime activities, as this period coincides with breaks for employees in and around the district, and the area offers numerous catering services (as detailed in Section 4.2.1). Vitality then shows a slight decrease between 12:00 p.m. and 2:00 p.m., possibly due to the conclusion of lunch breaks and potentially warmer midday temperatures. It rises again after 2:00 p.m. as afternoon commercial and leisure activities commence and reaches another peak between 8:00 p.m. and 10:00 p.m., reflecting the influence of night-time economic activities observed within the Shuitingmen neighborhood during the study period, after which a general decline in weekday activity was noted from the collected data. On rest days, vitality is generally higher and more balanced throughout the day, especially between 4:00 p.m. and 10:00 p.m., indicating that the neighborhood is more attractive to visitors during weekends. Morning activity (e.g., 8:00 a.m. to 10:00 a.m.) on rest days, while still lower than peak times, is often higher than the corresponding period on weekdays (as shown in Figure 6), as more local residents and tourists may begin their leisure and sightseeing activities earlier in the day. The sustained high vitality observed from late afternoon into the evening on rest days, particularly between 4:00 p.m.

and 10:00 p.m., suggests a strong draw from evening markets, diverse dining options, and other recreational venues that are popular during leisure hours. Regarding spatial distribution, the eastern and central areas exhibit higher vitality than the western areas, with West County Street and Shuiting Street forming significant high-vitality clusters. Daytime vitality (8:00 a.m.–2:00 p.m.) is lower than night-time levels, and vitality remains low before 10:00 a.m. A heat concentration emerges in the central area around noon. On weekdays, the spatial pattern shows a "convex" shape, with higher vitality in the middle and lower levels on both sides. These findings suggest that vitality is closely linked to the distribution of functional facilities—commercial, entertainment, and cultural venues attract more activity, while areas dominated by hotels and lodging tend to have lower vitality.



Figure 6. Daily variation in heat in neighborhoods. Source: Authors' elaboration based on Baidu heat map data analysis.

An analysis of street-level thermal values in the Shuitingmen Historical and Cultural District reveals significant crowd concentration differences between weekdays and rest days. Using 20 m × 20 m grid data and street buffer analysis, it is observed that most streets have higher thermal values on rest days, particularly street codes 1–5, 10, and 13–18, indicating that weekends draw more pedestrian traffic. Notably, the north section of Haoying Street (code 18) shows the most significant increase in heat value, suggesting that it becomes a hotspot for leisure, entertainment, and shopping on rest days. The heat value trends fall into the following: "approximate fluctuation type," where changes between weekdays and rest days are minimal, and "differential fluctuation type," where day-to-day variation is pronounced. To illustrate these distinct patterns, Figure 7 presents representative examples: Street 8 (Figure 7a) is representative of the "approximate fluctuation type," where the heat patterns and magnitudes on weekdays and rest days are more similar. In contrast, Street 18 (Figure 7b) exemplifies the "differential fluctuation type," showcasing a substantial increase in heat values and altered trend on rest days, particularly in the afternoon and evening. The detailed heat trend plots for all 19 studied streets are provided in Appendix A for a comprehensive overview. Streets exhibiting a "differential fluctuation type," such as Street 18 (Haoying Street–North Section), are often characterized by a high concentration of leisure, entertainment, and shopping venues, making them particularly attractive during weekend peaks and evenings when discretionary time and visitor numbers are higher. In contrast, streets showing an "approximate fluctuation type," like Street 8, may possess more consistent daily functions, such as those with a stronger residential presence or serving primarily as local access or through routes, leading to more stable, albeit sometimes lower, activity levels across different day types and times. This spatial pattern is further

confirmed at the individual street level, where commercial activities strongly influence crowd concentration along Shuiting Street, with commercially vibrant streets exhibiting higher vitality. In contrast, underdeveloped streets tend to lack sufficient commercial and recreational functions, leading to lower vitality. Some streets, such as Chaijia Lane, contain cultural display facilities but still experience low pedestrian density, suggesting that their cultural appeal remains underutilized. The overall spatial distribution of these combined heat values across the streets and alleys is depicted in Figure 8, providing a visual synthesis of crowd concentration.

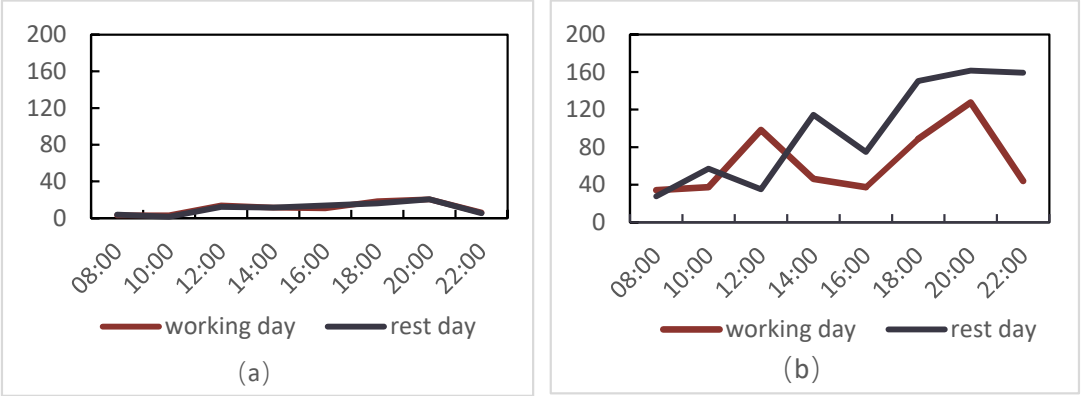


Figure 7. Daily heat trend variations for representative streets: (**a**) Street 8 (approximate fluctuation) and (**b**) Street 18 (differential fluctuation). Source: Authors' elaboration based on Baidu heat map data analysis.



Figure 8. Combined heat map of streets and alleys. Source: Base map from Google Earth (2025), with authors' additions based on Baidu heat map data analysis.

3.2. Multiple Vitality Influencing Factors

To investigate how functional diversity, accessibility, and other built-environment factors influence street-level vitality (addressing RQ2 and our hypothesis), this section

sequentially presents the quantitative analysis results for these key factors. The following subsections detail the findings for functional characteristics (Section 3.2.1), accessibility (Section 3.2.2), spatial scale and environmental quality (Section 3.2.3), and historical–cultural elements (Section 3.2.4), providing the foundational data for the subsequent composite vitality evaluation.

3.2.1. Functional Diversity Analysis

Based on buffer zones set at 20 m and 15 m on both sides of the street centerline, the number and types of POIs were extracted using ArcGIS. The POI density and mixing degree were quantitatively calculated and classified into five levels using the natural breaks method for visual representation. The analysis shows that the Shuitingmen Historical and Cultural Neighborhood contains 274 POIs, with scenic spots being the most common category, followed by catering and retail services. The overall functional density is 1767 POIs/km^2, indicating commercial service-oriented structure. The northern section of Jinshi Lane has the highest functional density at 0.28/m, while Xiao Chaijia Lane, No. 1 Street Alley, and the western section of Soapwood Lane have the lowest, below 0.03/m, suggesting these streets primarily serve transportation functions.

The functional mixing degree reveals the diversity of business types. The northern section of Xiaying Lane shows the highest mixing value at 2.209. In contrast, Xiao Chaijia Lane and streets coded 9–10 exhibit lower mixing values. This may be due to their shorter lengths or the dominance of large cultural or historical buildings, which limits the introduction of diverse businesses. Table 4 presents the detailed functional density (in pieces/m) and functional mixing degree for each of the 19 individual streets within the neighborhood. These findings suggest that the neighborhood is mainly composed of catering, shopping, and tourist accommodation services. However, the relative homogeneity of these industries may constrain further tourism development.

Table 4. Neighborhoods' individual streets' functional density extreme and functional mix. Source: Authors' calculation based on POI data.

Street	Functional Density (pcs/m)	Functional Mixing Degree
Shui Ting Street 1	0.244	2.166
Tianhuang Lane 2	0.049	1.355
First Street Alley 3	0.023	0.640
Little Tianhuang Lane 4	0.031	1.043
Huangya Lane 5	0.121	1.497
Jinshi Lane 6	0.142	1.634
Jinshi Lane 7	0.279	1.811
Chaijia Lane 8	0.104	1.597
Chaijia Lane 9	0.031	0.003
Chaijia Lane 10	0.037	0.003
Luohanjing 11	0.097	1.584
Ning Shao Lane 12	0.084	2.086
Third Street Alley 13	0.107	1.889
Little Chaijia Lane 14	0.009	0.003
Soapwood Lane 15	0.029	1.102
Soapwood Lane 16	0.034	1.043
Xiaying Lane 17	0.049	1.909
Shangying Lane 18	0.051	2.209
Fifth Street Alley 19	0.052	1.043

3.2.2. Accessibility Analysis

Vector road network data were obtained by crawling Gaode Map using Python 3.7, supplemented with field validation. Two indicators—road network integration and selectivity—were used to evaluate accessibility. Road network integration reflects a street's potential to attract pedestrian flow as a destination, while selectivity indicates the likelihood of a street being part of the shortest path. The results show that the northern part of the neighborhood has higher integration values than the southern part. Shuiting Street has the highest integration score, confirming its centrality and accessibility within the neighborhood.

Selectivity analysis shows that Shuiting Street also performs well due to its length and strong connectivity. Other shorter or poorly connected streets exhibit lower selectivity values, which limits pedestrian flow and reduces their contribution to spatial vitality. The calculated degree of integration and selectivity for each individual street in the neighborhood are provided in Table 5.

Table 5. Neighborhood's individual street road network integration and extreme selectivity. Source: Authors' calculation based on vector road network data and Depthmap analysis.

Street	Degree of Integration	Selectivity
Shui Ting Street 1	2.072	0.965
Tianhuang Lane 2	1.606	0.484
First Street Alley 3	1.253	0.080
Little Tianhuang Lane 4	1.338	0.136
Huangya Lane 5	1.352	0.043
Jinshi Lane 6	1.212	0.117
Jinshi Lane 7	1.374	0.046
Chaijia Lane 8	1.576	0.304
Chaijia Lane 9	1.285	0.236
Chaijia Lane 10	0.996	0.075
Luohanjing 11	1.331	0.028
Ning Shao Lane 12	1.212	0.066
Third Street Alley 13	1.460	0.041
Little Chaijia Lane 14	1.000	0.058
Soapwood Lane 15	1.004	0.059
Soapwood Lane 16	1.235	0.206
Xiaying Lane 17	1.147	0.323
Shangying Lane 18	1.724	0.595
Fifth Street Alley 19	1.179	0.003

3.2.3. Spatial Scale and Environmental Quality

Street height and width data were collected through field surveys and analyzed in ArcGIS using the natural break method to classify them into five levels. The results show that most streets have a width-to-height ratio between 1 and 1.5, indicating a comfortable walking environment. Ning Shao Alley and Shuiting Street have the highest ratios, close to 1.5, providing a good pedestrian scale. In contrast, streets such as Tianhuang Lane, Huangya Lane, all sections of Jinshi Lane and Chaijia Lane, Luohan Jing, and No. 5 Street Lane have ratios below 1. These streets, mostly lined with residential houses, exhibit a strong sense of enclosure and spatial inwardness. North–south-oriented streets in the central area tend to have lower width-to-height ratios due to the presence of large-volume cultural buildings on both sides, which creates a more confined walking space.

Street scene photos were processed using semantic segmentation software (ADE20k version), and the resulting data were analyzed in ArcGIS to determine green visibility and sky openness. These values were also classified into five levels. The distribution of observation points used for capturing the street scene photos for this analysis within the

Shuitingmen Historical and Cultural Quarter is shown in Figure 9. The results indicate that overall greening in the neighborhood is relatively good, but some streets lack vegetation, resulting in poor green visibility. Of the 19 streets, 8 have a green visibility rate above 15%, with Shuiting Street reaching the highest at 24%, followed by Xiaying Street and Soapwood Lane 16. However, 11 streets have rates below 15%, mainly due to narrow street sections or limited green space. High GVRs are mostly concentrated in the western and central areas near Shuiting Street.



Figure 9. Distribution of observation points in the Shuitingmen Historical and Cultural Quarter. Source: Base map from Google Earth (2025), with authors' designation of observation points.

In terms of sky openness, 11 streets exceed 0.1, with Haoying Street reaching over 0.2. Some streets with high green visibility have lower sky openness, suggesting an inverse relationship. For example, Lower Camp Street features high GVR and sky openness, attributed to its wide cross-section and spatial layering from trees and buildings. In contrast, eight streets have sky openness below 0.09, with Huangya Lane having the lowest value, mainly due to tall buildings on both sides. Streets with higher sky openness are mainly located in the western and southern parts, while the central area tends to be more enclosed. Table 6 summarizes the spatial scale (aspect ratio) and environmental quality (green rating and sky openness) data for all 19 streets in the neighborhood.

Table 6. The spatial scale and environmental quality of streets in the neighborhood. Source: Authors' calculation based on field surveys and streetscape image analysis.

Street	Aspect Ratio	Green Rating	Sky Openness
Shui Ting Street 1	1.426	0.240	0.095
Tianhuang Lane 2	0.588	0.151	0.107
First Street Alley 3	1.000	0.078	0.134
Little Tianhuang Lane 4	1.300	0.027	0.148
Huangya Lane 5	0.308	0.074	0.030
Jinshi Lane 6	0.844	0.224	0.086
Jinshi Lane 7	0.711	0.127	0.074
Chaijia Lane 8	0.533	0.030	0.089
Chaijia Lane 9	0.645	0.011	0.092
Chaijia Lane 10	0.645	0.001	0.110
Luohanjing 11	0.504	0.000	0.086
Ning Shao Lane 12	1.495	0.127	0.128
Third Street Alley 13	1.220	0.225	0.101
Little Chaijia Lane 14	1.167	0.093	0.124
Soapwood Lane 15	1.258	0.042	0.227
Soapwood Lane 16	1.000	0.237	0.178
Xiaying Lane 17	1.000	0.239	0.188
Shangying Lane 18	1.889	0.245	0.240
Fifth Street Alley 19	0.760	0.212	0.032

3.2.4. Vibrant Contribution of Historical and Cultural Elements

The proportion of old buildings and the density of historical elements were analyzed to evaluate their impact on neighborhood vitality. The results show that seven streets have old building coverage between 24% and 44%, while six streets exceed 50%. Shuiting Street and Tianhuang Lane are particularly notable, with over 80% of the buildings being old. These areas attract a large number of tourists and locals, becoming vibrant gathering places. Previous studies have shown a positive correlation between historic building density and spatial vitality, confirming the cultural draw of such environments.

In addition to the historic architecture, cultural display sites such as Luohan Well and Jinshi Alley also attract visitors, enhancing local vitality. Shuiting Street has the highest density of historical elements, reaching nine elements per 100 m^2, while No. 5 Street and Alley have zero density. Overall, six streets have a density of historical elements greater than or equal to three per 100 m^2. These cultural assets contribute significantly to the neighborhood's spatial appeal, serving as core resources that promote overall vitality. The percentage of old buildings and the density of historical elements (in pieces/100 m) for each street are detailed in Table 7.

Table 7. Neighborhood's streets' old building percentage and extreme historic element density. Source: Authors' calculation based on building attribute data and POI data.

Street	Percentage of Old Buildings	Density of Historical Elements (pcs/100 m)
Shui Ting Street 1	87.1%	9
Tianhuang Lane 2	80.3%	3
First Street Alley 3	16.9%	2
Little Tianhuang Lane 4	32.4%	2

Table 7. *Cont.*

Street	Percentage of Old Buildings	Density of Historical Elements (pcs/100 m)
Huangya Lane 5	59.8%	3
Jinshi Lane 6	22.2%	1
Jinshi Lane 7	43.8%	5
Chaijia Lane 8	50.7%	4
Chaijia Lane 9	32.3%	1
Chaijia Lane 10	6.5%	1
Luohanjing 11	55.3%	4
Ning Shao Lane 12	39.1%	2
Third Street Alley 13	41.9%	1
Little Chaijia Lane 14	7.7%	1
Soapwood Lane 15	23.5%	1
Soapwood Lane 16	24.7%	1
Xiaying Lane 17	37.3%	1
Shangying Lane 18	52.3%	2
Fifth Street Alley 19	0.0%	0

3.3. Comprehensive Vitality Evaluation

Building upon the analysis of individual factors presented in Section 3.2, this section integrates all quantified indicators to conduct a comprehensive vitality evaluation. To standardize indicators with different value ranges, each indicator classified into levels 1–5 is assigned a corresponding score from 1 to 5. These scores are then multiplied by the weights of each indicator, as determined in the previous section, to calculate the overall vitality index for each street.

The calculation formula for the street vitality index:

$$V = \sum_{j=1}^{m} D_j Y_j \quad (1)$$

In the formula, V is the comprehensive vitality value of the street space, D_j is the grading score of a single vitality factor of the street space, Y_j is the weight of the factor, j is the serial number of the factor for evaluating the vitality of the street space, and m = 10 (there are a total of 10 indicators in the evaluation of the vitality of the street space).The composite vitality index calculated for each street using this formula is presented in Table 8.

Table 8. The composite street vitality index. Source: Authors' calculation based on the vitality evaluation model.

Street Name	Street Code	Composite Vitality Index
Shui Ting Street	1	4.8
Shangying Lane	18	4.2
Tianhuang Lane	2	3.6
Ning Shao Lane	12	3.5
Xiaying Lane	17	3.4
Third Street Alley	13	3.2
Soapwood Lane	16	3
Jinshi Lane	7	2.9
Little Tianhuang Lane	4	2.7
Jinshi Lane	6	2.7
Chaijia Lane	8	2.7

Table 8. *Cont.*

Street Name	Street Code	Composite Vitality Index
luohanjing	11	2.6
Huangya Lane	5	2.4
Soapwood Lane	15	2.4
First Street Alley	3	2.3
Little Chaijia Lane	14	2.1
Chaijia Lane	9	2
Fifth Street Alley	19	1.9
Chaijia Lane	10	1.6

According to the data in Table 8, 12 streets—accounting for 63.16% of the total—have a comprehensive vitality index between 2.5 and 5.0, indicating a generally high level of vitality in the neighborhood. Streets with the highest vitality scores include Shuiting Street and the northern section of Haoying Street (street code 18), both exceeding a vitality index of 4.0. In contrast, seven streets have vitality indices below 2.5, including Huangya Lane, the western section of Soapwood Lane (street code 15), No. 1 Street Lane, Little Chaijia Lane, and the middle and southern sections of Chaijia Lane (street codes 9 and 10), as well as Fifth Street. The southern section of Chaijia Lane records the lowest vitality index, at just 1.6. Spatially, vitality is significantly higher in the central and western parts of the neighborhood than in the southeastern area, though a clear fragmentation in its distribution is evident. The sharp decline in vitality between adjacent streets suggests that high-vitality areas fail to effectively stimulate activity in their surroundings. This reflects weak functional complementarity across the neighborhood, preventing the formation of a positive cycle of vitality and hindering the area's sustainable development. Figure 10 provides a map illustrating the spatial distribution of this composite vitality index by street within the neighborhood.



Figure 10. Neighborhood composite vitality index by street. Source: Base map from Google Earth (2025), with authors' additions based on the calculated composite vitality index.

3.4. Street Vitality Levels and Compositional Characteristics

To further synthesize the results and provide a clearer understanding of the relationship between built-environment characteristics and vitality levels (informing RQ2 and the hypothesis), this section categorizes streets into high, medium, and low vitality levels based on the comprehensive assessment. The compositional characteristics of each vitality level are then analyzed. The indicator factor layers corresponding to each vitality level were quantified (see Table 9). Spatial agglomeration, as a subjective manifestation of vitality, was not treated as an influencing factor and was therefore excluded from this analysis. Table 9 presents an analysis of the quantitative results of these component factors (functional characteristics, walking accessibility, the space scale, environmental comfort, and the attractiveness of historical resources) for streets categorized into higher, medium, and inferior vitality levels.

Table 9. An analysis of the quantitative results of the component factors for each street. Source: Authors' analysis based on indicator scores.

Vitality Level	Neighborhood Code	Functional Characteristics		Walking Accessibility		Space Scale	Environmental Comfort		Attractiveness of Historical Resources	
		POI Mixedness Rating	POI Density Rating	Selectivity Rating	Integration Rating	Aspect Ratio Ratings	Green Ratings	Sky Openness Rating	Percentage of Old Buildings Scored	Historical Density Ratings
Higher Vitality Streets	1	√	√	√	√	√	√	√	√	√
	2	√	√	√	√	○	√	√	√	√
	12	√	√	○	○	√	√	√	√	√
	18	√	√	√	√	√	√	√	√	√
Medium Vibrancy Streets	3	○	○	○	○	√	○	○	○	√
	6	√	√	○	○	√	√	○	○	○
	7	√	√	○	√	○	√	○	√	√
	11	√	√	○	√	○	○	○	√	√
	13	√	√	○	√	√	√	√	√	○
Inferiority Vitality Streets	4	○	○	○	√	√	○	√	○	√
	5	√	√	○	√	○	○	○	√	√
	16	○	○	√	○	√	√	√	○	○
	17	√	√	√	○	√	√	√	√	○

After evaluating the remaining nine factors, it was found that high-vitality streets typically exhibit the following characteristics: diverse functionality, rich historical resources, strong pedestrian accessibility, appropriate spatial scale, and high environmental comfort. In contrast, low-vitality streets generally perform poorly across all five dimensions. Medium-vitality streets tend to show moderate performance, with relatively better functional diversity and spatial scale scores but weaker scores in terms of historic resource appeal, pedestrian accessibility, and environmental comfort.

4. Discussion

4.1. Issues in Objective Components

1. Monotonous Functional Business Forms

An evident trend towards functional homogeneity in business forms is a key issue constraining the sustainable vitality of the Shuitingmen Historical and Cultural Block. While overall POI data might suggest a relatively rich mix of business types, high-vitality streets like Shuiting Street, Haoying Street, and Jinshi Alley are predominantly characterized by catering and retail services. This concentration, often market-driven in tourist-oriented historic districts, leads to several interconnected problems. Firstly, it results in poor commercial complementarity between different streets, potentially increasing internal competition

rather than fostering a diverse business ecosystem. Secondly, certain cultural display functions within the block, such as in sections of Chaijia Lane, appear underactivated due to static utilization, meaning cultural assets do not fully translate into street-level vitality. For example, Shuitingmen is described in Section 2.1 as a carrier of Quzhou's 'outward shipping merchant culture' and the 'legacy of traditional Chinese medicine.' However, the current functional landscape shows few businesses or experiential offerings directly themed around these unique historical narratives. This represents a missed opportunity to leverage distinct local cultural capital for diversifying attractions beyond generic retail and catering, potentially contributing to the "monotony" by not fully expressing the block's unique historical identity in its active functions. Furthermore, physical constraints in shorter streets or those with large historical buildings (e.g., parts of Chaijia Lane, No. 5 Street Lane), alongside the primary transportation role of other streets (e.g., No. 1 Street Alley, sections of Soapwood Lane), limit business diversification and contribute to lower vitality. This relative uniformity in functions also contributes to the observed uneven spatial distribution of vitality, as the strong pull of functionally concentrated areas does not effectively permeate into adjacent streets lacking diverse attractors, hindering the overall vibrancy of the historic block.

2. Poor Street Connectivity and Commercial Space Encroachment

Pedestrian accessibility is limited in several streets, including Ning Shao Lane, No. 1 Street Lane, the east–west section of Jinshi Lane, the southernmost section of Chaijia Lane, Little Chaijia Lane, the western section of Soapwood Lane, and No. 5 Street Lane. Despite the overall integration of the neighborhood road network, some streets are low in selectivity, suggesting they are rarely chosen as routes for traffic, which reduces pedestrian flow. In some areas, excessive commercial use has reduced public pedestrian space, particularly along the east and west sections of Jinshi Lane and the west end of Soapwood Lane. The underlying reasons for poor connectivity in these specific alleys could stem from the historical evolution of the block, resulting in a fragmented internal path network despite overall good external connections. This lack of internal permeability not only reduces incidental pedestrian flow but also isolates certain areas, hindering the spread of vitality from more active zones. The issue of commercial encroachment on pedestrian space in streets like Jinshi Lane, while possibly a sign of commercial pressure, directly impacts walkability and perceived comfort, potentially deterring prolonged stays or exploration, thus negatively affecting sustained vitality despite high initial attraction.

3. Unfavorable Aspect Ratios and Enclosed Walking Spaces

Streets with poor spatial proportions include Tianhuang Lane, the north–south section of Jinshi Lane, Luohan Well, Little Tianhuang Lane, Huangya Lane, the full length of Chaijia Lane, and No. 5 Street Lane. Huangya Lane, formed spontaneously as a residential alley, has a strong sense of enclosure and a low width-to-height ratio. In other streets, large buildings on both sides create a visually compressed and uncomfortable pedestrian environment. The prevalence of unfavorable aspect ratios, leading to a strong sense of enclosure, can be attributed to the dense, organically developed fabric typical of historic residential alleys or the presence of large, imposing institutional buildings flanking narrower thoroughfares. While a sense of enclosure can sometimes create intimate and unique spatial experiences, excessively low width-to-height ratios often result in reduced natural light, poor air circulation, and a psychologically oppressive environment for pedestrians. This can directly diminish the street's appeal as a place for lingering or social interaction, thereby impacting its overall vitality, even if it serves as a necessary passage. The stark contrast in spatial comfort between streets with favorable and unfavorable aspect ratios is

visually illustrated in Figure 11, which compares the open, comfortable environment of Shuiting Street with the enclosed character of Huangya Lane.



(**a**) (**b**)

Figure 11. Visual comparison of contrasting street environments in Shuitingmen. (**a**) Shuiting Street (Street 1), exhibiting a comfortable pedestrian scale with a high aspect ratio and good environmental quality. (**b**) Huangya Lane (Street 5), characterized by a strong sense of enclosure due to a low aspect ratio, resulting in lower perceived spatial comfort.

4. Low Greenery and Poor Sky Openness

Streets such as No. 1 Street Lane, Luohan Well, and Huangya Lane exhibit low green visibility and limited sky openness due to dense buildings or tree cover, diminishing the sense of spaciousness. Jinshi Lane, in particular, is densely developed, resulting in restricted sky views and reduced environmental comfort. The observed low green visibility and limited sky openness in these streets are often consequences of dense historical building development with narrow street sections and insufficient planned or preserved green spaces. While maximizing land use was common in historical development, the lack of these environmental amenities in a contemporary context significantly detracts from pedestrian comfort and the perceived quality of the public realm. Poor greenery can reduce aesthetic appeal and thermal comfort, while restricted sky views contribute to feelings of confinement, collectively discouraging pedestrian presence and activity, which are foundational to street vitality.

4.2. Enhancement Strategies

As the transformation of historical and cultural neighborhoods must adhere to principles of authenticity, this study proposes a strategy of micro-renewal and fine-scale upgrades. The focus is on four key aspects: functional business types, pedestrian accessibility, spatial scale, and environmental comfort. Large-scale spatial redesign is not required. The proposed strategies follow the principle of "adapting to local conditions," aiming to preserve the existing urban fabric while gradually revitalizing the area through functional zoning, business renewal, improved network integration, and environmental optimization. These targeted strategies are designed to directly address the issues identified in Section 4.1—such as functional homogeneity, poor connectivity, unfavorable spatial proportions, and low environmental comfort—which were found to collectively undermine the vitality of certain areas within the Shuitingmen block and hinder its overall sustainable vibrancy. Each strategy aims to enhance specific aspects of the built environment, fostering a more diverse, accessible, and comfortable neighborhood, which ultimately contributes to its vitality.

4.2.1. Delineate Functional Zones and Strengthen District Identity

The density and mixing degree of POIs in Shuitingmen are uneven, with higher concentrations in the central area and Xiaying Street and weaker vitality spillover in areas like Ning Shao Lane. Although the overall mixing degree is high, the neighborhood's business model remains relatively uniform, with poor commercial complementarity. Many streets contain scenic-spot-type businesses but still have low vitality—for instance, sections 8–9 of Chaijia Lane, which function as static museums and fail to stimulate cultural activity.

Therefore, to directly address the critical issue of monotonous functional business forms and poor commercial complementarity previously identified, tailored functional interventions are needed to form distinct functional zones and enhance spatial vitality. The proposed zoning plan includes the following:

Traditional Commerce: Centered on Shuiting Street, focusing on time-honored brands and cultural–creative products. Introduce experiential spaces like handicraft workshops to recreate traditional commercial scenes. This concentration and enhancement of traditional commercial offerings are expected to strengthen the unique identity of this core area, increase visitor dwell time, and provide a distinct experience compared to more generic retail environments, thereby boosting its specific vitality.

Modern Commerce: Transform Xiaying Street, with its linear park landscape, into a modern pedestrian shopping street offering trendy retail, catering, and leisure, complementing the traditional business areas.

Cultural Exhibition: Develop Tianhuang Lane and Chaijia Lane as cultural experience corridors, showcasing Confucian heritage and folk traditions through the adaptive reuse of historical buildings. For example, one of the '36 historical buildings' (mentioned in Section 2.1) in Tianhuang Lane or Chaijia Lane could be transformed into an interactive space dedicated to Quzhou's specific Confucian narratives, perhaps focusing on notable local scholars or historical events, rather than generic displays. By revitalizing historical buildings for dynamic cultural experiences rather than static displays, this zone aims to transform underutilized cultural assets into active contributors to street vitality, attracting both culturally motivated tourists and local residents.

Hospitality and Dining: Develop high-quality dining and accommodation in Jinshi Alley, integrating boutique hotels and B&Bs to boost local economic returns.

Creative Offices: Retrofit narrow alleys, such as Huangya Lane and Little Chaijia Lane, into creative industry hubs and co-working spaces for cultural innovation. A proposed functional area plan for the neighborhood, incorporating these distinct zones (traditional commerce, modern commerce, cultural exhibition, hospitality and dining, and creative offices), is illustrated in Figure 12.

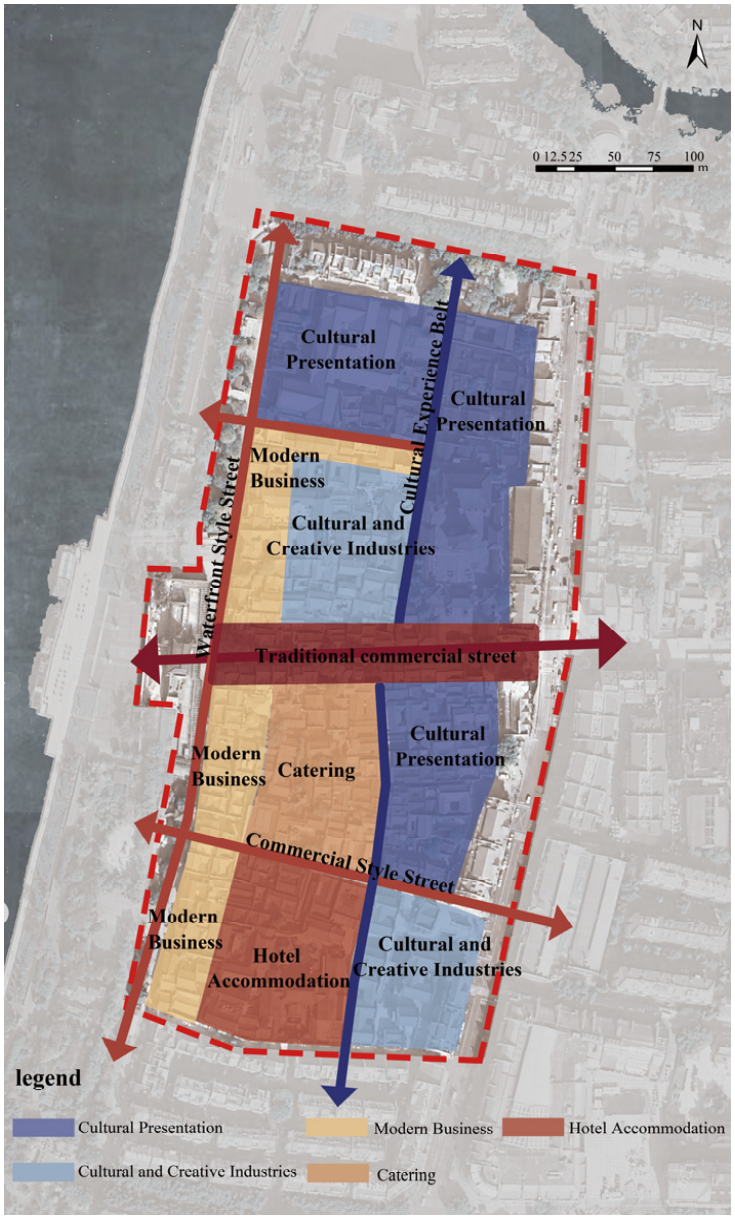


Figure 12. Neighborhood functional area plan. Source: Base map from Google Earth (2025), with authors' proposed plan.

4.2.2. Improve Pedestrian Connectivity to Enhance Accessibility

According to space syntax theory, highly integrated axial lines attract pedestrian flow and drive spatial reconfiguration. Shuiting Street is the most integrated core of the neighborhood. However, streets like Huangya Lane and Chaijia Lane, despite high functional density, lack vitality due to low accessibility. It is recommended that these alleys be opened while preserving their historical texture and that clear wayfinding signage be installed to guide pedestrian movement and enhance flow. This strategy directly targets the problem of poor street connectivity and low selectivity identified for several alleys. By improving internal permeability and guiding pedestrian flow more effectively, these interventions are expected to increase foot traffic in underutilized areas, better integrate them with high-vitality zones, and thus enhance their overall contribution to neighborhood vibrancy.

4.2.3. Adjust Spatial Proportions to Create Comfortable Streets

The pleasant street scale enhances pedestrian experience. Many low- and medium-vitality streets in the neighborhood, especially in Chaijia Lane, perform poorly in the width-to-height ratio. It is recommended to regulate building heights based on street function and maintain continuity between building facades and the pedestrian realm. For taller buildings in Chaijia Lane, use setbacks and elevated forms to reduce enclosure. In Huangya Lane, widen passages and incorporate small public spaces to improve walkability. These adjustments are aimed at mitigating the negative impacts of unfavorable aspect ratios and overly enclosed walking spaces. By creating more comfortable and visually appealing streetscapes, these measures are anticipated to encourage pedestrian lingering, social interaction, and a greater sense of spatial comfort, all of which are conducive to higher street vitality.

4.2.4. Enhance Landscape Design to Improve Environmental Comfort

High-vitality streets in the neighborhood perform well in green visibility and openness, while low-vitality streets lack both. For streets with insufficient greenery, vertical greening methods can be adopted. Streets with poor sky openness should incorporate pocket parks and small plazas to diversify spatial hierarchy and provide comfortable gathering areas for residents and tourists. These landscape enhancements directly respond to the issues of low greenery and poor sky openness identified for several streets. By improving the visual quality, perceived comfort, and ecological aspects of the street environment, these strategies are expected to make these streets more attractive and pleasant for pedestrians, thereby positively influencing their vitality.

5. Conclusions

This study's empirical analysis of the Shuitingmen Historical and Cultural Neighborhood revealed a complex vitality landscape, characterized by distinct temporal rhythms and significant spatial disparities. Temporally, the findings demonstrate a clear divergence between weekday vitality, which is closely tied to daily work and life schedules, and the higher, more leisure-driven vitality of rest days. Spatially, the analysis mapped a fragmented pattern of vibrancy, with a concentration of high-vitality streets in the central and western areas contrasting sharply with underperforming zones in the southeast. Critically, this research confirmed the study's underlying hypothesis: a strong positive correlation exists between these observed vitality levels and the comprehensively evaluated built-environment factors, where streets with superior functional, spatial, and environmental qualities consistently exhibited greater vibrancy.

The main contributions of this research are threefold:

Theoretically, this study enriches the existing literature by offering a refined multi-dimensional framework for understanding street vitality in historic urban settings, one that integrates objective spatial data with historical–cultural attributes and dynamic human activity patterns.

Methodologically, it demonstrates the effective application of multi-source geo-data (POI, LBS heatmaps, and street networks) with the Analytic Hierarchy Process (AHP) for a comprehensive, micro-scale assessment of street vitality, highlighting the value of composite evaluation over single-indicator analyses.

In practical terms, this study provides data-driven insights for the micro-scale renewal of the Shuitingmen neighborhood by identifying specific temporal patterns, spatial disparities, and problematic areas related to accessibility or functional monotony, thus informing targeted enhancement strategies.

While this study presents meaningful insights, certain limitations should be acknowledged. The analysis primarily relied on objective, quantitative geo-data and did not incorporate qualitative data capturing user perceptions or detailed socio-economic variables such as specific rental costs or income levels, which could offer a more holistic understanding. Incorporating such data through mixed-methods approaches represents an important direction for future research. Additionally, the temporal scope of some data (e.g., LBS heatmaps for two specific days) provides a snapshot rather than a long-term dynamic view. Future research could expand the dataset to capture longer-term vitality evolution and include other spatial elements like plazas in the evaluation framework. Furthermore, future inquiries could specifically address the cultural sustainability dimensions of vitality within historic districts, examining how revitalization efforts can effectively balance economic development with the preservation of authentic cultural identity and community values. This could involve comparative analyses with the vitality patterns of new contemporary urban spaces often shaped by globalized consumerism, thereby contributing to a deeper understanding of the complex interplay between spatial transformation, cultural identity, and sustainable urban life in modern cities.

Despite these limitations, the methodology and findings of this study offer valuable insights and can be adapted and applied to other historical and cultural neighborhoods, enhancing their broader applicability for sustainable urban revitalization. Ultimately, this study underscores the ongoing challenge for historic districts like Shuitingmen: to navigate the complexities of tourism-driven commercialization while preserving their authentic cultural identity and ensuring a vibrant, inclusive environment for both visitors and local communities. Achieving this requires a continuous, adaptive management process informed by multi-faceted vitality assessments like the one presented here.

Author Contributions: Data Curation: Guoquan Zheng, Lingli Ding, Jiehui Zheng; Formal Analysis: Guoquan Zheng, Lingli Ding, Jiehui Zheng; Funding Acquisition: Guoquan Zheng; Investigation: Guoquan Zheng, Lingli Ding, Jiehui Zheng; Methodology: Guoquan Zheng, Lingli Ding, Jiehui Zheng; Project Administration: Guoquan Zheng, Lingli Ding, Jiehui Zheng; Resources: Guoquan Zheng; Software: Guoquan Zheng, Lingli Ding, Jiehui Zheng; Supervision: Guoquan Zheng; Validation, Guoquan Zheng, Lingli Ding, Jiehui Zheng; Visualization: Guoquan Zheng, Lingli Ding, Jiehui Zheng; Writing—Original Draft Preparation: Guoquan Zheng, Lingli Ding, Jiehui Zheng; Writing—Review and Editing: Guoquan Zheng, Lingli Ding, Jiehui Zheng. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Social Science Fund of China (reference number 19BSH109), with funding acquisition carried out by Guoquan Zheng.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author(s).

Acknowledgments: We would like to thank the anonymous reviewers for their constructive comments and feedback to improve this manuscript.

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

Appendix A

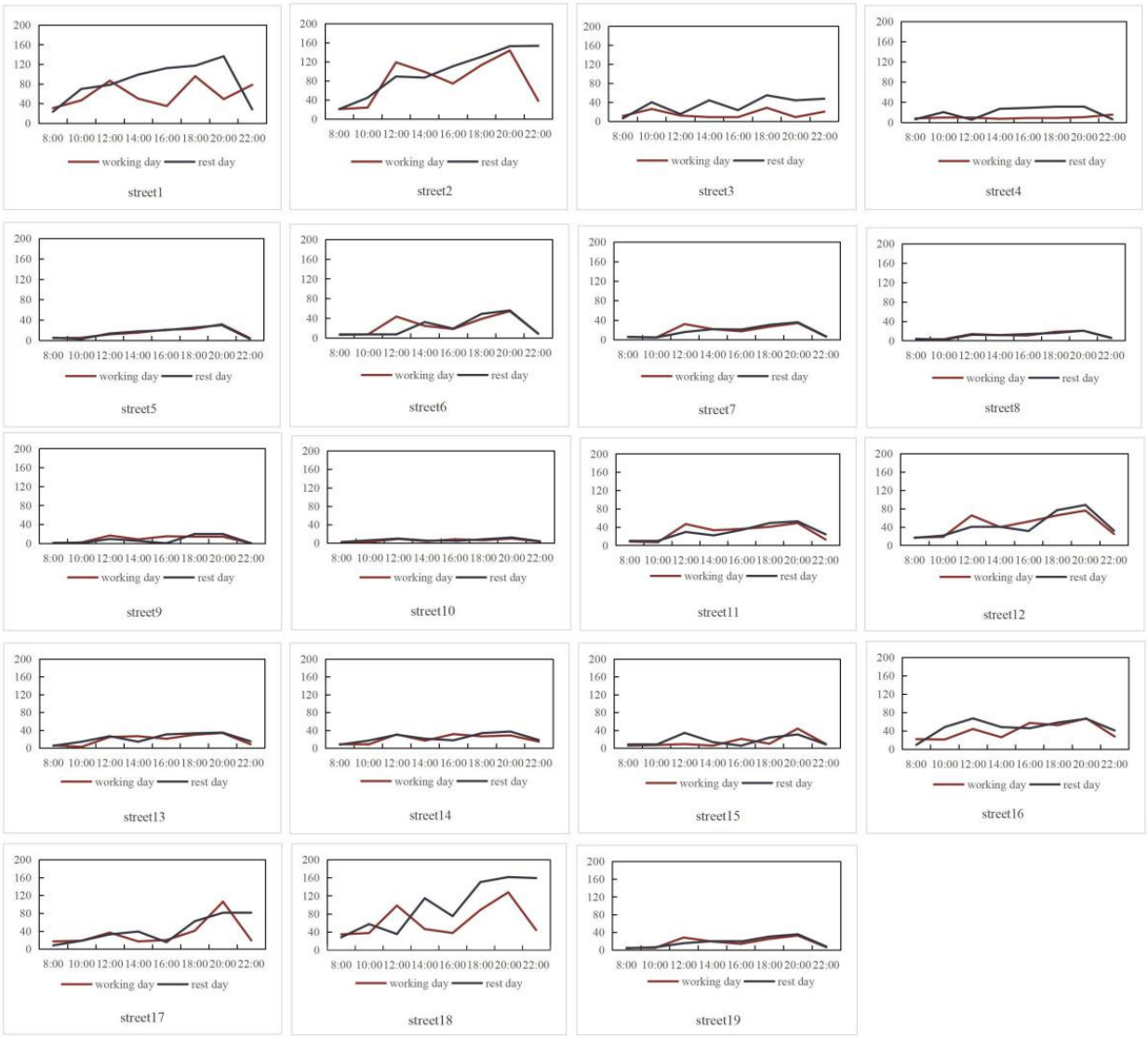


Figure A1. Change in heat trends by street in neighborhoods.

Appendix B

Table A1. Thresholds for the 5-level classification of vitality indicators.

Evaluation Factor (from English MS Table 3)	Level 1 (Score 1)	Level 2 (Score 2)	Level 3 (Score 3)	Level 4 (Score 4)	Level 5 (Score 5)	Unit
Spatial concentration of people (C1)	6.46–12.7	12.8–20.3	20.4–28.5	28.6–45.2	45.3–90.3	Relative Index
POI mixing (C2)	0.003	0.004–1.102	1.103–1.634	1.635–1.909	1.910–2.209	Index (Shannon)

Table A1. *Cont.*

Evaluation Factor (from English MS Table 3)	Level 1 (Score 1)	Level 2 (Score 2)	Level 3 (Score 3)	Level 4 (Score 4)	Level 5 (Score 5)	Unit
POI density (C3)	0.009	0.010–0.037	0.038–0.052	0.053–0.142	0.143–0.279	POIs/m
Road network integration (C4)	0.996–1.09	1.10–1.25	1.26–1.46	1.47–1.72	1.73–2.07	Index
Road network selectivity (C5)	0.00–0.046	0.0461–0.13	0.137–0.323	0.324–0.595	0.596–0.965	Index
Street aspect ratio (C6)	0.308–0.533	0.534–0.760	0.761–1.00	1.01–1.50	1.51–1.89	Ratio
Green vision (C7) (green visibility rate)	0.000–0.042	0.043–0.093	0.094–0.151	0.152–0.225	0.226–0.245	Proportion (0–1)
Sky opening (C8) (sky openness)	0.030–0.03	0.033–0.091	0.092–0.110	0.111–0.148	0.149–0.240	Proportion (0–1)
Percentage of old buildings (C9)	0.000–6.541	6.542–24.74	24.748–43.78	43.785–59.845	59.846–87.10	%
Density of historic elements (C10)	0	1	2	3–5	6–9	Elements/100 m
Composite vitality index (for reference)	1.6–2.0	2.1–2.4	2.5–3.0	3.1–3.6	3.7–4.8	Index

References

1. Chen, B. Revitalization Strategy in Conservation and Renewal of Historical and Cultural Districts: A Case Study of Shangxiahang in Fuzhou City. *J. Landsc. Res.* **2021**, *13*, 57–62.
2. Li, M.; Liu, J.; Lin, Y.; Xiao, L.; Zhou, J. Revitalizing historic districts: Identifying built environment predictors for street vibrancy based on urban sensor data. *Cities* **2021**, *117*, 103305. [CrossRef]
3. Mouratidis, K.; Poortinga, W. Built environment, urban vitality and social cohesion: Do vibrant neighborhoods foster strong communities? *Landsc. Urban Plan.* **2020**, *204*, 103951. [CrossRef]
4. Lu, L.; Chi, C.G.; Liu, Y. Authenticity, Involvement, and Image: Evaluating Tourist Experiences at Historic Districts. *Tour. Manag.* **2015**, *50*, 85–96. [CrossRef]
5. Zhang, Y.; Han, Y. Vitality Evaluation of Historical and Cultural Districts Based on the Values Dimension: Districts in Beijing City. *Chin. Herit. Sci.* **2022**, *10*, 137. [CrossRef]
6. Yong, H.; Sun, Y. Review on Historical District Preservation and Renovation Practice. *Planner* **2015**, *31*, 98–104.
7. Chen, Y.; Lei, C. Evolution of the Conservation Problems and Planning Strategies of Pingjiang Historic and Cultural Area: Mechanism Simulation Analysis Based on System Dynamics. *Urban Plan* **2022**, *46*, 84–95.
8. Ehrig, S.; Jung, B.C.; Schaffer, G. *Exploring the Transnational Neighbourhood: Perspectives on Community-Building, Identity and Belonging*; Leuven University Press: Leuven, Belgium, 2022; p. 341.
9. Jacobs, J. *The Death and Life of Great American Cities*; Random House: New York, NY, USA, 1961.
10. Whyte, W. *The Social Life of Small Urban Spaces*; Project for Public Spaces: New York, NY, USA, 1980.
11. Lynch, K. *The Image of the City*; MIT Press: Cambridge, MA, USA, 1964.
12. Bentley, I. *Responsive Environments: A Manual for Designers*; Routledge: London, UK, 1985.
13. Gehl, J. *Life Between Buildings: Using Public Space*; Island Press: Washington, DC, USA, 2012.
14. Niu, X.Y.; Wu, W.; Li, M. Influence of built environment on street vitality and its spatiotemporal characteristics based on LBS positioning data. *Urban Plan. Int.* **2019**, *34*, 28–37. [CrossRef]

15. Liu, S.; Ge, J.; Ye, X.; Wu, C.; Bai, M. Urban vitality assessment at the neighborhood scale with geo-data: A review toward implementation. *J. Geogr. Sci.* **2023**, *33*, 1482–1504. [CrossRef]
16. Tong, M. How urban fabric can help sustain the vitality of cities. *Urban Plan. Forum* **2014**, *21*, 85–96.
17. Zhou, C. Research on the Vitality Improvement of Historic and Cultural Block of Guantao Road in Qingdao. Master's Thesis, Qingdao University of Technology, Qingdao, China, 2019.
18. Guo, X.; Yang, Y.; Cheng, Z.; Liu, Y. Spatial social interaction: An explanatory framework of urban space vitality and its preliminary verification. *Cities* **2022**, *121*, 103487. [CrossRef]
19. Fodde, E. Fired Brick and Sulphate Attack: The Case of Moenjodaro, Pakistan. *J. Archit. Conserv.* **2007**, *13*, 69–80. [CrossRef]
20. Yu, B.; Sun, J.; Wang, Z.; Chen, Y.; Wang, S. Influencing Factors of Street Vitality in Historic Districts Based on Multisource Data: Evidence from China. *ISPRS Int. J. Geo-Inf.* **2024**, *13*, 277. [CrossRef]
21. Zeng, Z.; Li, Y.; Tang, H. Multidimensional Spatial Driving Factors of Urban Vitality Evolution at the Subdistrict Scale of Changsha City, China, Based on the Time Series of Human Activities. *Buildings* **2023**, *13*, 2448. [CrossRef]
22. Liu, M.; Jiang, Y.; He, J. Quantitative evaluation on street vitality: A case study of Zhoujiadu community in Shanghai. *Sustainability* **2021**, *13*, 3027. [CrossRef]
23. Yue, W.; Chen, Y.; Thy, P.T.M.; Fan, P.; Liu, Y.; Zhang, W. Identifying urban vitality in metropolitan areas of developing countries from a comparative perspective: Ho Chi Minh City versus Shanghai. *Sustain. Cities Soc.* **2021**, *65*, 102609. [CrossRef]
24. Ma, Z. Deep exploration of street view features for identifying urban vitality: A case study of Qingdao city. *Int. J. Appl. Earth Obs. Geoinf.* **2023**, *123*, 103476. [CrossRef]
25. Katz, P. *The New Urbanism: Toward an Architecture of Community*; McGraw-Hill: New York, NY, USA, 1994.
26. Montgomery, J. Making a city: Urbanity, vitality and urban design. *J. Urban Des.* **1998**, *3*, 93–116. [CrossRef]
27. Jin, X.; Long, Y.; Sun, W.; Lu, Y.; Yang, X.; Tang, J. Evaluating cities' vitality and identifying ghost cities in China with emerging geographical data. *Cities* **2017**, *63*, 98–109. [CrossRef]
28. Kang, C.; Fan, D.; Jiao, H. Validating activity, time, and space diversity as essential components of urban vitality. *Environ. Plan. B Urban Anal. City Sci.* **2021**, *48*, 1180–1197. [CrossRef]
29. Chen, M.; Cai, Y.; Guo, S.; Sun, R.; Song, Y.; Shen, X. Evaluating implied urban nature vitality in San Francisco: An interdisciplinary approach combining census data, street view images, and social media analysis. *Urban For. Urban Green.* **2024**, *95*, 128289. [CrossRef]
30. Wu, C.; Ye, X.; Ren, F.; Du, Q. Check-in behaviour and spatio-temporal vibrancy: An exploratory analysis in Shenzhen, China. *Cities* **2018**, *77*, 104–116. [CrossRef]
31. Chu, H.; Shi, X.; Tang, J. Vitality Evaluation and Enhancement Strategies of Wuzhou Historical and Cultural Districts Based on Semantic Differential Method. In Proceedings of the 2024 International Conference on Culture-Oriented Science & Technology (CoST), Beijing, China, 25–28 August 2024; IEEE: Piscataway, NJ, USA, 2024; pp. 126–131.
32. Song, J.; Zhu, Y.; Chu, X.; Yang, X. Research on the Vitality of Public Spaces in Tourist Villages through Social Network Analysis: A Case Study of Mochou Village in Hubei, China. *Land* **2024**, *13*, 359. [CrossRef]
33. Wang, M.; He, Y.; Meng, H.; Zhang, Y.; Zhu, B.; Mango, J.; Li, X. Assessing Street Space Quality Using Street View Imagery and Function-Driven Method: The Case of Xiamen, China. *ISPRS Int. J. Geo-Inf.* **2022**, *11*, 282. [CrossRef]
34. Rose, G. *Seeing the City Digitally: Processing Urban Space and Time*; Amsterdam University Press: Amsterdam, The Netherlands, 2022; p. 276.
35. Wagner, C. *Visualizations of Urban Space: Digital Age, Aesthetics, and Politics*; Routledge: London, UK, 2022.
36. Zarin, S.Z.; Niroomand, M.; Heidari, A.A. Physical and social aspects of vitality case study: Traditional street and modern street in Tehran. *Procedia Soc. Behav. Sci.* **2015**, *170*, 659–668. [CrossRef]
37. Long, Y.; Zhou, Y. Quantitative evaluation on street vibrancy and its impact factors: A case study of Chengdu. *New Archit.* **2016**, *1*, 52–57.
38. Wu, Z.-J. Reweaving Cultural Fabrics of Neighborhood Heritage: The Case of Shuitingmen Street Cultural Heritage Study. *Stud. Cult. Art.* **2012**, *5*, 19–27.
39. Paiva, D. The paradox of atmosphere: Tourism, heritage, and urban liveability. *Ann. Tour. Res.* **2023**, *101*, 103600. [CrossRef]
40. Amore, A.; Falk, M.; Adie, B.A. One visitor too many: Assessing the degree of overtourism in established European urban destinations. *Int. J. Tour. Cities* **2020**, *6*, 117–137. [CrossRef]
41. Hao, X.H.; Long, Y.; Shi, M.; Wang, P. Street vibrancy of Beijing: Measurement, impact factors and design implication. *Shanghai Urban Plan. Rev.* **2016**, *3*, 26–33.
42. Ye, Y.Y.; Zhuang, Y.; Zhang, L.; Van Nes, A. Designing urban spatial vitality from morphological perspective—A study based on quantified urban morphology and activities' testing. *Urban Plan. Int.* **2016**, *31*, 26–33.
43. Huang, D.; Dai, D. Effect of Living Street's Elements on Vitality: Taking Typical Streets in Shenzhen as an Example. *Chin. Landsc. Archit.* **2019**, *35*, 89–94.

44. Zhang, Y.; Yang, C.; Qi, L. Study on the assessment of street vitality and influencing factors in the historic district—A case study of Shichahai historic district. *Chin. Landsc. Archit.* **2019**, *35*, 106–111.
45. Mao, Z.R.; Chen, X.K.; Xiang, Z.H.; Chen, Y.R. Research on the measurement and influencing factors of street vigour in historic districts: A case study of Wenming Street historic district in Kunming. *South Archit.* **2021**, *4*, 54–61.
46. Zhou, D.; Hu, J.; Wu, L. A study on spatial characteristics and planning guidance of micro public space under the orientation of spatial vitality: A case study of Guangzhou central districts. *Urban Dev. Stud.* **2021**, *28*, 24–28.
47. Li, W.; Jin, B.; Song, Q.; Wang, L.; Zhong, Y. Historic street vibrancy estimation and mechanism: A case study of Liwan District, Guangzhou. *Chin. Overseas Archit.* **2024**, *2*, 63–70.
48. Zachary, D.; Dobson, S. Urban development and complexity: Shannon entropy as a measure of diversity. *Plan. Pract. Res.* **2021**, *36*, 157–173. [CrossRef]
49. Aikoh, T.; Homma, R.; Abe, Y. Comparing conventional manual measurement of the green view index with modern automatic methods using google street view and semantic segmentation. *Urban For. Urban Green.* **2023**, *80*, 127845. [CrossRef]
50. Xia, Y.; Yabuki, N.; Fukuda, T. Sky view factor estimation from street view images based on semantic segmentation. *Urban Clim.* **2021**, *40*, 100999. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.