sustainability

Article

The Association between Street Built Environment and Street Vitality Based on Quantitative Analysis in Historic Areas: A Case Study of Wuhan, China

Han Zou [1,2,*], Ruichao Liu [1], Wen Cheng [1], Jingjing Lei [3] and Jing Ge [1]

[1] School of Civil Engineering, Architecture and Environment, Hubei University of Technology, Wuhan 430068, China
[2] Innovation Demonstration Base of Ecological Environment Geotechnical and Ecological Restoration of Rivers and Lakes, Hubei University of Technology, Wuhan 430068, China
[3] School of Architecture and Urban Planning, Huazhong University of Science and Technology, Wuhan 430074, China
* Correspondence: zouhan@hbut.edu.cn

Abstract: Over the past decade, enhancing the quality of cities and building vibrant urban streets has become a hot topic in urban planning in China. Although there are many studies on how the built environment affects street vitality, the unique built environment of the street space in historic areas, as the core node of the city, has not been fully explored. This study constructs an association model between the street built environment (SBE) and street vitality in historic areas and evaluates the influence of SBE on street vitality by spatial analysis and statistical analysis methods using POI data, road network data, and Baidu heat map data, taking Wuhan, China, as an example. The results showed that (1) appropriate built environment development intensity, street width-to-height ratio, and facade ratio of historic buildings on the street frontage all can promote street vitality; (2) the spatial distribution of historic buildings converted to commercial functions in historic areas has a high consistency with the spatial distribution of street vitality, and the consistency is significantly higher than that of general urban streets; (3) historic buildings converted to residential functions and those in vacancy or under renovation in historic areas have a significant inhibitory effect on street vitality; and (4) the spatial distribution of transportation facilities and the spatial distribution of street vitality are mutually exclusive in historic areas. This study proposes a method for studying the SBE and street vitality in historic areas and initially explores the relationship between the influences of the SBE on street vitality in historic areas. Since the functional replacement of historic buildings can affect the street vibrancy in historic areas, our findings suggest moderating commercial renovation rather than simply repairing or maintaining the status for enhancing the street vitality. Moreover, the intervention of transportation facilities will reduce the street vitality in historic areas, which provides a basis for the strategy of renewing historic areas into pedestrian street spaces.

Keywords: historic areas; street built environment; street vitality; quantitative analysis; spatial analysis and statistical analysis

check for updates

Citation: Zou, H.; Liu, R.; Cheng, W.; Lei, J.; Ge, J. The Association between Street Built Environment and Street Vitality Based on Quantitative Analysis in Historic Areas: A Case Study of Wuhan, China. *Sustainability* **2023**, *15*, 1732. https://doi.org/10.3390/su15021732

Academic Editors: Hao Wu, Lingbo Liu and Yang Yu

Received: 19 November 2022
Revised: 27 December 2022
Accepted: 5 January 2023
Published: 16 January 2023

1. Introduction

Under modern urban planning theory, which integrates the street into the urban system, the street not only has a traffic function to join the different types of space in the city, but also serves a social function as the carrier of public space [1]. Moreover, citizens' life and travel rely on streets of various types and scales in the city, so their existence plays an important role in human life. As Jacobs claims, when we think of a city, what first comes to mind is the street; when the streets are lively, the city is lively, and when the street is boring, the city is boring [2]. Since Yoshinobu Ashihara put forward humanism and aesthetic thoughts, the experiences and feelings of pedestrians in the street space have gradually become the core components of street planning and design [3]. As an important cultural memory of the city, the street space of historic areas and the surrounding environment infiltrate each other, and the cultural vitality generated by the unique street space style has become an important node that cannot be ignored in city culture [4].

Nevertheless, since the 21st century, with the urbanization development of China's road design, dominated by car behavior, the traffic function of urban streets has become stronger and stronger, but its social function has gradually disappeared, and this situation will bring great challenges to the street form and city style [5]. At the same time, scholars in mounting numbers have gradually begun to pay attention to the social value of streets [6–12]. Furthermore, the Chinese government has put forward a people-oriented new urbanization strategy since 2016. People have also begun to rethink the previous urban development mode and pay attention to the quality of street space. In October 2016, the Shanghai government issued the "Shanghai Street Design Guidelines", in which the concept of street vitality, street safety, and people-oriented streets aroused widespread discussion [13]. In June 2018, "Guangzhou Complete Street Design Manual", issued by the Guangzhou government, also proposed that urban streets should be transformed from traffic-oriented to people-oriented [14]. In June 2019, the Wuhan government successively issued "Planning and Design Guidelines for Total Factors in Wuhan Urban Streets", which put forward the design guidelines for building a people-oriented and vibrant urban street space in order to improve the quality of urban construction [15].

The concept of "street vitality" was first proposed by Jane Jacobs, who highlighted the public space properties of streets from the perspective of "the diversity of people's lives" [2]. Since then, street vitality has become an important indicator to evaluate the attraction and potential of urban sustainable development. Meanwhile, with the development of modern urban planning theory and practice, people are paying more and more attention to diverse and vibrant street spaces, which will improve the happiness and social cohesion of urban residents. Therefore, as an important space for urban residents' activities, the built environment of the street is closely related to the vitality of the city.

Specifically, relevant studies on how the street built environment (SBE) affects street vitality can be traced back to the 1960s. However, the existing discussions have not fully established the association between the two [16]. On the one hand, the activity behavior of people is dynamic and intangible, which is difficult to evaluate [17–21]. Therefore, in the past, researchers have often relied on personal observations. On the other hand, it is still challenging to systematically construct evaluation indexes for many variables of SBE and to build the relationship between SBE and street vitality. Therefore, the current research concerns which variables of SBE have an impact on street vitality [22–25].

In recent years, the research on the relationship between SBE and street vitality has grown. There have been some empirical studies on the variables of urban street space, such as the continuity of street interface, greenery rate, sky visibility rate, POI function, and others, which will promote street vitality [26–30]. With the development of information technology, some scholars have applied big data research methods to the research of street vitality at present. They use cell phone signaling data [31,32], format POI data [33], Internet social data [34], street view data [35,36], and others to study the spatial structure of the city and the spatial–temporal evolution of vitality and other aspects, and analyze the correlation between human activity and urban features.

In summary, the research trend of street vitality has two aspects. First, theoretical research and practical research show a rapid growth trend. Second, the research methods have gradually transformed from qualitative analysis to quantitative analysis and from traditional research to big data research. The research on street vitality in recent years, big data, and the quantitative research trend continue to increase. The research method of street vitality has shifted from field surveys and interviews to multi-source data for the mainstream trend, and the research on the SBE features has expanded from a single analysis method, such as space syntax, to a multi-source data analysis method.

It is not difficult to know from the above-mentioned research of many scholars that, whether based on traditional research methods or emerging data, they all build an association between human behavior and evaluation indexes on the common features of streets. However, for streets with historical and cultural features, there is a lack of relevant research on the impact of their characteristic features on street vitality.

Nevertheless, as a street space in historic areas, the street form that is generated by its unique architectural style is the environmental features that are not available in the usual street space. From the macroscopic perspective, those unique environmental features are one of the important factors in forming the overall cultural features of the city, because their historical value will have an important impact on the connotation quality of urban vitality in the cultural aspects [37]. From the microscopic perspective, the existence of unique environmental features also has a significant impact on the feelings of those who are active in these street spaces [38]. Therefore, as an important part of the urban communication space, the street space, especially in historic areas reflecting the historical context of the city, is the most direct embodiment of urban vitality and is the core node of urban vitality [39].

The research on SBE of historic areas mainly focuses on its characteristics and the correlation between it and human behavior. For the study of its characteristics, it is often reflected in the study of interface features, physical characteristics, and cultural values of street space [40–43]. At the same time, some scholars study it from the perspective of the relationship between people and street space, using tools such as environmental psychology or quantitative assessment of features, so as to establish an association between features of street space and people's activities [38,44–46].

Furthermore, it can be seen that the current studies on SBE of historic areas mostly start from the perspective of conservation strategies from the above studies. Although some scholars have analyzed the relationship between street space and human activities from the perspective of environmental psychology, they have not established a relationship with street vitality.

Although many new methods and tools have been used in the research on street vitality and SBE, there is no segmented research on some specific areas at present. The most obvious is that common features of SBE, such as greenery rate, sky visibility rate, POI function, and other characteristics, have been correlated with street vitality by scholars, but the characteristics of streets are rarely studied. Nowadays, some scholars divide streets into residential streets, commercial streets, and mixed streets according to their functions from the macroscopic perspective [47]. However, there are few studies on the subdivision of visual environment features and cultural value features from microscopic perspective.

Therefore, our study attempts to elucidate the influence mechanism of street vitality generated by SBE features and human activities in historic areas, and the research horizon is refined from common street features to characteristic street features to make up for the lack of existing research on street vitality. In this way, this work provides a new idea and perspective for the research of street vitality and its related SBE characteristics.

2. Materials and Methods

2.1. Study Area

Wuhan, the capital of Hubei Province, is the largest city in Central China. In 2021, its GDP reached 1.77 trillion RMB, ranking ninth in China. Wuhan has a population of 13.649 million, and the migrant population is 5.156 million, which accounts for 37.78% of the total population. Among these people, more than 1.68 million were college students, and this number is first in China (from http://tjj.wuhan.gov.cn/, accessed on 8 October 2022). These economic and demographic factors have contributed to the vitality of Wuhan. In history and culture, there are 16 historical and cultural style areas and 93 excellent historical buildings in Wuhan. Among them, there are ancient relics, concession buildings, early modern Li-Fen culture, revolutionary historical sites, industrial sites, and other types of cultural heritage. These diverse cultural styles constitute the multicultural cultural characteristics and the unique historical and cultural style in Wuhan [48].

As presented in Figure 1, this study focuses on three historical areas: the Qingdao Road area, the August 7th Meeting site area, and the Jianghan Road and Zhongshan Avenue area, located in the district of Wuhan old city, referenced by "System planning of historical and cultural style area in Wuhan Main City". These three historical areas are geographically connected and have unified historical and cultural features. At the same time, the historical buildings and historical environment features in this area are basically the original objects retained by history and have relatively complete historical features. Therefore, this study takes these three areas as the study area.

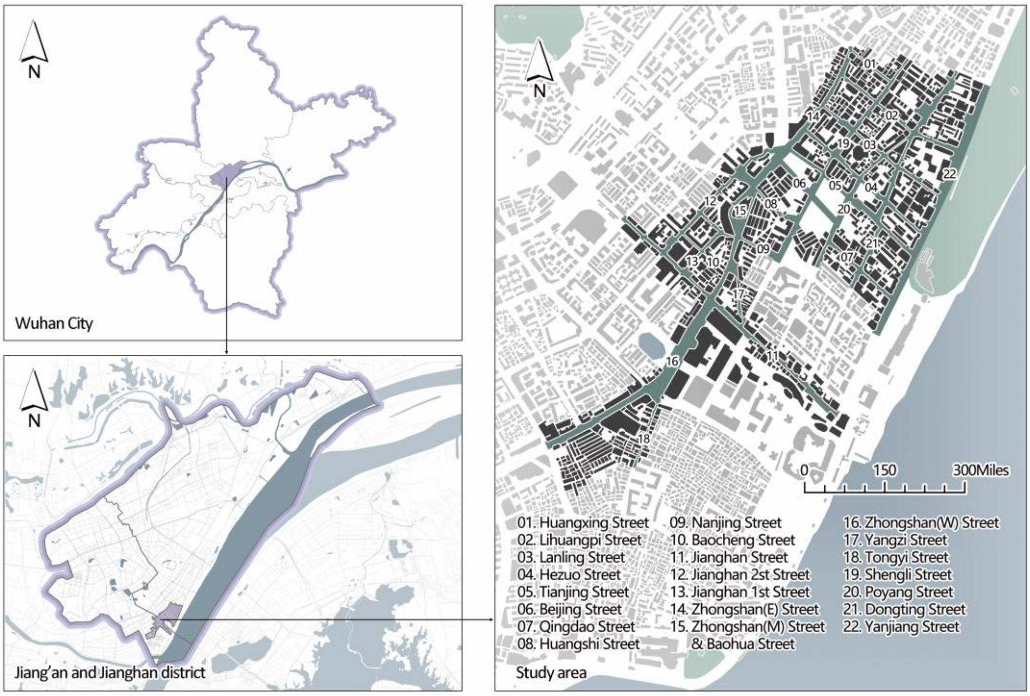

Figure 1. Location of the study area (http://datav.aliyun.com/portal/school/atlas/area_selector, accessed on 15 September 2022).

2.2. Research Design

As claimed by Mehta, a vibrant street is where many people participate in a series of fixed or continuous activities, especially social activities [49]. Moreover, the physical environment of the street provides a place for people's activities, which has a certain impact on these activities [50]. Therefore, the study of street vitality can be carried out in two dimensions: SBE is the internal factor of street vitality, and pedestrian activity intensity is the exterior characterization of street vitality.

Furthermore, we chose to use the intensity characteristics of pedestrian activity as the independent variables of street vitality, and the functional characteristics of buildings and the morphological characteristics of streets as the independent variables of SBE, based on the literature study in Section 1. The reason for these variables is explained in detail in Section 2.3. Subsequently, these variables were objectively described through spatial analyses, statistical analyses, and semantic analyses. Then, we compared these results with the results of the analysis of pedestrian activity intensity. By comparative research, it is possible to capture which dimensions would play a more important role in street vitality in historic areas, and which dimensions affect street vitality differently in the particular context of historic areas as opposed to general urban spaces (Figure 2).

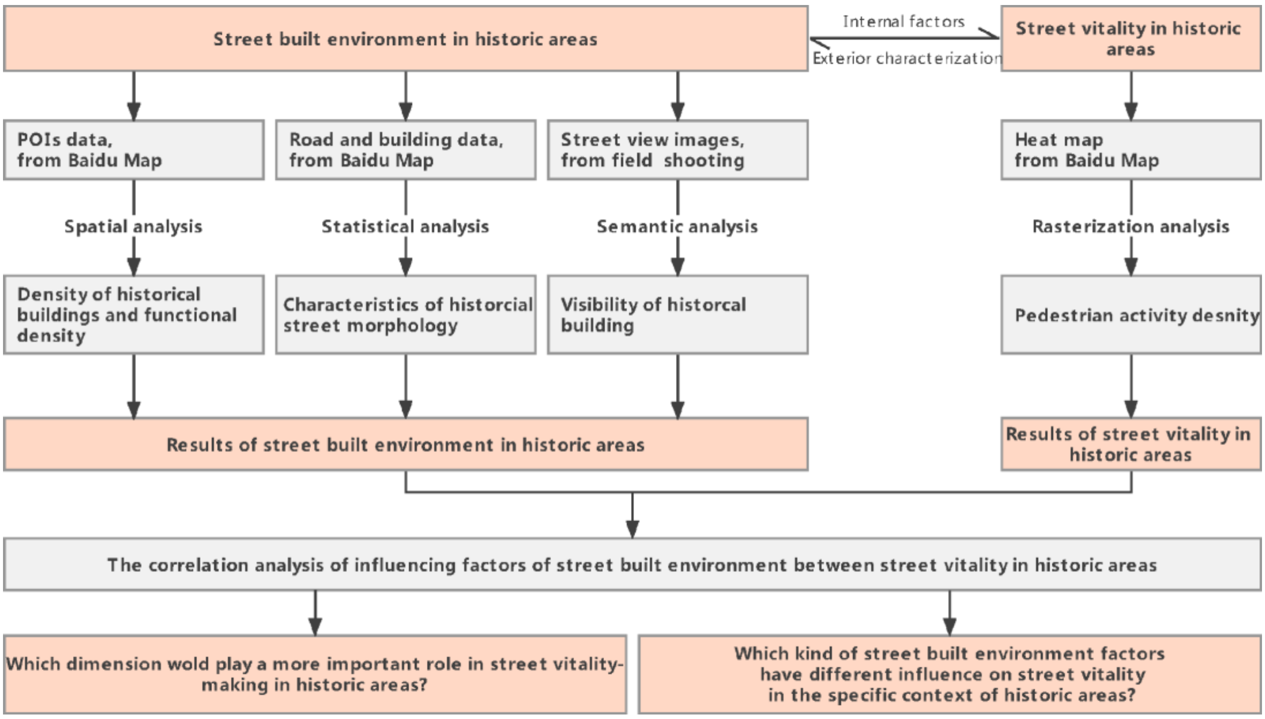

Figure 2. The framework of the study.

2.3. Variables of Indicators

In terms of internal factors, SBE mainly includes its characteristics and surrounding characteristics which are manifested in the location of streets, street texture, development intensity, traffic accessibility, and functional density [16,51–56]. This study mainly focuses on the built environment indicators of historical streets, which are composed of unique built environment features. At the same time, this study combines the results of previous studies to measure and compare the unique features of historic streets with the features that significantly affect the vitality of the street, such as functional density of the street, and we analyze the differences in their relationship to vitality.

In exterior characterization, the description of human activity intensity in a specific space can be expressed by a variety of data, such as heat map data, cell phone signaling data, nighttime light imagery, social media data, and census data [57–59]. Considering the representativeness, precision, and availability of data, it can be known that the heat map data provided by the Internet can be better applied in the study of street vitality as the representative data of human activity intensity.

2.3.1. Variables of SBE

Pedestrians' spatial perception is significantly influenced by various environmental features in the street, and spatial perception also directly affects street vitality [60]. In this regard, many scholars have confirmed the relationship between various variables of SBE and street vitality [22,61]. Among them, many features such as street function distribution, development intensity, interface characteristics, and visual environment have been proven to have an influence on street vitality [62–69]. Therefore, combined with the above research results, this study will select several significant SBE indicators, and at the same time add related indicators of SBE characteristics unique to historical streets to study their relationship with street vitality in the special environment of historic streets (Table 1).

Table 1. Variables of SBE.

Indicators		Meaning	Data Source
Macroform	Historical Building Density	The number and distribution of historical buildings in statistical research	An Overview of Outstanding Historic Buildings in Wuhan
	Functional Density of Historical Buildings	Statistics and analysis of functional types of historic buildings after renovation	An Overview of Outstanding Historic Buildings in Wuhan
	Functional Density of POI	Statistical POI point for analysis, the functional density of the street is the POI point density of the street	POI Data
	Traffic Facilities	Statistics and analysis of the distribution and quantity relationship of traffic facilities	POI Data
Street Interface	Built Environment Development Intensity	Statistics of the underlying area of the street surface buildings, multiplied by the number of floors to obtain the total area of the building, calculate the ratio of the underlying building area	3D Building Data
	Street Width-to-Height Ratio	Statistics of the average width of the street and the height of the building, and calculate the ratio of the two	Baidu Map Data
	Facade Ratio of the Historical Buildings on Street Frontage	The ratio of facade contour length of historic buildings along the street to the contour length of all buildings along the street	3D Building Data
	Visibility of Historical Buildings	Statistics on the proportion of historic building interfaces in panoramic images of central points of different vital sections in streets	Street View Image Data

2.3.2. Variables of Street Vitality

The essence of street vitality originates from the pedestrian engaged in various activities on the street, and the change in street vitality is caused by the intensity and pattern of pedestrian activity in the street space [70,71]. Therefore, we argue that pedestrian activity intensity can be used as the exterior characteristic of street vitality [72]. In this study, to avoid the impact of the rush hour of weekday commuting, the activity intensity data from September 17 to 18, 2022, within the specified study area will be collected, which come from the platform interface of developer API provided by Baidu Map [73–78]. According to privacy protection requirements, detailed coordinates cannot be provided directly. As an alternative, the vector graphic data which can reflect the activity intensity were used as characteristics of street vitality imported into ArcGIS for statistical analysis.

2.4. Source and Type of Data

The road data, 3D building data, and point of interest (POI) data were provided by the Baidu Map open platform (https://lbsyun.baidu.com/, accessed on 29 August 2022). The Baidu Map open platform is the online mapping service provided by Baidu since 2005; its collected data has covered all cities in China, with over 500 million users, 180 million POI data, and coverage of 98% of the country's points of interest. The data relating to historical buildings were provided by Wuhan: Overview of National Historical and Cultural Cities and An Overview of Outstanding Historic Buildings in Wuhan [79,80].

The data used in this paper are divided into textual data and spatial vector data. Among them, urban facilities POI data and historical building data are text data, and Baidu heat map data, road network traffic, and 3D building data are spatial vector data. In addition, we also obtained the land use planning map of the main urban area of Wuhan 2022 (http://whonemap.zrzyhgh.wuhan.gov.cn:8020/, accessed on August 2022), and the spatial structure and grading map of the overall protection system of the historical and cultural style districts of Wuhan (http://gtghj.wuhan.gov.cn/qs/pc-993-59911.html, accessed on 31 July 2022) as supplements to the data in this study.

Through the API platform interface of Baidu Map Developer, we obtained 22,879 POI data of various facilities in Jiang'an District and Jianghan District of Wuhan, including the name, latitude, longitude, function type, and detailed address of the facilities. The historical building data were obtained from the historical building information provided in books. We obtained data on a total of 105 historical buildings from the first batch to the tenth batch of Wuhan in the category of Jiang'an District and Jianghan District, including building names, detailed addresses, and function status.

Immediately, as demonstrated in Table 2, combined with the data classification of Baidu Map API, the data were defined as street functional types of commercial function, life service function, official function, residential function, and traffic function. After that, they were imported into ArcGIS by coordinate correction to form vectorial spatial data. Historical building data refer to the above classification and are defined by five categories of functional forms: commercial function, life service function, living function, official function, and under repair or vacant. Subsequently, the vector spatial data were created in ArcGIS by building addresses and function information provided in *An Overview of Outstanding Historic Buildings in Wuhan*.

Table 2. Function type classification.

Classification		Street Function Types	Amount of Data
Functional Density	Commercial Function	Recreational facility, shopping, restaurant, hotel	13,640
	Life Service Function	Hospital, research and education institutions, cultural facilities, sports facilities	3378
	Official Function	Enterprise, training base, studio, government, social groups	1239
	Residential Function	District, apartment, residence	4286
	Traffic Function	Bus station, subway station, parking lot, pier	336
Functional Density of Historic Buildings	Commercial Function	Shopping, restaurant, hotel	45
	Life Service Function	Medical establishment, cultural facilities, convenience service facilities	11
	Official Function	Enterprise, training base, studio, government, social groups	22
	Residential Function	Residence	45
	Under Repair or Vacant	Under repair or vacant	9

2.5. Methods

2.5.1. Kernel Density Estimation

Kernel density estimation (KDE) is a nonparametric statistical method used to estimate unknown probability distributions in probability theory [81,82]. It is a generalization of the idea of histogram density estimation proposed by Rosenblatt and Emanuel Parzen [83,84]. When a histogram is used for density estimation, the histogram is always a discontinuous step function; even if random variables are continuous, KDE can solve this shortcoming. Conceptually, KDE of point elements means that each point is covered by a smooth surface, and the position of the point has the highest surface value. With the increase in the distance from the point, the surface value will gradually decrease, and it will eventually be zero where the distance from the point is equal to the search radius.

This formula defines the predicted kernel density at (x, y) position:

$$Density = \frac{1}{(radius)^2}\sum_{i=1}^{n}\left(\frac{3}{\pi}\times pop_i\left[1-\left(\frac{dist_i}{radius}\right)^2\right]\right)$$
$$For dist_i < radius$$

In the equation, $i = (1, \ldots, n)$ is the input point, pop_i is the number of samples to calculate the location of the target, $dist_i$ is the distance between point i and the (x, y) position, and *radius* is the bandwidth at which the KDE algorithm works, which is the most important parameter in KDE. Although there are many different mathematical forms of KDE in practical applications, the kernel functions of various mathematical forms have little effect on the kernel density as long as the bandwidth is determined. This study is based on the quartic function described in Silverman's work (1986 edition, p. 76, equation 4.5) [81].

This formula defines the radius value of the bandwidth:

$$Searchradius = 0.9 \times min\left(\sqrt{\frac{\sum_{i=1}^{n}(x_i-\overline{x})}{n}+\frac{\sum_{i=1}^{n}(y_i-\overline{y})}{n}}, \sqrt{\frac{1}{In2}}\times D_m\right)$$

In the equation, x_i, y_i are the latitude and longitude coordinates of factor i, $\overline{x}$, $\overline{y}$ are the average central coordinates of the elements, D_m is the median distance from the mean center, and N is the total number of all factors. The method used to select the bandwidth is based on the bandwidth estimation formula of the Silverman Rule of Thumb, which has been adjusted to apply to multiple dimensions [81]. Compared with other calculation methods, this calculation method can avoid the phenomenon of "circles around points" in sparse datasets and prevent spatial outliers. In this study, ArcGIS10.8 was used to conduct kernel density analysis and relevant mapping of functional POI data, point of historic buildings, and point of functional density of historic buildings after reconstruction within the study area.

2.5.2. Histogram Analysis

Histogram analysis is a method for calculating the distribution and proportion of features in an image. The specific operation is to import the image into Adobe Photoshop, use histogram data and color range tools to classify and count each element of the rasterized image, and set the cache level to 1 to count the number of pixels of each graph. Finally, we can obtain the average value [85].

This formula determines the distribution ratio of each feature in the image:

$$HBR = \frac{\sum_{i=1}^{n} s_i}{S_i}$$

In the equation, S is the number of pixels of a building's facade visible in the image, and *s* is the number of pixels visible on the facade of a historic building in the image. In this study, Adobe Photoshop was used to conduct histogram analysis and relevant mapping of the visibility of historical buildings.

3. Results

3.1. Variables of SBE Analysis

3.1.1. Morphological Characteristics Analysis

Historical building data and functional POI data are corrected and standardized by ArcGIS spatial analysis tools. Then, the data are imported for kernel density analysis (KDA). The relevant mapping of historical building density, the functional density of historic buildings after reconstruction, and functional density were used with the Jenks classification method to reflect the distribution characteristics in the KDA diagram.

(1) Analysis of historical building density

Figure 3 demonstrates the spatial distribution of the historic buildings in the study area. On the whole, the spatial distribution demonstrates a multi-core state, mainly concentrated in Janghan Street, Zhongshan Street (M) and Baohua Street, and Huangxing Street. Among them, Janghan Street has the highest aggregation density, Zhongshan Street (M) and Baohua Street have higher values of kernel density, while Huangxing Street also demonstrates a trend of concentrated distribution of historical buildings.

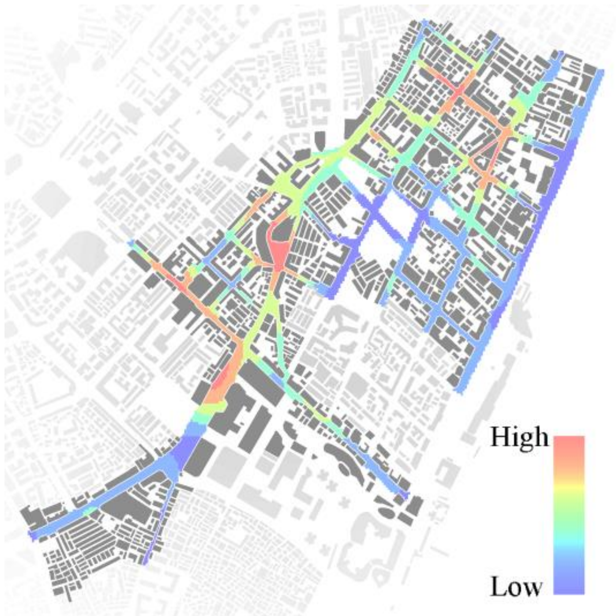

Figure 3. Spatial distribution of density of historic buildings.

(2) Analysis of functional density of historical buildings and POI

Figure 4a,b demonstrates the spatial distribution of commercial functions of historical buildings and the spatial distribution of POI's commercial functions. First, historical buildings with commercial functions are mainly concentrated in the north and central parts of Jianghan Street, and there is also a certain gathering phenomenon on Lihuangpi Street. The distribution of these buildings in other locations is more scattered, such as the north of Dongting Street and the north of Yanjiang Street. The POI's commercial functions are mainly concentrated in the north of Jianghan Street and Zhongshan Street (W), while the distribution of commercial functions in other parts is low.

Figure 4c,d demonstrates the spatial distribution of life service functions of historical buildings and the spatial distribution of POI's life service functions. First, the spatial distribution of life service functions of historical buildings demonstrates a double core state, located near Huangxing Street, Lihuangpi Street, and Zhongshan Street (M) and Baohua Street, respectively, and there is also a certain distribution in the south of Poyang Street. The spatial distribution of POI's life service functions has broader coverage compared to the former. Except for Baohua Street and Yanjiang Street, there is a high distribution of life service functions. This distribution characteristic indicates that the service functions that are more relevant to the daily life of the residents tend to exist along with other functions that contribute to the efficiency of the services.

Figure 4e,g demonstrates the spatial distribution of the official function and residential function of historical buildings, and Figure 4f,h demonstrates the spatial distribution of POI's official function and residential function. The spatial distribution characteristics of these two types of functions are similar, and both demonstrate a more significant distribution characteristic of aggregation. First, the official function of historical buildings is concentrated on Lihuangpi Street, the south of Shengli Street, and the south of Poyang Street, while the residential function of historical buildings is mainly concentrated in the middle of Baohua Street and Zhongshan Street, and partly in the vicinity of Lihuangpi

Street. The POI's official function is mainly distributed on Lihuangpi Street and Qingdao Street, and the POI's residential function is concentrated on Jianghan 1st Street, Jianghan 2nd Street, and the intersection of Nanjing Street and Huangshi Street, and there is also a relatively high concentration in the middle section of Shengli Street.

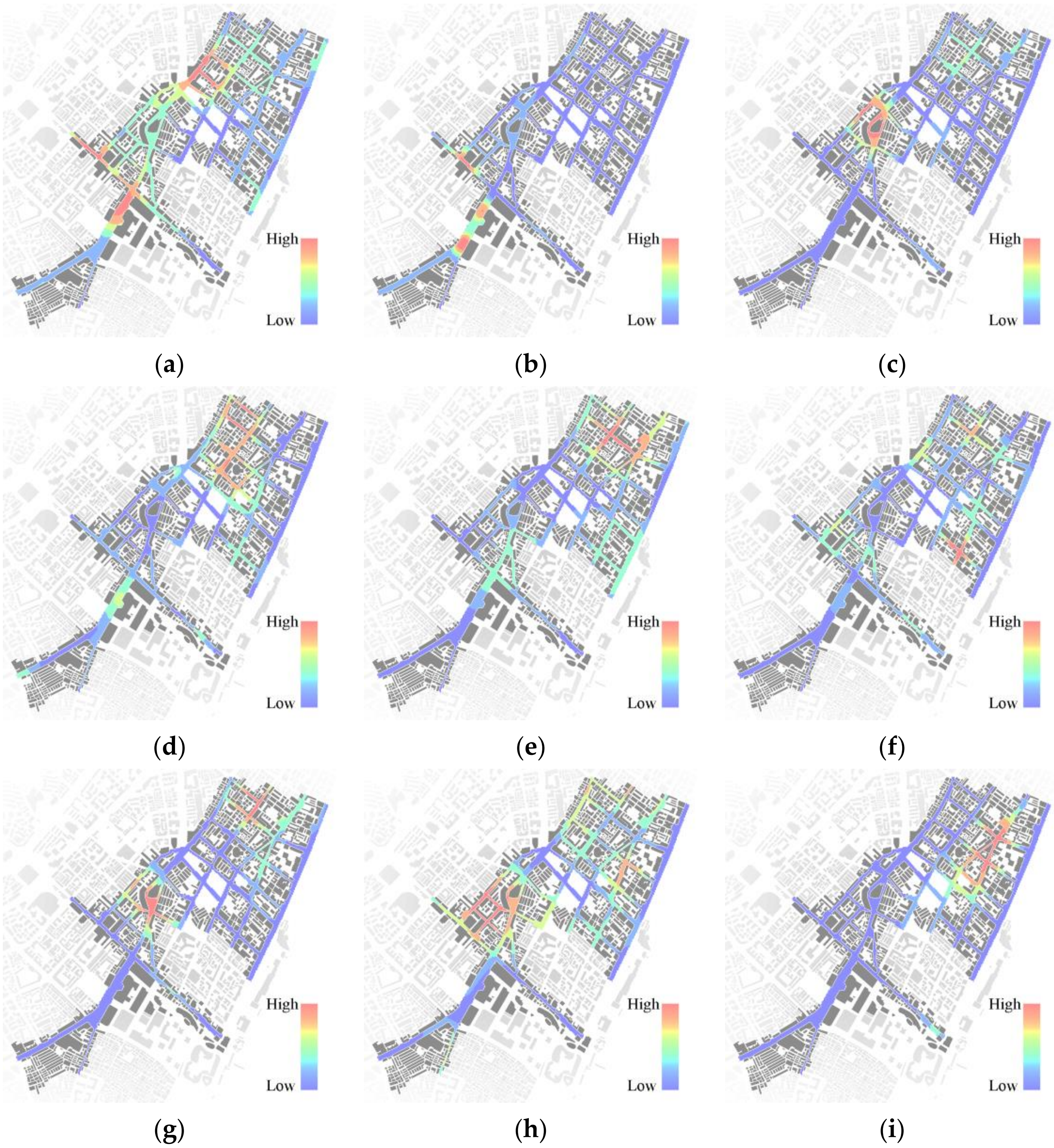

Figure 4. Spatial distribution of function type density of historic buildings. (**a**) Commercial function (historical building); (**b**) commercial function (POI); (**c**) life service function (historical building); (**d**) life service function (POI); (**e**) official function (historical building); (**f**) official function (POI); (**g**) residential function (historical building); (**h**) residential function (POI); (**i**) under repair or vacant (historical building).

Figure 4i demonstrates the spatial distribution of under-repair or vacant historical buildings. They are concentrated in the north of Poyang Street, the middle of Dongting Street, Lihuangpi Street, the middle of Lanling Street, and Hezuo Street, with Panoffs' Mansion as the core. The whole distribution demonstrates a significant aggregated distribution pattern.

(3) Analysis of traffic facilities

Figure 5 demonstrates the spatial distribution of traffic facilities. It demonstrates three core parts, among which the highest gathering density is located on the north side of Zhongshan Street and at the intersection of Nanjing Street and Zhongshan Street, followed by the south side of Yanjiang Street. The main reason for this distribution is that the road network is dense in these areas. Bus stops, subway stations, flyovers, and other transportation facilities are often placed at points with the above characteristics.

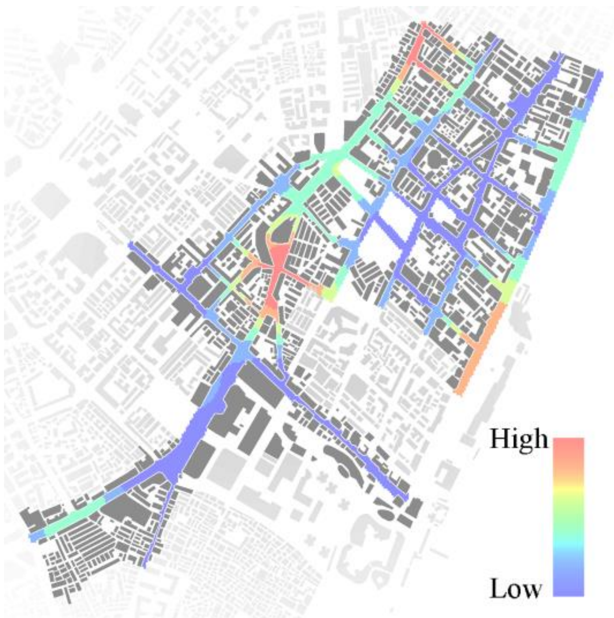

Figure 5. Spatial distribution of traffic facility density.

3.1.2. Street Interface Characteristics Analysis

(1) Analysis of built environment development intensity

While dense buildings improve the integrity of the street, more floorage allows the street to have more capacity, both for pedestrians and functions. Therefore, the built environment development intensity is the prerequisite for the street to generate the necessary activities and the basis for influencing its vitality. This study counts and summarizes the built environment development intensity of 22 streets in the study area, using the floor area ratio as a measure of the built environment development intensity.

Figure 6 demonstrates that Lanling Street, Baocheng Street, Jianghan Street, Jianghan 2nd Street, and Zhongshan Street (W) have higher development intensity, while Huangxing Street, Beijing Street, Zhongshan Street (M) and Baohua Street, and Tongyi Street have lower development intensity. Among them, Jianghan Street has the highest development intensity, reaching 1.25 times the average development intensity, and Beijing Street has the lowest development intensity, only 0.46 times the average development intensity.

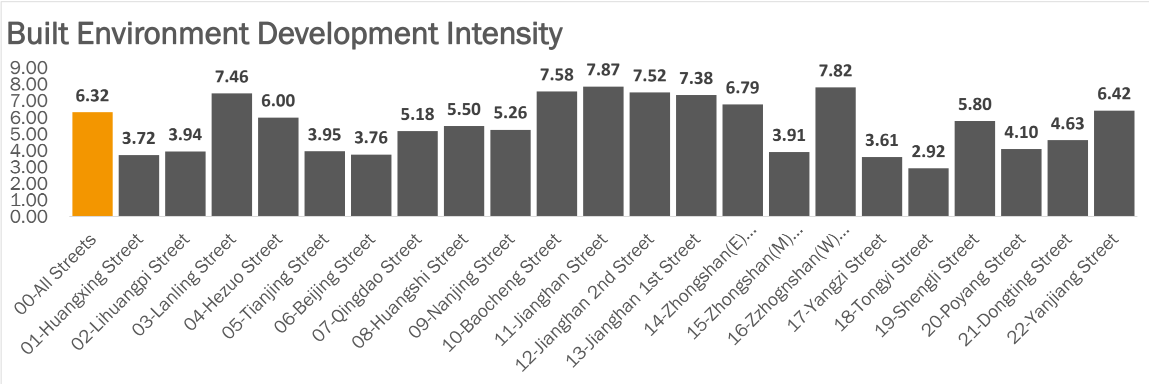

Figure 6. Built environment development intensity.

(2) Analysis of street width-to-height ratio

Jacobs claims that tight spacing can often lead to a clear sense of street space definition more easily than a loose layout [86]. Generally speaking, if the spacing between buildings is large, then the architectural volume presented by the building body will become the focus of vision, and if the spacing between buildings is small, then the interface of the building as a whole is continuous, and the continuity and change of the building interface become the center of vision and it is the conscious composition of the senses on the street [87]. Similarly, a desirable street width-to-height ratio reflects the comfort and continuity of the interface scale in the street space [88]. R. Hedman also believes that the need to conform to the human visual field between the enclosed interfaces is the key to a pleasant spatial scale of the street to ensure the movement of pedestrians [89].

This formula determines the street width-to-height ratio:

$$SAR = \frac{\sum_{i=1}^{n} h_i}{W_i}$$

In the equation, h_i is the average height of buildings on both sides of the street. W_i is the average width of the street, which is calculated from the ratio of the enclosed street area to the length of the street centerline.

Figure 7 demonstrates the street width-to-height ratio data for each street within the study area. Among them, Beijing Street and Huangxing Street have a low street width-to-height ratio, which indicates that these streets have wider streets as well as low street frontage buildings. Streets such as Poyang Street and Dongting Street have a higher street width-to-height ratio, which indicates that these streets are narrow and crowded in pedestrians' perception.

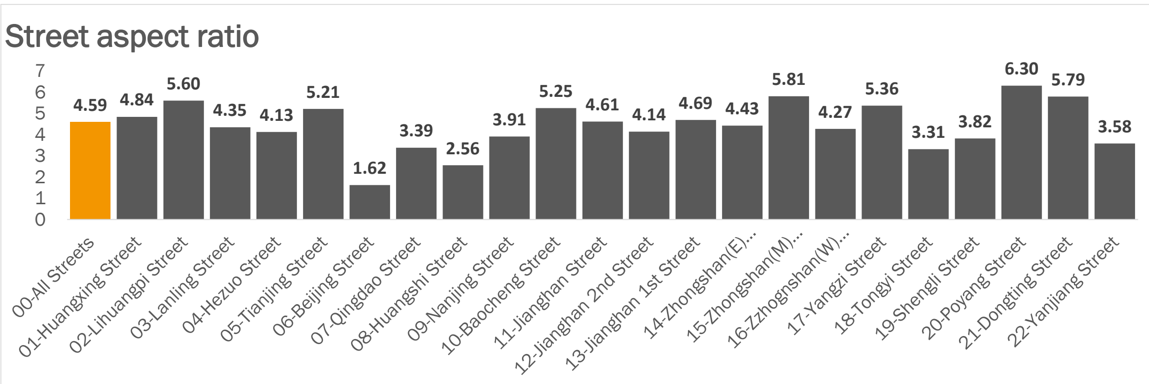

Figure 7. Street aspect ratio.

(3) Analysis of facade ratio of the historical buildings on street frontage

The order of historical buildings, as usable and observable symbols of history, and non-historical buildings in the street space reinforces the pedestrian's sensory perception of the historic area, and the alternation of different architectural features creates a dynamic superposition in the pedestrian's sensory memory, constantly awakening the pedestrian's long cultural memory [90].

Figure 8 demonstrates the facade ratio of the historical buildings on street frontage for each street within the study area. Overall, the ratio of historical building frontage varies widely by street. Jianghan Street, Zhongshan Street (M) and Baohua Street, and Poyang Street have a higher ratio. While Beijing Street and Baocheng Street have a lower ratio, they all have values below 10%.

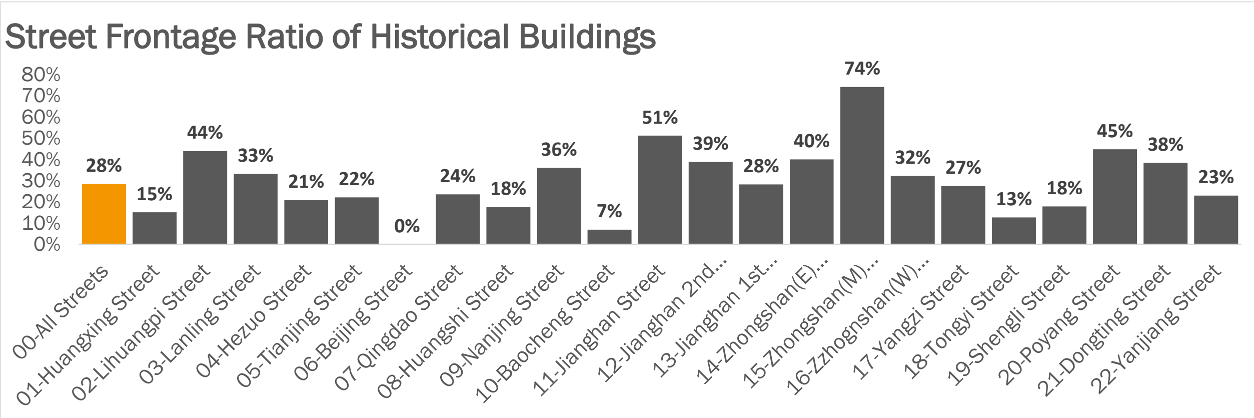

Figure 8. Street frontage ratio of historical buildings.

3.2. Variables of Street Vitality Analysis

In this study, we tracked the distribution of the Baidu heat map for two days from September 17 to 18, 2022, and acquired the heat map data in the time period from 9:00 to 21:00 every three hours. After correcting the coordinates, the data were classified into 6 levels in raster cells, and heat maps were averaged for different time periods in ArcGIS. The pattern of pedestrian activity distribution was then summarized.

Figure 9 demonstrates the distribution of pedestrian activity intensity at different times and the average distribution of pedestrian activity intensity, which can identify that the distribution of pedestrian activity intensity in the study areas on weekends will not be greatly affected by the change in time. The vitality core is mainly located in Jianghan Street, Zhongshan Street (W), Zhongshan Street (E), and Jianghan 2nd Street, which demonstrates that these areas have the largest flow of pedestrians. Secondly, there is also greater vitality in parts of Lanling Street, Hezuo Street, and Yanjiang Street, but in general, its intensity is less than the core part. However, located at the intersection of Lihuangpi Street, Dongting Street, Poyang Street, Beijing Street, and Zhongshan Street (M), there is a large pedestrian hole.

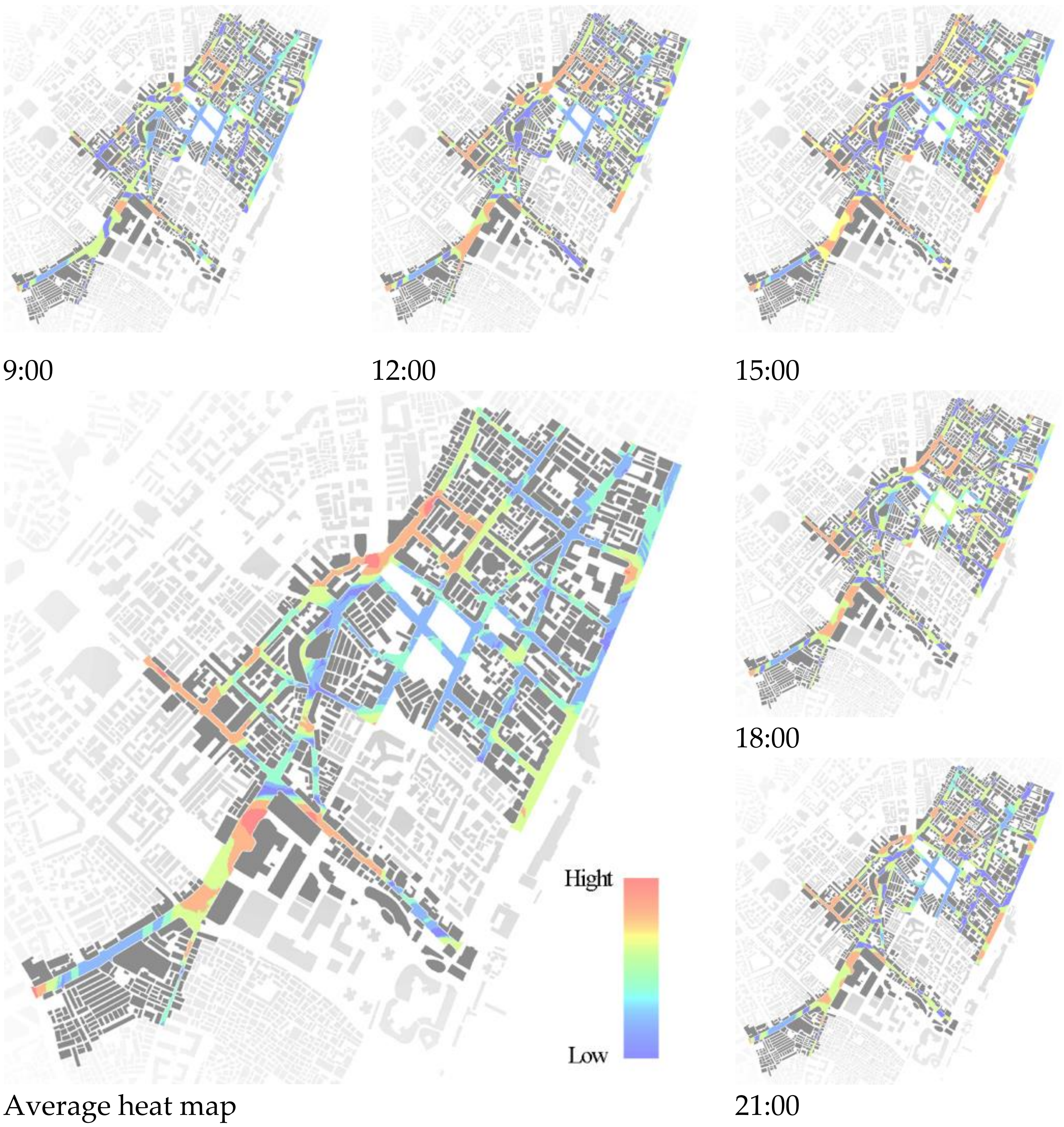

Figure 9. Heat maps at different times and the average heat map after treatment.

The street vitality intensity of the 22 streets was measured by rasterizing the data for different vitality areas, using the average vitality of all streets as the standard value, and Figure 10 demonstrates the street vitality intensity of each street. It demonstrates that Lanling Street, Jianghan Street Jianghan 1st Street, Jianghan 2nd Street, Zhongshan Street (E), and Zhongshan Street (W) have high street vitality, and their street vitality intensity is 1.23 to 1.62 times higher than the average intensity. For streets with lower street vitality, such as Lihuangpi Street, Beijing Street, Zhongshan Street (M) and Baohua Street, Poyang Street, and Dongting Street, their street vitality intensity is 0.71 to 0.84 times lower than the average intensity.

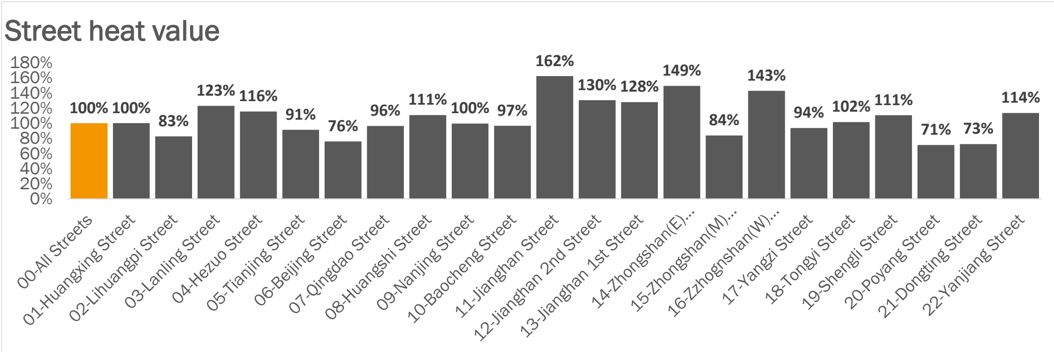

Figure 10. Street vitality intensity.

3.3. Correlation Analysis between SBE and Street Vitality in Historic Areas

3.3.1. Correlation Analysis between Morphological Characteristics and Street Vitality

Figure 11 demonstrates the spatial distribution of historical buildings and the spatial distribution of street vitality. By comparing the two, we find that areas with a concentrated distribution of historical buildings show two contrasting results in terms of street vitality. On one hand, the northern and central sides of Jianghan Road and the central part of Zhongshan Avenue (West) have a high density of historical buildings along with the presence of high street vitality. On the other hand, Huangxing Street, Lihuangpi Street, Zhongshan Street (M), and Baohua Street have a high density of historical buildings and a low street vitality.

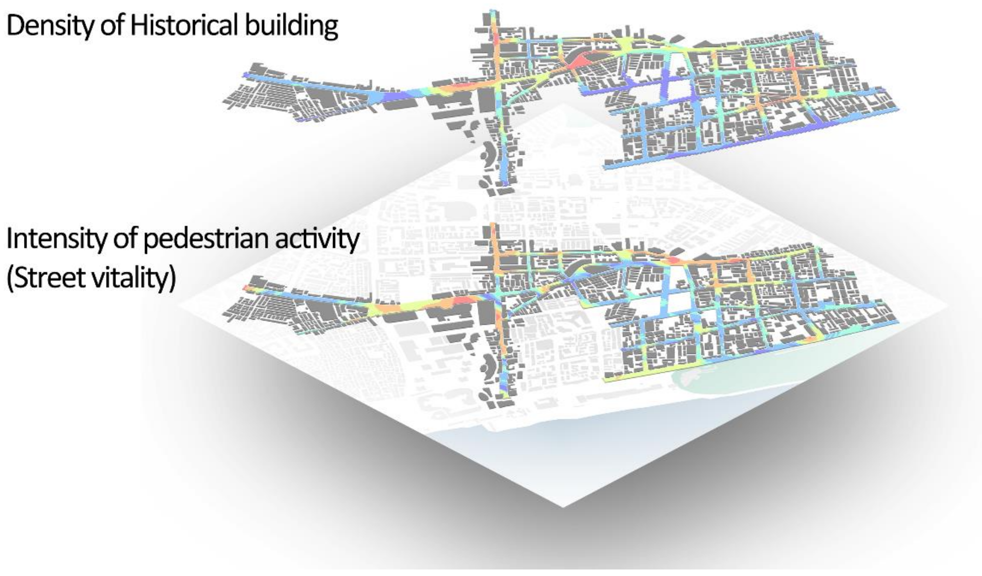

Figure 11. Spatial distribution of street vitality versus spatial distribution of historical buildings.

To explain the reasons for this spatial distribution phenomenon, we further compare the spatial distribution of historical building functions, the spatial distribution of POI functions, and the spatial distribution of street vitality.

Figure 12a demonstrates that the street vitality is higher in the district with higher density of historical buildings with commercial functions. Meanwhile, the street vitality is lower in the district with lower density of historic buildings. The spatial distribution of historical building density fits much better with the spatial distribution of street vitality than the spatial distribution of POI functional density.

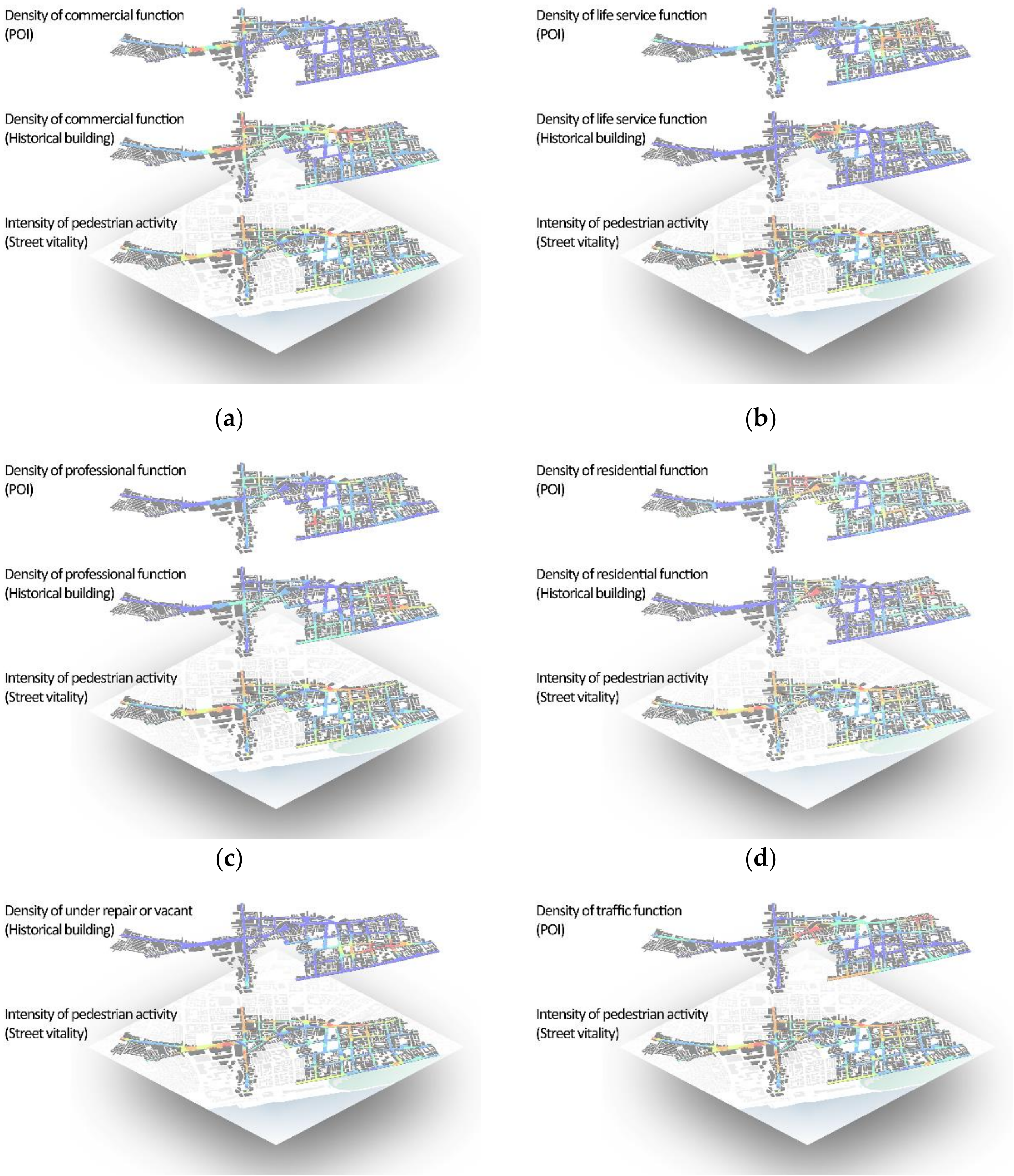

Figure 12. Spatial distribution of street vitality versus spatial distribution of function type of historical building. (**a**) Commercial function; (**b**) life service function; (**c**) official function; (**d**) residential function; (**e**) under repair or vacant; (**f**) traffic function.

Figure 12b,c demonstrates that for life service functions and official functions, street vitality is lower in both locations with a higher density of historical buildings and locations with a higher density of corresponding POI functions.

Figure 12d demonstrates that for residential functions, the higher the density of historical buildings and the corresponding POI function, the lower the street vitality. The lower the density of the former, the higher the street vitality tends to be.

Figure 12e demonstrates that the higher the density of historical buildings under repair or vacant, the lower the street vitality.

Figure 12f demonstrates that for traffic functions, the higher the density of traffic facilities, the lower the street vitality. The lower the density of traffic facilities, the higher the street vitality tends to be.

3.3.2. Correlation Analysis between Street Interface and Street Vitality

In order to make a cross-sectional comparison between street vitality and built environment development intensity, street width-to-height ratio, and facade ratio of the historical buildings on the street frontage, we used the values of all streets as the benchmark for measurement, and recalculated the statistics for each variable with values relative to all streets.

Table 3 demonstrates the result of street vitality versus built environment development intensity, street width-to-height ratio, and facade ratio of the historical buildings on street frontage.

Table 3. Street vitality versus built environment development intensity, street width-to-height ratio, and facade ratio of the historical buildings on street frontage.

Street	Street Vitality		Built Environment Development Intensity		Street Width-to-Height Ratio		Facade Ratio of the Historical Buildings on Street Frontage	
	Value	Ratio	Value	Ratio	Value	Ratio	Value	Ratio
00—All Streets	1.000	100.00%	6.319	100.00%	4.588	100.00%	0.285	100.00%
01—Huangxing Street	1.001	100.07%	3.721	58.88%	4.838	105.46%	0.051	17.88%
02—Lihuangpi Street	0.827	82.69%	3.942	62.38%	5.599	122.05%	0.389	136.73%
03—Lanling Street	1.229	122.94%	7.462	118.08%	4.348	94.78%	0.232	81.60%
04—Hezuo Street	1.155	115.52%	6.001	94.96%	4.126	89.95%	0.129	45.21%
05—Tianjing Street	0.914	91.39%	3.954	62.57%	5.212	113.61%	0.221	77.55%
06—Beijing Street	0.759	75.95%	3.759	59.48%	1.620	35.31%	0.000	0.00%
07—Qingdao Street	0.965	96.47%	5.180	81.97%	3.385	73.79%	0.235	82.65%
08—Huangshi Street	1.108	110.81%	5.496	86.97%	2.555	55.70%	0.076	26.64%
09—Nanjing Street	0.996	99.60%	5.262	83.27%	3.910	85.22%	0.561	196.98%
10—Baocheng Street	0.966	96.64%	7.577	119.90%	5.248	114.40%	0.069	24.19%
11—Jianghan Street	1.622	162.20%	7.872	124.57%	4.610	100.50%	0.382	134.18%
12—Jianghan 2nd Street	1.304	130.36%	7.519	118.98%	4.139	90.23%	0.278	97.83%
13—Jianghan 1st Street	1.279	127.93%	7.377	116.74%	4.693	102.31%	0.252	88.59%
14—Zhongshan(E) Street	1.493	149.32%	6.791	107.46%	4.425	96.46%	0.100	35.20%
15—Zhongshan(M) Street and Baohua Street	0.838	83.75%	3.913	61.92%	5.809	126.63%	0.741	260.44%
16—Zzhognshan(W) Street	1.429	142.91%	7.824	123.81%	4.271	93.09%	0.322	113.12%
17—Yangzi Street	0.938	93.76%	3.610	57.13%	5.361	116.85%	0.394	138.50%
18—Tongyi Street	1.015	101.50%	2.924	46.27%	3.314	72.24%	0.046	16.19%
19—Shengli Street	1.106	110.64%	5.797	91.73%	3.822	83.31%	0.179	62.75%
20—Poyang Street	0.713	71.30%	4.100	64.88%	6.301	137.35%	0.448	157.33%
21—Dongting Street	0.725	72.51%	4.626	73.20%	5.792	126.26%	0.384	134.96%
22—Yanjiang Street	1.136	113.57%	6.423	101.64%	3.583	78.10%	0.229	80.61%

First, for the built environment development intensity, the streets with high street vitality all have higher development intensity than average and are significantly higher than other streets, while the streets with low street vitality all have lower development intensity and are significantly lower than the average development intensity.

Second, for the street width-to-height ratio, the streets with high street vitality all have street width-to-height ratios between 4.348 and 4.610. As for the streets with low street vitality, their street width-to-height ratios are all too high or too low, among which the ratio of Beijing Street is significantly lower than other streets, only 1.62, while the ratio of Poyang Street is significantly higher than other streets, reaching 6.301.

Thirdly, for the facade ratio of the historical buildings on the street frontage, the streets with high street vitality have a higher percentage of historical building facades than average. The streets with low street vitality have a large difference in values. For example, there are no historical buildings on the street frontage of Beijing Road, while the ratios of the other five streets are above the average, but combined with Section 2.4 and the field survey, there are more vacant or renovated historical buildings on these streets.

4. Discussion

This study discusses the association between the influence of SBE and street vitality in historic areas. Among them, the SBE, which is the material basis of street vitality, is centered around the unique street environment factors possessed by the historic areas. The pedestrian activity intensity, which is the exterior characterization of street vitality, is reflected by the heat map. In addition, we conducted geospatial visualization analysis, statistical analysis, and raster data analysis to visually represent the relationship between the spatial distribution of SBE and the spatial distribution of street vitality. Furthermore, evaluating the functional types of historical buildings assumes an important role in the creation of street vitality in historic areas, and compared to the general urban space, the intervention of traffic facilities can have a different impact on the street vitality in historic areas.

In addition, the impact of SBE features on street vitality has been discussed in the existing literature. As the material basis for street vitality, the street location, development intensity, accessibility, functional mix, functional density, and related characteristics of the street itself (length, width, road class, speed limit, greenery, etc.) have been studied by many scholars. Furthermore, many scholars have proposed ways to improve the spatial quality and comfort of streets through rational planning and design techniques to enhance street vitality [19,20,23–25]. While the above-mentioned factors are often common in urban street spaces, special streets such as historical streets, which have an important place in urban spaces, have rarely been explored. This study has provided new insights from the perspective of these special spaces in cities such as historic areas.

First, the spatial distribution of historical buildings in historic streets leads to a more differentiated distribution of street vitality. It shows that the street vitality may become higher or lower in areas where historical buildings are concentrated.

The main reason for this phenomenon is that these historical buildings have been renovated and they assume different types of functions in the streets. Among them, the spatial distribution of historical buildings converted to commercial functions has high consistency with the spatial distribution of street vitality, and the consistency is significantly higher than that of spatial distribution for commercial functions in general. The conversion of historical buildings to life service functions and official functions has an inhibiting effect on street vitality. Moreover, the spatial distribution of historical buildings converted to residential functions, as well as those in repair or vacancy, is diametrically opposed to the spatial distribution of street vitality. This demonstrates that the existence of such historical buildings will significantly inhibit street vitality.

In conclusion, it is not difficult to know that the dimension of functional features is one of the most important variables in street vitality. This finding is largely consistent with the results of theoretical studies of street vitality and recent empirical studies. Jacobs argues that functional diversity is the most important fundamental factor in attracting citizen visitors to activities, as confirmed by Long Y. and Zhou K. et al. [34,50]. Compared to physical built environment features, functional features can be adjusted and changed relatively easily in a short period of time in response to changes in actual conditions, and they are reflective of the immediate needs of current pedestrians [16]. Second, functional features with historical attributes have a more significant impact on street vitality than those without. This also validates Jiang's explanation of urban vitality, which posits that cultural vitality is the spiritual connotation of urban vitality, and is an important expression of human spiritual pursuit on top of social and economic vitality [70]. History and culture are the deepest connotations of a city; therefore, a street environment with historical style tends to be more attractive to pedestrians, which is an important characteristic variable factor of street space in historical districts.

In addition, it is worth paying attention to the mutually exclusive phenomenon of the spatial distribution of traffic facilities and the spatial distribution of street vitality, which is contrary to the conclusions reached by previous studies scholars [91]. The reason for this phenomenon may be that although the presence of traffic facilities will improve the convenience of the area, the intervention of bus stops, subway stations, flyovers, and other facilities located in the historical landscape will destroy the pedestrian environment of the historical streets, thus leading to the phenomenon of reduced street vitality. On the contrary, streets such as Jianghan Street are the most vibrant of all, even though they are only walkable. This phenomenon can also reflect the fact that the distribution of traffic facilities can have a different impact on street vitality in the particular street environment of historic areas.

Furthermore, the higher intensity of SBE will have a positive effect on street vitality. This is reasonable because a street with a higher intensity of development means that it has more places for activities and can accommodate a large number of pedestrians to stay for the corresponding activities, thus promoting street vitality [92]. In addition, too high or too low street width-to-height ratios can have an inhibiting effect on street vitality. In general, if the buildings are relatively loose and have low massing, this will result in the street environment having no visual center to focus on from the pedestrian perspective, which is detrimental to street vitality [90]. However, if the street is overdeveloped with an emphasis on high-density buildings, it can cause street space to be crowded in scale. Therefore, by maintaining the appropriate volume relationship of the street while keeping the continuity of the street interface, the area can provide a suitable physical environment for the existence of street vitality. This also confirms Allan Jacobs' description of the "limited sense of street space" [86]. Moreover, streets with a high proportion of historic building facades will enhance street vitality to some extent. However, if there are a large number of historical buildings under restoration exposed to the built environment of the street, this will have a significant inhibiting effect on street vitality, which may be determined by the sense of security.

5. Conclusions

Historic areas are witnesses of a city's development and the carriers of its spirit and material. The built environment constitutes the city's historical and cultural landscape and unique personality characteristics and is the city's historical heritage. To protect the history of the city is to protect the continuity of the city's history and culture and to preserve the memory and heritage of the city [93]. Therefore, preserving and sustaining the character of historic areas, especially the street space, which is an important part of urban space, is an important agenda in the sustainable development and renewal planning of every city in the world today. Driven by the development of new research methods and data sources, this study uses ArcGIS to quantitatively analyze street vitality by applying open data such as street network data, 3D building data, and POI, and also combining historical building-related data provided by books. The impact of SBE on street vitality was assessed through spatial analysis and statistical analysis methods. The empirical results of three historic areas in Wuhan demonstrate that the SBE in historic areas plays a key role in the creation of street vitality.

The contribution of this study is threefold. First, the association between the functional transformation of historical buildings and street vitality suggests that rational restoration and renewal of historical buildings in historic areas and transformation into public or even commercial-oriented functions can effectively promote street vitality. Second, when designing the renewal of street spaces in historic areas, the principle of not destroying the original street texture should be adopted. External space design that preserves the spatial characteristics of the historic environment and the spirit of the place is an effective way to enhance the street vitality of historic areas. Moreover, although the presence of transportation facilities can bring more visitors and pedestrians to the streets of the area, they cannot be perfectly integrated into the historic environment compared to the general urban streets, and thus can reduce the street vitality in the small area around them. This verifies that transforming streets in historic areas into pedestrian-oriented streets is more likely to stimulate their potential to activate urban vitality as historical resources. These findings will help urban designers and planners develop better renovation planning strategies for sustainable development and renewal and revitalization of historic areas.

However, this study has certain limitations. Street vitality is a complex and intangible concept that cannot be fully represented by data from a single time period. Future studies ought to integrate other data sources, such as cell phone signaling data or nighttime light remote sensing data, to establish more accurate measures of street vitality. Additionally, at the early stage of the study, we intended to investigate the ratio of various SBE factors and the visibility rate of historical buildings by panoramic street view images, but these images have not yet been collected and need to be further verified. Although we have considered using street view image data provided by web platforms as a substitute solution, there are two problems with these data. On the one hand, the timeliness of the data is poor. There are large numbers of street-view images that are old and differ greatly from the current site status. On the other hand, the integrity of the data is low. Most of the street view image data provided by the web platform are collected by companies through street view cars, but there are many pedestrian streets in historic areas, which resulted in there being many streets within the study area that have no street view images now. Therefore, the analysis of relevant indicator variables was not complete at the end of this study, and future studies should take into account the impact of these indicators on street vitality.

Author Contributions: Conceptualization, H.Z.; methodology, H.Z. and R.L.; validation, R.L., H.Z. and W.C.; formal analysis, R.L.; investigation, R.L., J.L. and J.G.; writing—original draft preparation, H.Z. and R.L.; writing—review and editing, R.L. and H.Z.; visualization, R.L. and J.G.; supervision, H.Z.; project administration, H.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Ministry of Education, Humanities and Social Sciences Youth Fund (grant number: 20YJC760145), the Humanities and Social Sciences Fund of Hubei Education Department (grant number: 20Y044), the Hubei University of Technology Green Industry Science and Technology Leading Program (grant number: XJ2021005501), and the Innovation Demonstration Base of Ecological Environment Geotechnical and Ecological Restoration of Rivers and Lakes (2020EJB004).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Written informed consent was obtained from all participants.

Data Availability Statement: The heat map data, road data, 3D building data, and point of interest (POI) data were from https://lbsyun.baidu.com/, accessed on 29 August 2022.

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

References

1. Keeble, L. *Principles and Practice of Town and Country Planning*; Estates Gazette, Ltd.: London, UK, 1964.
2. Jacobs, J. *The Death and Life of Great American Cities*; Random House: New York, NY, USA, 1961.
3. Ashihara, Y. *The Aesthetic Townscape*; MIT Press: Cambridge, MA, USA, 1983.
4. Chen, W. The Study on the Conservation Theory and Method of Heritage. Ph.D. Thesis, Chongqing University, Chongqing, China, 2006.
5. Wang, J.G. *Urban Design*, 3rd ed.; Nanjing Southeast University Press: Nanjing, China, 2001; p. 259.
6. Ewing, R.; Handy, S. Measuring the Unmeasurable: Urban Design Qualities Related to Walkability. *J. Urban Des.* **2009**, *14*, 65–84. [CrossRef]

7. Wang, D.; Zhang, Y. Study of Street Space Perception in Shanghai Based on Semantic Differential Method. *J. Tongji Univ. Nat. Sci.* **2011**, *39*, 1000–1006.
8. Wang, H.; Jiang, D.F. Evaluation system research on vitality of urban public space. *J. Railw. Sci. Eng.* **2012**, *9*, 56–60. [CrossRef]
9. Chen, Y.; Zhao, X.H. Research on Ground-Floor Interfaces Along Streets From the Perspective of Pedestrians: A Case Study of HuaiHai Road in ShangHai. *City Plan. Rev.* **2014**, *38*, 24–31.
10. Li, C.D.; Sun, A.L.; Jia, Y. Study on Evaluation Significance & Evaluation Index System of Spatial Quality of City CentralBusiness Area. *J. Hum. Settl. West China* **2014**, *29*, 98–106. [CrossRef]
11. Li, X.J.; Zhang, C.R.; Li, W.D.; Ricard, R.; Meng, Q.Y.; Zhang, W.X. Assessing street-level urban greenery using Google Street View and a modified green view index. *Urban For. Urban Green.* **2015**, *14*, 675–685. [CrossRef]
12. Tan, Z. Three Faces of the New Urbanism: Norms, Methods and References. *New Archit.* **2017**, *219*, 4–10.
13. Shanghai Planning and Land Resource Administration Bureau; Shanghai Municipal Transportation Commission. *Shanghai Street Design Guidelines*; Tongji University Press: Shanghai, China, 2016.
14. Hu, F. *Guangzhou Complete Street Design Manual*; China Building Industry Press: Shanghai, China, 2018; p. 531.
15. Wuhan Natural Resources and Planning Bureau. Planning and Design Guidelines for Total Factors in Wuhan Urban Streets. 2019. Available online: http://www.dxh.gov.cn/ZWGK/bmxxgk/bwbjxxgk/qzrzyhghj/zcwj/202005/P020200519766794648688.pdf (accessed on 6 January 2023).
16. Yj, A.; Yun, H.; Ml, D.; Yu, Y. *Street Vitality and Built Environment Features: A Data-Informed Approach from Fourteen Chinese Cities*; Elsevier: Amsterdam, The Netherlands, 2022.
17. Han, H.Y.; Yu, X.; Long, Y. Identifying Urban Functional Zones Using Bus Smart Card Data and Points of Interest in Beijing. *City Plan. Rev.* **2016**, *40*, 52–60.
18. Chen, L.; Lu, Y.; Sheng, Q.; Ye, Y.; Wang, R.Y.; Liu, Y. Estimating pedestrian volume using Street View images: A large-scale validation test. *Comput. Environ. Urban Syst.* **2019**, *81*, 101481. [CrossRef]
19. Wu, W.S.; Niu, X.Y.; Li, M. Influence of Built Environment on Street Vitality: A Case Study of West Nanjing Road in Shanghai Based on Mobile Location Data. *Sustainability* **2021**, *13*, 1840. [CrossRef]
20. Liu, M.; Jiang, Y.; He, J.L. Quantitative Evaluation on Street Vitality: A Case Study of Zhoujiadu Community in Shanghai. *Sustainability* **2021**, *13*, 3027. [CrossRef]
21. Liang, Y.; Domenico, D.U.; Alessandro, S.; Andrea, R. The more walkable, the more livable? *Can urban attractiveness improve urban vitality? Transp. Res. Procedia* **2022**, *60*, 322–329.
22. Montgomery, J. Making a city: Urbanity, vitality and urban design. *J. Urban Des.* **1998**, *3*, 93–116. [CrossRef]
23. Pikora, T.J.; Bull, F.C.; Jamrozik, K.; Knuiman, M.; Giles-Corti, B.; Donovan, R.J. Developing a reliable audit instrument to measure the physical environment for physical activity. *Am. J. Prev. Med.* **2002**, *23*, 187–194. [CrossRef] [PubMed]
24. Kjc, A.; Adls, B.; Dr, C. The development and testing of an audit for the pedestrian environment—ScienceDirect. *Landsc. Urban Plan.* **2007**, *80*, 95–110.
25. Yang, X.; Pei, X. The Review of Public Open Space Desktop Auditing Tool. *Urban Plan. Int.* **2016**, *31*, 44–50. [CrossRef]
26. Zhu, W. Research on Physical Spaces of Vitality in Hanzheng Streets. Master's Thesis, Huazhong University of Science and Technology, Wuhan, China, 2008.
27. Fang, R. Spatial features of elements and planning design methods for the streets for life. *Urban Probl.* **2015**, *12*, 46–51. [CrossRef]
28. Zhang, Z.H.; Gong, W. Influence Factors and Promotion Strategies of Community Street Vitality—Take Beijing Tiantongyuan As an Example. *Design* **2018**, 155–157.
29. Wang, N.D. Study on the Influence of Living Street Physical Environment on Street Vitality: Evidence from the Main Urabn Area of Harbin. Master's Thesis, Harbin Institute of Technology, Harbin, China, 2019.
30. Han, Z. Multidimensional Urban Vitality on Streets: Spatial Patterns and Influence Factor Identification Using Multisource Urban Data. *ISPRS Int. J. Geo-Inf.* **2021**, *11*, 2.
31. Wang, R.Y.; Lu, Y.; Wu, X.Y.; Liu, Y.; Yao, Y. Relationship between eye-level greenness and cycling frequency around metro stations in Shenzhen, China: A big data approach. *Sustain. Cities Soc.* **2020**, *59*, 297–307. [CrossRef]
32. Zhang, Y.F.; Zhong, W.J.; Wang, D.; Feng-Tyan, L. Understanding the spatiotemporal patterns of nighttime urban vibrancy in central Shanghai inferred from mobile phone data. *Reg. Sustain.* **2021**, *2*, 297–307. [CrossRef]
33. Hao, X.H.; Long, Y.; Shi, M.; Wang, P. Street Vibrancy of Beijing: Measurement, lmpact Factors and Design Implication. *Shanghai Urban Plan. Rev.* **2016**, *3*, 37–45.
34. Zhou, K.; Zhang, H.T.; Xia, Y.N.; Liu, C. New Urban Consumption Space Shaped by Social Media: A Case Study of the Geo-Tagging Places of Changsha on Xiaohongshu. *Mod. Urban Res.* **2021**, *10*, 20–27.
35. Carmelino, G.; Hanazato, T. The built environment of Japanese shopping streets as visual information on pedestrian vibrancy. *Front. Archit. Res.* **2019**, *8*, 261–273. [CrossRef]
36. Li, Y.Q.; Yabuki, N.; Fukuda, T. Exploring the association between street built environment and street vitality using deep learning methods. *Sustain. Cities Soc.* **2022**, *79*, 103656. [CrossRef]
37. Warnaby, G. Look up! Retailing, historic architecture and city centre distinctiveness. *Cities* **2009**, *26*, 287–292. [CrossRef]
38. Zhang, L.M.; Zhang, R.X.; Yin, B. The impact of the built-up environment of streets on pedestrian activities in the historical area. *Alex. Eng. J.* **2021**, *60*, 285–300. [CrossRef]
39. Tong, M. Hou Urban Fabric Can Help Sustain the Vitality of Cities. *Urban Plan. Forum* **2014**, 85–96.

40. Yang, X. Research on the Interface of the Space of Lanes and Alleys in Hanzheng Jie Area. Master's Thesis, Huazhong University of Science and Technology, Wuhan, China, 2007.
41. Du, X. Preservation and Renewal Research of the Traditional Streets and Lanes in Old city. Master's Thesis, Nanjing Forestry University, Nanjing, China, 2010.
42. Samadi, Z.; Yunus, R.M. Physical and Spiritual Attributes of Urban Heritage Street's Revitalization. *Procedia Soc. Behav. Sci.* **2012**, *36*, 342–349. [CrossRef]
43. Sun, Q. Study on the Interface of the Traditional Streets in Fenghuang Ancient City. Master's Thesis, Huazhong Agricultural University, Wuhan, China, 2014.
44. Bai, Y.J. Analysis of the Street Space for Rongxiang by the Space Syntax. Master's Thesis, Jiangnan University, Wuxi, China, 2009.
45. Pan, L.S. Research on the Interface of Lanes and Alleys of the Old City Residential Community: Xiagang Area as An Example. Master's Thesis, Huaqiao University, Quanzhou, China, 2014.
46. Luo, F. Research on the Street Space of Historical Blocks Based on the Interaction Behavior—Take Yingping Block in Xiamen as an Example. Master's Thesis, Xiamen University, Xiamen, China, 2017.
47. Mehanna, E.H. Urban renewal for traditional commercial streets at the historical centers of cities. *AEJ Alex. Eng. J.* **2019**, *58*, 1127–1143. [CrossRef]
48. Wuhan Natural Resources and Planning Bureau. System Planning of Historical and Cultural Style Area in Wuhan Main City. 2013. Available online: http://zrzyhgh.wuhan.gov.cn/zwgk_18/fdzdgk/ghjh/zzqgh/202001/t20200107_602819.shtml (accessed on 6 January 2023).
49. Mehta, V. Lively Streets: Determining Environmental Characteristics to Support Social Behavior. *J. Plan. Educ. Res.* **2007**, *27*, 165–187. [CrossRef]
50. Long, Y.; Zhou, Y. Quantitative Evaluation on Street Vibrancy and Its Impact Factors: A Case Study of Chengdu. *New Archit.* **2016**, *1*, 52–57.
51. Wu, W.; Ma, Z.; Guo, J.; Niu, X.; Zhao, K. Evaluating the Effects of Built Environment on Street Vitality at the City Level: An Empirical Research Based on Spatial Panel Durbin Model. *Int. J. Environ. Res. Public Health* **2022**, *19*, 1664. [CrossRef] [PubMed]
52. Ortegon-Sanchez, A.; Vaughan, L.; Christie, N.; McEachan, R.R.C. Shaping Pathways to Child Health: A Systematic Review of Street-Scale Interventions in City Streets. *Int. J. Environ. Res. Public Health* **2022**, *19*, 5227. [CrossRef]
53. Wangbao, L. Spatial impact of the built environment on street vitality: A case study of the Tianhe District, Guangzhou. *Front. Environ. Sci.* **2022**, *10*, 966562. [CrossRef]
54. Sarmiento, O.L.; Useche, A.F.; Rodriguez, D.A.; Dronova, I.; Guaje, O.; Montes, F.; Stankov, I.; Alejandra Wilches, M.; Bilal, U.; Wang, X.; et al. Built environment profiles for Latin American urban settings: The SALURBAL study. *PLoS ONE* **2021**, *16*, e0257528. [CrossRef]
55. Niu, X.Y.; Wu, W.S. Influence of Built Environment on Street Vitality and Its Spatiotemporal Characteristics Based on LBS Positioning Data. *Urban Plan. Int.* **2019**, *34*, 28–37. [CrossRef]
56. Adu-Brimpong, J.; Coffey, N.; Ayers, C.; Berrigan, D.; Yingling, L.R.; Thomas, S.; Mitchell, V.; Ahuja, C.; Rivers, J.; Hartz, J.; et al. Optimizing Scoring and Sampling Methods for Assessing Built Neighborhood Environment Quality in Residential Areas. *Int. J. Environ. Res. Public Health* **2017**, *14*, 273. [CrossRef]
57. Huang, B.; Wang, J. Big spatial data for urban and environmental sustainability. *Geo-Spat. Inf. Sci.* **2020**, *23*, 16. [CrossRef]
58. Mellander, C.; Lobo, J.; Stolarick, K.; Matheson, Z. Night-Time Light Data: A Good Proxy Measure for Economic Activity? *PLoS ONE* **2017**, *10*, e0139779. [CrossRef]
59. Harvey, L. Defining and Measuring Employability. *Qual. High. Educ.* **2001**, *7*, 97–109. [CrossRef]
60. Gehl, J. *Life between Buildings: Using Public Space*; Van Nostrand Reinhold: Washington, DC, USA, 1987.
61. Montgomery, J. Editorial Urban Vitality and the Culture of Cities. *Plan. Pract. Res.* **1995**, *10*, 101–110. [CrossRef]
62. Gehl, J.; Kaefer, L.J.; Reigstad, S. Close encounters with buildings. *Urban Design Int.* **2006**, *11*, 29–47. [CrossRef]
63. Marcus, L. Spatial Capital. *J. Space Syntax* **2010**, *1*, 30–40.
64. Braun, L.M.; Malizia, E. Downtown vibrancy influences public health and safety outcomes in urban counties. *J. Transp. Health* **2015**, *2*, 540–548. [CrossRef]
65. Zeng, C.; Song, Y.; He, Q.S.; Shen, F.X. Spatially explicit assessment on urban vitality: Case studies in Chicago and Wuhan. *Sustain. Cities Soc.* **2018**, *40*, 296–306. [CrossRef]
66. Yue, H.; Zhu, X.Y. Exploring the Relationship between Urban Vitality and Street Centrality Based on Social Network Review Data in Wuhan, China. *Sustainability* **2019**, *11*, 4356. [CrossRef]
67. Zang, P.; Lu, Y.; Ma, J.; Xie, B.; Wang, R.; Liu, Y. Disentangling residential self-selection from impacts of built environment characteristics on travel behaviors for older adults. *Soc. Sci. Med.* **2019**, *238*, 112515. [CrossRef] [PubMed]
68. Zhang, A.Q.; Li, W.F.; Wu, J.Y.; Lin, J.; Xia, C. How can the urban landscape affect urban vitality at the street block level? *A case study of 15 metropolises in China. Environ. Plan. B Plan. Des.* **2020**, *48*, 1245–1262.
69. Jizhong, S.; Minge, Y.; Guan, L.; Ye, L.; Dan, L.; Yanran, T.; Yuxin, Z.; Qize, S. Urban Sub-Center Design Framework Based on the Walkability Evaluation Method: Taking Coomera Town Sub-Center as an Example. *Sustainability* **2021**, *13*, 6259.
70. Jiang, D.F. *The Theory of City Form Vitality*; Southeast University Press: Nanjing, China, 2007; p. 286.
71. Liu, S.; Nai, S.Q. Measurement of Urban Public Space Vitality Based on Big Data. *Landsc. Archit.* **2019**, *26*, 24–28. [CrossRef]

72. Niu, T.; Qing, L.B.; Han, L.M.; Long, Y.; Hou, J.X.; Li, L.D.; Tang, W.; Teng, Q.Z. Small public space vitality analysis and evaluation based on human trajectory modeling using video data. *Build. Environ.* **2022**, *225*, 109563. [CrossRef]
73. Wu, Z.Q.; Ye, Z.N. Research on Urban Spatial Structure Based on Baidu Heat Map: A Case Study on the Central City of Shanghai. *City Plan. Rev.* **2016**, *40*, 33–40.
74. Wang, C.L. Spatial-temporal Characteristics of Urban Population Aggregation Based on Baidu Heat Map in Central Areas of Wuhan City. *J. Hum. Settl. West China* **2018**, *33*, 52–56. [CrossRef]
75. Feng, D.Y.; Tu, L.L.; Sun, Z.W. Research on Population Spatiotemporal Aggregation Characteristics of a Small City: A Case Study on Shehong County Based on Baidu Heat Maps. *Sustainability* **2019**, *11*, 6276. [CrossRef]
76. Min, Z.R.; Ding, F. Analysis of Temporal and Spatial Distribution Characteristics of Street Vitality Based on Baidu Thermal Diagram:the Case of the Historical City of Nanchang City, Jiangxi Province. *Urban Dev. Stud.* **2020**, *27*, 31–36.
77. Zhou, Y.J. Spatial-temporal Dynamics of Population Aggregation during the Spring Festival based on Baidu Heat Map in Central Area of Chengdu City, China. *Mod. Appl. Sci.* **2020**, *14*, p44. [CrossRef]
78. Xu, H.; Li, B.H. Urbanization in China: A Study From the Perspective of Conceptual History. *City Plan. Rev.* **2019**, *43*, 22–28.
79. *Wuhan: Overview of National Historical and Cultural Cities*; Wuhan Publishing House: Wuhan, China, 2014; p. 282.
80. Wuhan Municipal Bureau of Housing, ICOMOS-WRCSBH. *An Overview of National Historical and Cultural City in Wuhan*; Wuhan Publishing House: Wuhan, China, 2018.
81. Silverman, B.W. Density estimation for statistics and data analysis. *Monogr. Stat. Appl. Probab.* **1986**.
82. Xu, S. Temporal and Spatial Characteristics of the Change of Cultivated Land Resources in the Black Soil Region of Heilongjiang Province (China). *Sustainability* **2018**, *11*, 38. [CrossRef]
83. Murray, R. Remarks on Some Nonparametric Estimates of a Density Function. *Ann. Math. Stat.* **1956**, *27*, 832–837.
84. Emanuel, P. On Estimation of a Probability Density Function and Mode. *Ann. Math. Stat.* **1962**, *33*, 1065–1076.
85. Shi, Y.M.; Cai, Q.; Shi, L.; Lu, D.F. Study on Green Looking Ratio of Shangxiahang Historic District in Fuzhou City. *Trop. Agric. Eng.* **2019**, *43*, 160–163.
86. Jacobs, A.B. *Great Streets*; The MIT Press: Cambridge, MA, USA, 1993.
87. Fry, R.E. *Vision and Design*; Dover Publications: Miniola, NY, USA, 1998.
88. Harvey, C.W. Measuring Streetscape Design for Livability Using Spatial Data and Methods. *Diss. Gradworks* **2014**.
89. Hedman, R. *Fundamentals of Urban Design*; American Planning Association: Washington, DC, USA, 1985.
90. Xu, X.W.; Xu, Y.H.; Xia, Q.; Tang, Y. The Mathematical Analysis of Spatial Principles of Streetscape in Historical Areas, A Case Study of Nottingham, UK. *Archit. J.* **2021**, *18*, 84–90. [CrossRef]
91. Yu, Y.; Nes, A.V. Quantitative tools in urban morphology: Combining space syntax, spacematrix and mixed-use index in a GIS framework. *Urban Morphol.* **2014**, *18*, 97–118.
92. Fang, Z.G.; He, L.J.; Zhang, D.Y. Measurement of Street Space Amenity and Identification of Influencing Factors in Shanghai Based on Multi-source Data. *New Archit.* **2021**, *12*, 142–147.
93. Tiesdell, S.; Oc, T.; Heath, T. *Revitalizing Historic Urban Quarters*; Architectural Press: New York, NY, USA, 1996.