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# Spatial Form Cognition of Historical Streets in Hongcun Village through a Space Syntax Approach

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**Abstract.** This study explores the relationship between spatial form and inner vitality, and discusses the impact of three morphological variables on spatial vitality and spatial cognition of residents and tourists. The purpose of this study is to investigate the internal relationship between spatial morphological characteristics, spatial vitality, and people's spatial cognition. In China, the over-commercialization of tourism has led to changes in the historical spaces of many traditional villages, and the problems of homogenization and commercialization have become increasingly obvious. To address this, this study will use a combination of space syntax and cognitive imagery to understand the historical street space. Space syntax theory quantifies the division of spatial scales and studies the relationship between spatial form and human behavior. The concept of cognitive imagery reproduces the user's spatial cognition through imagery, and explores the relationship between spatial elements and cognition. Combining these two theories can provide a better understanding of the laws of spatial form and behavioral cognition. This study investigates the historical streets in Hongcun village, a World Cultural Heritage Site located in China. The research sample consists of 51 tourists who have been traveled to Hongcun, and 49 villagers who still reside in the study area. Spatial analysis was performed using DepthmapX software. The results show that there is a positive correlation between the degree of integration, intelligibility, and optionality of traditional street space, the vitality of the space, and people's cognition. However, residents and tourists have different perceptions of the same traditional street space due to their different identities and awareness. When formulating protection and utilization plans, the needs of residents and tourists should be considered comprehensively to achieve a reasonable allocation of village spaces. The study's results provide a reference for policymakers to better understand the relationship between the spatial form and inner vitality of traditional villages.

## 1. Introduction
Spatial form cognition of historical streets refers to the cognitive processes involved in perceiving, understanding, and interacting with the physical layout and design of historical streets. It involves how individuals mentally represent and navigate through these streets, how they interpret the spatial

relationships between various elements, and how they experience and respond to the unique characteristics of the built environment. In Southern Anhui, China, there are two ancient villages that have been inscribed on the UNESCO World Cultural Heritage List, namely Xidi and Hongcun Villages, since the year 2000. Both villages are renowned for their well-preserved traditional architecture, urban layout, and cultural heritage. The buildings in these villages exhibit exquisite craftsmanship, with intricate carvings and decorative elements that showcase the rich cultural history of the region. This study will take Hongcun Village, a UNESCO World Cultural Heritage site in China, selected as a case study example. The author conducted research on the relationship among traditional street space, spatial vitality, and spatial cognition in Hongcun Village.

### 1.1. Research Aim

In this context, as a World Heritage Site, Hongcun attracts numerous visitors each year, both domestic and international, who come to experience the unique charm, architectural beauty, and cultural heritage of these ancient villages. However, with the acceleration of urbanization and the development of tourism, Hongchun Villages is facing new challenges. As an important representative of ancient villages in southern Anhui, and the most complete and culturally authentic representative of ancient villages in Ming and Qing Dynasties in China, Hongcun's street plan, architecture, comprehensive water systems, traditional culture and folk customs are unique surviving examples [1]. In this context, as World Heritage Sites, Hongcun attracts numerous visitors each year, both domestic and international, who come to experience the unique charm, architectural beauty, and cultural heritage of these ancient villages. However, with the acceleration of urbanization and the development of tourism, Hongchun Villages is facing new challenges.

Nonetheless, the process of incorporating tourist service facilities into traditional spaces can introduce a dual challenge of simultaneously deconstructing and reconstructing the village's traditional spatial structure. On one hand, the arrival of tourists and the establishment of these facilities may bring about modifications to the village's physical layout and organization. The need to construct new buildings or adapt existing structures to accommodate tourist amenities can potentially disturb the village's traditional spatial arrangement. Consequently, this may result in the erosion of its historical fabric and the disruption of the harmonious alignment of buildings and spaces.

In order to explore the relationship between traditional village spatial form, spatial vitality and spatial intention from the perspective of integrity and subjective cognition, this research adopts a space syntax-based analysis method to analyze typical street spaces. The aim of the research is to offer valuable insights to governmental bodies, developers, urban planners, and managers. By enhancing their comprehension of how spatial layout, vitality, and cognitive behavior intertwine, this research serves as a foundation for making informed decisions.. These decisions can be instrumental in optimizing the spatial structure of traditional villages and establishing a sustainable development model.

### 1.2. Research Background and Context

Langston et al. pointed out that tourism helps to publicize the cultural value of heritage [2], Xiaohua, Xinqiu et al. also pointed out that the moderate development of tourism can help revitalize the space of traditional villages, and it is one of the common ways to protect and revitalize traditional villages [3, 4]. Precisely because the traditional villages themselves have extremely high historical and cultural value and tourism development value, development of tourism also has many benefits in promoting economic development, such as the protection and activation of material and intangible heritage. Therefore, many traditional villages in China use their own advantages to develop tourism. However, Andereck et al. found that the tourism industry contributes to garbage pollution problems [5]. Song et al. pointed out that due to the uneven distribution of tourism resources and weak path connections in traditional villages, it is easy to lead to unbalanced village development, which is not conducive to the cognitive experience of tourists and residents [6]. Ruyi et al. pointed out that the "functional expansion" produced by tourism will have an impact on residents' life, culture and ecological

environment [7]. COVID-19, which began in 2020, has had a significant impact on traditional villages that heavily rely on tourism as their primary economic source. The pandemic has exposed the economic vulnerability resulting from an overreliance on tourism.

As one of the earliest traditional villages in China to develop the tourism industry, Hongcun also has been seriously affected. Since 1986, Hongcun village has embarked on formal tourism development. As a complex World Cultural Heritage site since 2000, Hongcun's tourism and cultural status has risen to a higher level. After more than 30 years of development, the main community who use the space have changed from residents to tourists. Despite undergoing several rounds of protection and renewal, Hongcun village still faces challenges that need to be addressed. Some of these issues include the over-commercialization of tourism, uneven development within the village, commercial reconstruction altering the original functions of buildings, and the presence of non-traditional general layouts and landscape designs.

Traditional research methods are difficult to accurately describe complex spaces such as traditional villages and the impact of tourism on the original space, but space syntax can accurately describe the characteristics of space and the relationship between space and human behavior. Space syntax is a systematic theory about architectural and urban space analysis. It studies the relationship between spatial form and human behaviors, and then it will systematically explain complex and diverse social phenomena [8].

Cognitive intentions are mainly analyzed through mental maps. The mental map is a cognitive sketch based on the intentional feelings from memory, based on the layman's experience of the environment, and has "primitive" and "intuitive". Spatial features and connections that are important and obvious to the experiencer can be identified. The mental map is mainly obtained in two ways: (1) After investigating residents or tourists' spatial psychological feelings and impressions of a certain area, the researchers analyze the obtained information and translate it into a map. (2) Directly draw a spatial perception sketch of a certain area by residents or tourists themselves [9].

Although both space syntax and cognitive intention have been widely used in urban planning and other fields, there are still some limitations and controversies when used alone. The combination of the two methods can play a complementary effect. For example, Xiao Feng et al. used the cognitive map method and space syntax to study some areas of the historical urban area of Hengyang City, and found a feasible point where the two theories complement each other [10].

Chen Chi et al. used space syntax and cognitive image theory to interpret the relationship between spatial morphological characteristics and spatial cognition in Qinchuan Village [11]. Therefore, this article attempts to take Hongcun Village, a World Cultural Heritage Site, as the research object. It combines space syntax and cognitive intention, explores the relationship between spatial form and cognition, and provides a basis for optimizing the spatial layout of traditional villages and building a sustainable development model.

## 2. Literature Review

### 2.1. Spatial Morphology Cognition

Theories of spatial morphology cognition explore how individuals perceive, understand, and interact with spatial environments. Relevant theories mainly include Gestalt Theory, Environmental Cognition, Mental Maps, Spatial Syntax, etc. These theories aim to uncover the cognitive processes and mechanisms underlying spatial perception and cognition.

*2.1.1. Gestalt Theory.* Kevin Lynch used Gestalt theory to study human perception and understanding of the historical environment, proposed the concept of "image", and discussed the readability and image of the urban environment [12]. Birer, Schroeder et al. used Gestalt theory to discuss people's perception of public space in different regions, and proposed related design principles and methods [13, 14]. Gestalt theory proposes that humans perceive and interpret visual information as organized wholes rather than individual parts. It emphasizes the importance of holistic perception and how elements in a spatial environment are perceived as meaningful patterns.

*2.1.2. Environmental Cognition.* William H. et al. conducted research on environmental cognition from the aspects of spatial perception and the influence of physical environment on human behavior [15]. Kaplan, S. discussed how individuals' cognitive evaluation and emotional responses to the environment affect their preferences and behaviors [16]. Based on environmental cognition, Eben Saleh et al. evaluated the aesthetic quality and value of Al-Alkhalaf rural landscape in Asir, and pointed out that when looking for a new way of relationship between man and nature, we should start from three aspects: aesthetic value, aesthetic quality and visual quality [17]. This theory explores how individuals mentally construct internal representations (cognitive maps) of the physical world around them.

*2.1.3. Mental Maps.* Peter Gould et al. gave a comprehensive overview of Mental maps research, and discussed the cognitive processes involved in the creation of Mental maps, influencing factors, and the relationship between Mental maps and behavior [18]. However, there are also shortcomings in Mental Maps. Paül et al. compared the results obtained by cognitive maps with those obtained by measuring heart rate variation (HRV), and found that there was a large difference between the results obtained by the two methods [19]. These maps help individuals navigate through their environment, make wayfinding decisions, and understand spatial relationships between different places.

*2.1.4. Spatial Syntax.* In order to supplement the lack of subjective cognition, Hillier used space syntax to explore the artificial nature of spatial forms in architecture, as well as the contingency and inevitability thereof, providing a valuable reference for understanding the generation of spatial forms in architecture [20]. However, space syntax also has certain limitations. Yamu et al. pointed out that as an auxiliary decision-making and technical analysis method, space syntax has certain limitations in the study of the relationship between space and people. If it is difficult to discover complex spatial characteristics and details such as architectural style and cultural characteristics, and lack of consideration of context and emotion, it should be used in combination with other methods to obtain a more accurate and comprehensive understanding [21]. These studies provide important perspectives for our in-depth understanding of the cognition and application of spatial form. On the basis of these researchs, this study will combine spatial cognitive intention and space syntax to comprehensively analyze the historical streets of Hongcun Village. It quantifies spatial properties like integration, connectivity, and visibility to understand the relationships between spaces and their impact on human movement and cognition.

## 2.2. Space Syntax

Space Syntax was formulated by Bill Hillier and Julienne Hanson with their colleagues. It is a theoretical and analytical framework used to study the relationship between spatial configuration and human behavior in the context of architecture, urban planning and design. It provides a systematic approach to understanding how the arrangement and connectivity of spaces influence movement patterns, social interactions, and spatial experiences. Space syntax analyzes the spatial layout and connectivity of streets, buildings, and open spaces within a given environment. The analysis involves the use of graph theory and mathematical models to quantify and represent the spatial relationships between different elements in a network. The findings from space syntax analysis can inform design and planning decisions, guiding the layout of spaces, the positioning of landmarks, and the connectivity of networks [22-24]. After the 1980s, space syntax has been rapidly used and developed in both theory and practice. Relevant research in the field of urban and rural planning mainly focuses on three aspects: spatial form research, public space analysis, and historical space protection.

*2.2.1. Spatial Form Research.* Fu Lieshan et al. used space syntax to analyze the urban spatial structure of the sixth edition of the master plan of Zhuzhou City, and analyzed the causes and internal mechanisms of the morphological changes from the basic and social levels [25]. Zhan Q et al. analyzed the spatial pattern of large stores based on space syntax theory, and explored the correlation between changes in syntactic accessibility and the spatial pattern of large stores [26]. Giannopoulou et al. verified and explained the functional structure of the city by using space syntax to identify the core form of the city, the main and most congested road axes, and the allocation of central land use [27].

Spatial form research plays a crucial role in enhancing our understanding of how spatial layouts impact human experiences and interactions with the built environment.

*2.2.2. Common Space Analysis.* Monokrousou et al. used space syntax, GIS database, etc. to explain and predict pedestrian movement in public space, and proposed a method framework to overcome these limitations [28]. Ingy et al. analyzed the outdoor spaces and routes of a university campus in the Delta region (Egypt) and students' perception of outdoor spaces based on space syntax. The importance of providing appropriate places, paths, and routes for social interaction on campus that meet the needs of students is noted. And based on the space syntax theory, an optimization strategy is proposed [29]. Wiem et al. used space syntax to analyze the city of Kuikul, an Algerian Roman city located in Sétif, and discussed the spatial structure of the city and how public space is used for movement, activities and interactions between people [30]. It is a quantitative approach that analyzes the patterns of connectivity and integration within a space to uncover the relationships between different elements and how they influence human movement and behavior.

*2.2.3. Historical Space Protection.* Wang Chengfang et al. based on the theory of space syntax and cognitive imagery, explained the internal relationship between the spatial morphological characteristics of Qinchuan Village and spatial cognition, and proposed specific optimization strategies [31]. Taking Xiaozhou Village in Guangzhou as an example, Tao Wei et al. discussed how the spatial form of the village affects users' spatial cognition, and pointed out that some landmark elements played a more significant role in spatial cognition [32].

### 2.3. The Spatial Cognition of Historic Streets

Historical streets usually refer to those streets with a long history and rich cultural heritage. They have important cultural, scientific, educational and aesthetic values, and are also one of the most attractive spaces in the city. Research on the spatial cognition of historic streets aims to understand how individuals perceive, navigate, and interact with the physical environment of historical street settings and sustainable development of historical streets, and then play a guiding role in the space optimization. Relevant research mainly focuses on perception and sensory experience, spatial orientation and wayfinding, social interaction and behavior, cultural and historical context, etc. Spatial cognition research often employs techniques such as cognitive mapping, eye-tracking studies, and behavioral observations to gain insights into how people perceive and interact with historic streets.

*2.3.1. Perception and Sensory Experience.* Scheer et al. pointed out that historical streets help to enhance the city's sense of place and identity, and the street and plot patterns should be protected [33]. Zhu et al. studied the relationship between tourists' landscape evaluation and place attachment in historical districts, and pointed out that tourists' visual preference, authenticity evaluation and destination image have a significant positive impact on place attachment [34]. Overall, perception and sensory experience significantly shape how individuals interact with the world, enriching their understanding of their surroundings and contributing to their overall sensory well-being.

*2.3.2. Spatial Orientation and Wayfinding.* Srinurak et al. took the exit point and accessibility of the urban network as the research object, combined space syntax with GIS, analyzed the urban form and street accessibility of historical areas in Chiang Mai, and provided route planning suggestions for safe evacuation in historical areas [35]. Wang et al. used multi-source data to analyze the ancient town of Fengjing in Shanghai, and pointed out that clear tourist space boundaries, rich folk activities, and continuous tourist routes can help tourists form a more systematic spatial cognition [36].

*2.3.3. Social Interaction and Behavior.* Xu et al. used the micro-scale built environment (MiBE) variable system to capture the characteristics of historical streets, and recorded the walking and stopping behavior of 109 tourists in Wudaoying Hutong, and found the influence of cultural related factors on tourists' walking behavior [37]. Mundher et al. used photo surveys, Likert scales, and heat map analysis techniques to assess the visual quality of historical streetscapes and identify elements that might affect them. Finally, they pointed out that modern building facades can have a negative impact. However, unique cultural and religious buildings, green plants can have a positive impact [38].

*2.3.4. Cultural and Historical Context.* Ja'afar et al. focused on the vegetation, street furniture, water features and paving materials in three traditional streets in Malacca, emphasizing the important role of these landscape features in enhancing the aesthetics, culture and function of traditional streets in Malaysia [39]. Zhang et al. used Internet data such as Tencent location big data to study some historical and cultural blocks in China, and established an index system for the protection and development of historical and cultural blocks. They pointed out that historic blocks have profound historical and cultural heritage and life form characteristics, and they should be accurately positioned to achieve healthy and sustainable development of protection and utilization of the area [40].

Existing studies have analyzed the spatial cognition of historical streets from different angles, but none of them can fully reflect the relationship between the three aspects of spatial structure, spatial social nature, and spatial image cognition. Based on these, this research combines space syntax and cognitive intention to explore the cognitive rules and mechanisms of tourists and residents in the historical streets of Hongcun Village, and reveal how people perceive and participate in these unique street environments. And provide a basis for optimizing the spatial layout of traditional villages and building a sustainable development model.

## 3. Research Methods

This research was conducted in two phases. The first stage is qualitative research, the purpose is to describe and analyze the unique street environment and people's behavior perception in Hongcun Village. The author and the team conducted three preliminary investigations in Hongcun Village on April 15, May 20, and June 17, 2023. The main purpose is to:

(1) Understand the distribution and characteristics of streets and alleys in Hongcun, and establish a basic understanding of the area.

(2) Obtain a heat map through Baidu Maps to understand the approximate distribution of the crowd.

(3) Observe the behavior trajectory of residents and tourists, and understand the characteristics of most people staying in the photo space in the streets and alleys.

(4) In the form of questionnaires and interviews, cognitive surveys were conducted among local residents and tourists to obtain samples of mental maps. A total of 100 valid samples were collected, including 51 tourists and 49 local residents. Incorporate the data of spatial cognition elements of different groups into the statistical analysis of space syntax, and compare and explore the internal relationship among group identity, spatial form, spatial cognition, and environmental behavior.

The second stage is quantitative research. This paper mainly uses the axis method in space syntax and Depthmap software to analyze the spatial form cognition of Hongcun Village. The following three morphological variables are mainly used:

(1) Integration value. Designed to analyze the degree of agglomeration or dispersion of a space relative to other spaces in the system.

(2) Optionality. It aims to investigate the number of times a space appears on the shortest topological path, indicating the potential of a space to attract crossing traffic.

(3) Intelligibility. It aims to analyze the ability to perceive the overall space from the connectivity of the local space.

## 4. Case Study

*4.1. Overview of Historical Streets in Hongcun Village*

Hongcun Village is located in the northeast of Yi County, Huangshan City, Anhui Province, China. It was built in the first year of Shaoxing in the Southern Song Dynasty (AD 1131), and has a history of 892 years. As a world cultural heritage site, Hongcun Village is an important representative of traditional villages in Huizhou, and it is also a clan-style settlement where people live together. The construction of the village is influenced by traditional Chinese Fengshui theory and Cheng-Zhu Neo-Confucianism, forming a unique cow-shaped village [41]. It takes the mountain as the head, the tree as the corner, the building complex as the body, the bridge as the corner, the moon marsh as the stomach,

and the artificial water well as the cow's intestines (Figure 1). Until now, Hongcun Village still preserved the overall setting and sphere of the village, the traditional street structure and more than 130 traditional residential buildings left over from the Ming and Qing Dynasties.
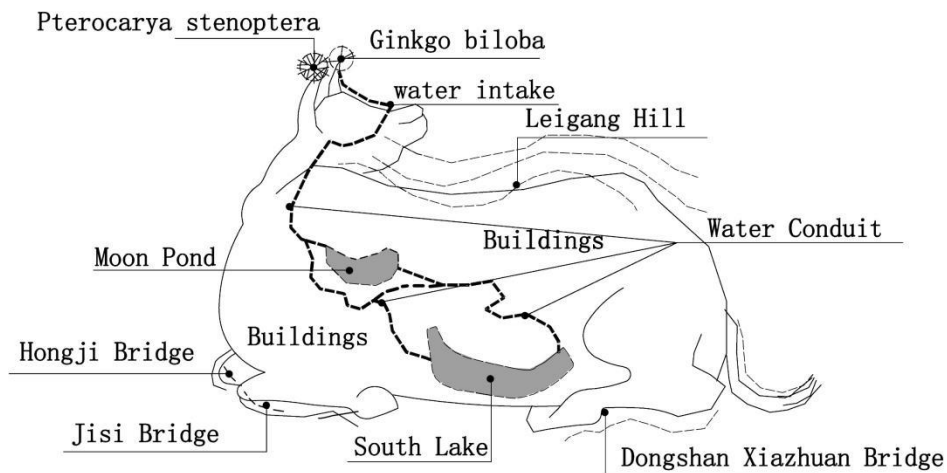


**Figure 1.** Intention Analysis Diagram of Hongcun Village Bull Shape.

The development of material space in Hongcun Village roughly went through five stages: the settlement stage (AD 1131-1276), the development stage (AD 1276-1607), the peak stage (AD 1607-1855), the decline stage (AD 1855-1976), and the re-development stage (AD 1976-present) [42]. From the initial four residences on Leigang Hill, Hongcun Village gradually developed to a village centered on Moon Pond and Ancestral Hall of Wang Family, and then to the construction of South Lake and South Lake Academy in its heyday, Hongcun gradually formed a three-level street system. The first-level streets, such as Hongcun Street, Back Street, Hubin North Road, etc., are mainly 2.3m~3.5m wide, and the space is relatively open. The second-level streets, such as Chahang alley and Shangshuizhen alley, are mainly in the width of 1.4m~2.2m. They are the streets with the most abundant spatial changes and the most distinctive features in the village. Most of the third-level streets have no names, and the width of the streets is mainly 0.5m~0.9m, which is very narrow and can only meet the traffic demand. In terms of street form, the roads in the entire village form a ring-like centripetal structure with the main temple and the Moon Pond as the center. The streets near the ancestral hall buildings and the Moon Pond on the outer ring road are relatively regular in shape. The vertical and horizontal streets and alleys are perpendicular to each other. The streets and alleys in other areas are relatively free. According to the spatial structure of Hongcun Village and the results of field research, the author uses the axis to represent the skeleton of the streets and alleys of Hongcun Village, forming a spatial texture map of the main streets and alleys of Hongcun Village (Figure 2).

**Figure 2.** Spatial Texture Map of Historical l Streets in Hongcun Village.

*4.2. Data Acquisition：The Spatial Syntax Analysis of Historical Streets in Hongcun Village*
Based on the spatial texture map of the main streets and alleys of Hongcun and the results of field surveys, the author draws the traditional streets of Hongcun into a spatial axis diagram. Then save the axis diagram as a *.dxf file and import it into the space syntax analysis software DepthmapX to generate a diagram of syntax variables and analyze the degree of spatial integration, intelligibility and selectability.

*4.2.1. Spatial Integration Analysis.* The degree of integration indicates the relative accessibility of spatial nodes. The higher the degree of integration, the stronger the accessibility of the space in the region. Red is the maximum value and blue is the minimum value [43]. From the axis diagram of Hongcun's overall integration degree generated by DepthmapX software (Figure 3), it can be found that the core areas with a high degree of integration are mainly distributed around South Lake (Nanhu) and Moon Pond (Yuezhao). Hubin North Sidewalk and Hongcun Street having the highest degree of integration, then followed by Front Street and Back Street. The average global integration degree of Hongcun Village is 0.63, and the axes greater than 0.63 account for 55.2% of the total number of axes. The results show that the streets in Hongcun Village are well connected, the overall integration degree is relatively higher, and the overall accessibility is better. In the local integration map, it can be found that the streets in the middle and south of the village are highly integrated. On the one hand, it is because the ancestral hall and the residence of the big family surnamed Wang occupy the best location in the center of the village. On the other hand, it is because this part of the space has been developed in the process of tourism development.

The closer to the village edge, the lower the global integration degree. It shows that the connectivity and accessibility of streets and alleys in marginal areas are poor. And this is in line with the typical characteristics of clan-style settlements like Hongcun Village, which attaches great importance to the communication within the clan. There are very few nodes connected to the outside

world, reflecting strong defensiveness and repulsion. But in terms of the actual needs of residents, the low degree of integration at the edge of the village is not suitable for people's life today.
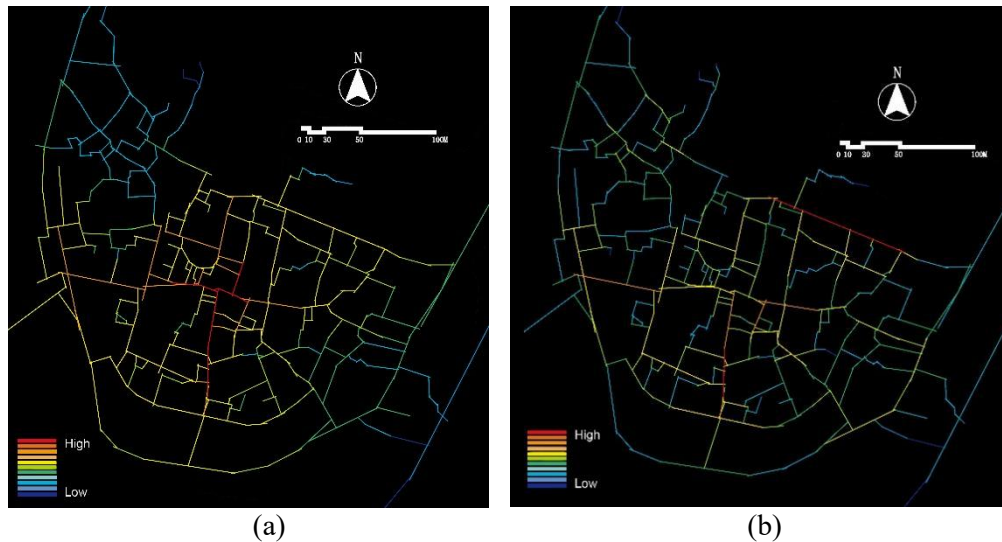


**Figure 3.** Analysis on spatial integration degree of streets in Hongcun Village:(a) Global Integration, (b) Local Integration.

*4.2.2. Spatial selectivity analysis.* The degree of selectivity can reflect the number of times the shortest path between any two spaces in the village is selected. The higher the degree of selectivity, the stronger the attraction of the space node. The authors used DepthmaX software to generate angular selectivity and topological selectivity axis plots (Fig. 4). It was found that the three streets with a high degree of selectivity were mainly Hongcun Street, front street, and back street, which highly overlapped with the areas with a high degree of spatial integration. Judging from the actual research, there are a large number of public buildings and space nodes on both sides of Hongcun Street, Front Street, and Back Street, which were the core space of production and life in Hongcun Village. It has both the function of passage and the potential of being a destination.
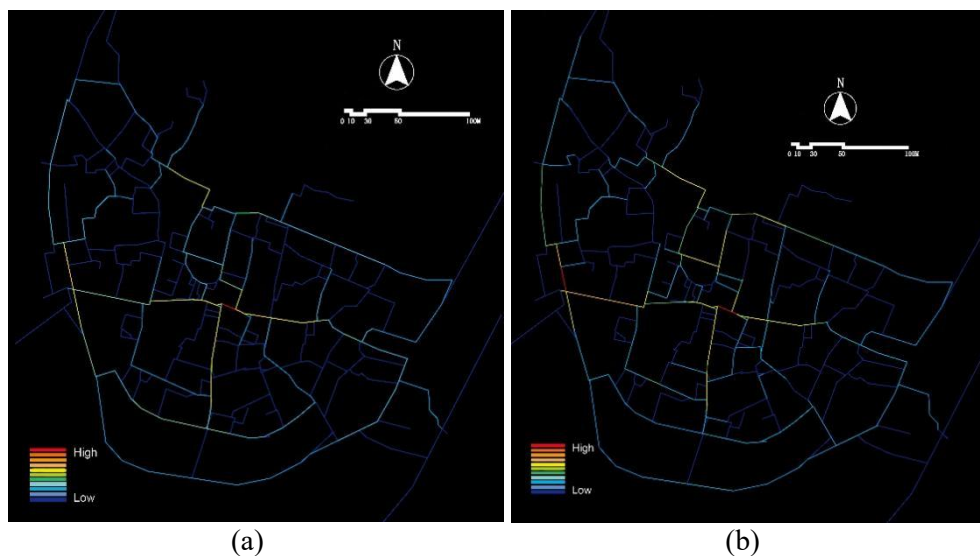


**Figure 4.** Analysis on spatial integration degree of streets in Hongcun Village: (a) Angular selectivity, (b) topological selectivity.

*4.2.3. Spatial intelligibility analysis.* Intelligibility reflects whether the local spatial structure can help people establish an understanding of the entire spatial system. Both connectivity and integration are high, indicating that this is a well-understood spatial system. Further, a high degree of understanding

indicates a strong consistency between the local space and the overall space. In the DepthmapX software, the author first selected two sets of data of spatial connectivity and global integration (Integration [HH]) for linear regression analysis (Figure 5(a)), and R2 was 0.151. Then select the two sets of data of spatial connectivity and local integration ([HH]R3) for regression linear analysis (Figure 5(b)), and R2 is 0.64. Then, two sets of data of global integration (Integration [HH]) and local integration (Integration [HH]R3) were selected for linear regression analysisto analyze the relationship between the local space and the overall space of Hongcun Village (Figure 5(c)), R2 is 0.413. The results show that the spatial connection value of streets and alleys in Hongcun Village is not strongly correlated with the global integration degree, but is strongly correlated with the local integration degree, and the intelligibility of the street and lane system is average. This interesting result shows that Hongcun is a large space with poor intelligibility composed of several small spaces with good intelligibility. The primary reason for this result is that the formation of Hongcun Village is mainly based on bottom-up construction by villagers, so several small spaces with better intelligibility have been formed. Secondly, tourism intervention in the later period further sorted out the road network structure in the central area on the basis of the original spatial texture, and strengthened the intelligibility of the space [44].
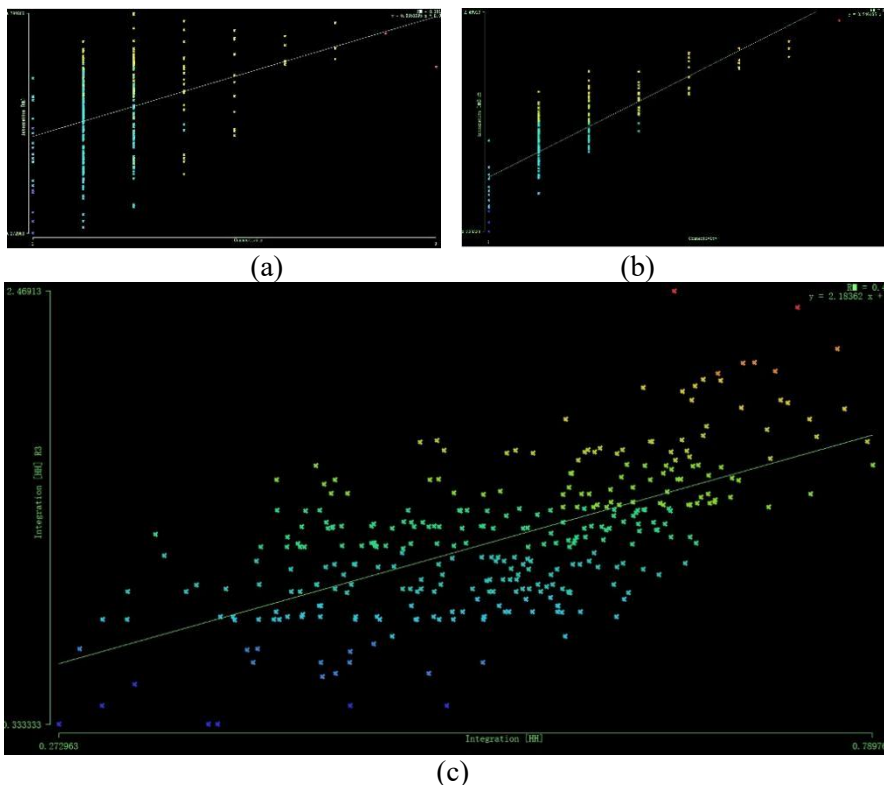


(a)                    (b)

(c)

**Figure 5.** Analysis on spatial integration degree of streets in Hongcun Village: (a) Correlation analysis between connection value and global integration degree, (b) Correlation analysis between connection value and local integration degree , (c) Correlation analysis of global integration degree and local integration degree.

*4.3. Data Acquisition: Spatial Vitality Analysis of the Historical Streets of Hongcun Village*
Judging from the distribution of the flow of people shown in the heat map of Baidu Maps, the crowds are mainly concentrated on Hongcun Road and the west side of Moon Pond on weekends and holidays (Figure 6). Take May 20, 2023 as an example. Around 8:00 in the morning, the number of tourists gradually increased, and the crowds were mainly concentrated near Hubin North Road. Around 10:00 a.m., the crowd began to concentrate on Hongcun Street and the west side of Moon Pond, and the situation basically lasted until around 6:00 p.m.. Afterwards, the crowd began to move towards the exit on the west side of the Moon Pond. Some people staying in this village are scattered on the west side of Moon Pond and the east side of Hubin North Road. On non-holidays, when tourists are less,

the back streets, Shangshuizhen, Chahang street become more vibrant areas in the village. Villagers gather here to chat, wash clothes, and bask in the sun.
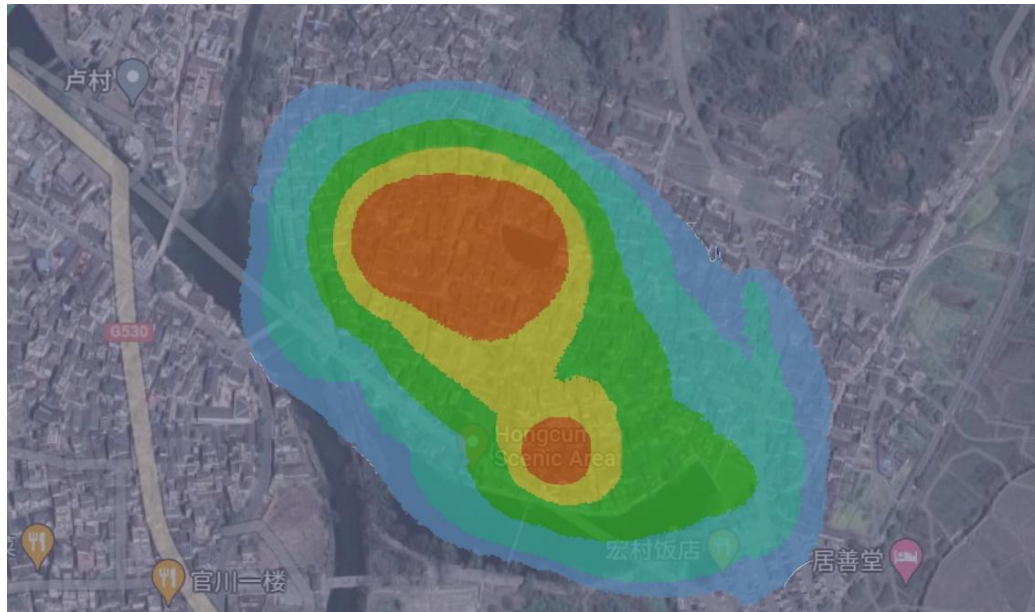


Figure 6. The main distribution of the flow of people in Hongcun Village (at 10 am on May 20, 2023).

### 4.4. Data Acquisition: Spatial Cognitive Analysis of Historical Streets in Hongcun Village

*4.4.1. Spatial cognition analysis of residents and tourists.* The space syntax theory believes that areas with a higher degree of integration have more frequency of use and flow of people, and are easier to be remembered by people [32]. In order to compare with the analysis results of space syntax, the authors analyze the spatial cognition results of residents and tourists. Based on the mental map, the author found that the three most impressive historical streets for tourists are Hongcun Street, Hubin North Road, and Front Street. The three most impressive scenic spots are South Lake, Moon Pond, and South Lake Academy. The three historical streets that residents are most impressed with are Hubin North Road, Hongcun Street and Back Street. The three most impressive scenic spots are South Lake, Moon pond, and Shuizhen street (Table 1).

**Table 1.** Hongcun Spatial Cognitive Elements Occurrence Frequency Statistical Table.

| Identity | Street Name (Frequency) | Attractions (frequency) |
|---|---|---|
| Tourists | Hongcun Street (42) Hubin North Sidewalk (21) Front Street (15) Shangshuizhen Street (10) ongtangli   Alley (10) TingqianLu Street (9) Linhu Street (7) Chahang Alley (6) Huanbi Alley (4) Middle Street (4) Others (4)Back Street (1) | South Lake (37) South Lake Academy (31) Moon Pond (29) Ancient Trees at the Entrance of the Village (14) Jingde Hall (10) Chengzhi Hall (9) Taoyuan Residence (7) Wang's Ancestral Hall (7) Shuren Hall (6) Water Town (5) Jingxiu Hall (4) Deyi Hall (4) Biyuan (4) Wang Daxie's Former Residence (3)Ancient Theater (3) Leigang Hill (0) Others (0) |
| Residents | Hubin North Sidewalk(38) Hongcun Street(22) Back Street(21)Shangshuizhen | South Lake (41) Moon Pond (32) Water Town (29) South Lake Academy (28) Ancient Trees at the Entrance of the Village |

Street(15)Linhu Street(13) Chahang Alley(11) Middle Street(7) TingqianLu Street(8) Front Street(6)Others(4) Huanbi Alley(1）Nongtangli Alley（1） | (18) Wang's Ancestral Hall (13) Chengzhi Hall (12) Jingde Hall (9) Ancient Theater (5) Taoyuan Residence (5) Others (5) Biyuan (3) Shuren Hall (3) Jingxiu Hall (3) Deyi Hall (2) Leigang Hill (2) Wang Daxie's Former Residence (1)

According to the results of the on-site follow-up investigation, there are two main routes for the flow of people, both of which pass through Hubin North Sidewalk, Hongcun Street and Front Street.

(1) South Lake→South Lake Academy→Jingde Hall→Wang Daxie's Former Residence (Zhenqi Hall) →Moon Pond→Lexu Hall→Jingxiu Hall→Chengzhi Hall→Deyi Hall→Shuren Hall→Taoyuan Residence

(2) South Lake→South Lake Academy→Water Town→Jingde Hall→Moon Pond→Wang's Ancestral Hall→Jingxiu Hall→Chengzhi Hall→Shuren Hall→Taoyuan Residence→Ancient Trees at the Entrance of the Village

*4.5. Data Inference: The relationship between spatial cognitive imagery and global integration*
Cognitive survey results show that the respondents have a high degree of awareness of local space. In the local space, residents and tourists have the highest awareness of scenic spots, followed by streets. 54% of the aborigines can fully describe the overall spatial structure of the village, 36% of the new residents can also fully perceive the overall space of the village, while only 18% of tourists can fully perceive the overall space of the village. The specific reason is that the aborigines have lived in Hongcun Village for a long time, so they have a high awareness of the spatial structure of the village. The new residents don't stay for a long time, and most of them only know the areas where they often move. For tourists, the spatial structure of Hongcun Village is complex, and the global intelligibility of the space is relatively low, so it is difficult to understand the overall spatial layout of Hongcun Village through partial space. In addition, the commercial atmosphere of the local space is too strong, the lack of participatory folk activities to connect the whole space, and the short stay time are also one of the reasons for the low understanding of the space for tourists.

The results of the cognition survey also show that the historical streets with high awareness among villagers and tourists are Hongcun Street, Hubin North Sidewalk, Front Street and Back Street. It is basically consistent with the streets which have high degree of integration, selectivity and intelligibility determined by the quantitative analysis of space syntax. This conclusion also verifies the viewpoint of space syntax theory. From the perspective of space, the scale of these historical streets is relatively appropriate. The width of the road and the height ratio (D/H) of the enclosed buildings on both sides (or one side) are both between 1/2~1/3, which can make people feel friendly. The direction of the street is strong, but the angle changes, so that people can't see the end at a glance, which can generate better attraction. In addition, the architectural style with regional characteristics and the unique performance of the landscape in the space strengthen people's recognition.

Among the four historic streets, Hongcun Street, Front Street, and Back Street are surrounded by traditional Huizhou buildings with regional characteristics. However, the facades of the buildings in the back street are not uniform enough, the commercial atmosphere is weak, the flow of people is small, and there are no unique attractions, so most tourists do not enter. The north side of Hubin North Road is Huizhou-style buildings, and the south side of the South Lake is relatively empty, so you can better appreciate the natural scenery of the South Lake and its surroundings. Regrettably, although there are many tourists, most of them don't stay in these streets for a long time. They basically just take a photo and then leave.

In terms of cognition of the street space, due to different identities, different stay time and familiarity, there are certain differences in the cognition of the space between tourists and residents.

Traditional streets with high tourist awareness are greatly affected by traffic, scenic spots and commercial atmosphere. Among them, Hongcun Street and Front Street are the busiest streets in Hongcun Village. The traditional Huizhou buildings on both sides are filled with various snacks and

small commodities, including Chinese clothing such as Han-style clothing and cheongsam, four treasures of study such as brushes and inkstones. Although the tourist awareness is high, many tourists complain that the commercial atmosphere is too strong, tourism products lack regional characteristics, and are too homogeneous compared with other regions. They suggested developing more small commodities with Hongcun characteristics, and increasing folk activities that tourists can participate in, so that tourists can truly feel the unique cultural charm of Hongcun Village. Hubin North Sidewalk is the best way to see the South Lake and take pictures in Hongcun, and it is distributed with scenic spots with high tourist awareness such as South Lake Academy and Huxin Building.

The three streets with the highest awareness among villagers are more focused on life. Among them, Hubin North Sidewalk and Hongcun Street overlap with tourists' cognition, while Back Street has obvious difference with tourists' cognition. The reason for residents who have a higher awareness of Hubin North Sidewalk is that it is close to the South Lake, has better natural scenery, and is the only way for some villagers to enter the village. The reasons why residents have a high awareness of Hehongcun Street are: (1) It is also the only way to enter the village, connecting the two core areas of Nanhu and Yuezhao. (2) Some villagers participate in commercial operations on Hongcun Street, or as local tour guides, often take tourists to visit and shop here. However, some villagers also complain that the commercial atmosphere of Hongcun Street is too strong, which weakens the regional characteristics. The traffic flow of people during holidays is too large, which has a great impact on their traffic and normal life. The Back Street located on the north side of the village is a street formed in the early stage of Hongcun's development. With the development of the village to the south, although the status of the back street has gradually weakened, the villagers still have a strong awareness of it. There are two reasons why residents have a high awareness of this historical street: (1) It is less disturbed by tourism, and residents prefer to choose activities in it; (2) Public service facilities such as village committees and elderly activity centers are distributed in the street.

*4.6. Suggestions for Historical Streets in Hongcun Village*
The purpose of studying the historical streets in traditional villages is to better protect and utilize traditional spaces and serve residents and tourists. Based on the space syntax analysis of the historical streets in Hongcun Village and the spatial cognition analysis of the residents and tourists on the historical streets of Hongcun Village, some suggestions for optimizing the space of the historical streets in traditional villages are put forward:

(1) Hongcun Village can moderately improve the connectivity of the roads in the core area, increase the complexity of the space, and set up folk activities that tourists can participate in in multiple open node spaces to extend the time for tourists to visit. This method can not only improve tourists' awareness and understanding of space, but also avoid periodic congestion in a certain space. For fringe areas with low integration and intelligibility, moderately increase the external connection, improve the convenience of residents' life and the overall integration of the village. Repair the incomplete streamlines of streets and alleys, repair the internal road surface, and increase the accessibility and safety of these spaces, and meet the daily needs of residents.

(2) Historical streets are one of the most original characteristic elements in traditional villages, but the development of tourism activities will overlap the living space originally belonging to residents and the tourist space of tourists, and even invade and destroy the original space in the village [45]. Similar problems exist in Hongcun Village at this stage. The daily flow of tourists should be reasonably controlled according to the actual space capacity, so as to avoid the impact of excessive commercialization on the daily life of residents. In addition, the living space of the aborigines should be considered reasonably, the activity of the public space should be maintained, and the disorderly penetration of tourism should be avoided to completely turn traditional villages into scenic spots. The vitality of traditional villages should not only focus on the number of tourists, but also consider the needs of the aborigines. Only by enhancing the endogenous power of traditional village protection and development can it be conducive to the sustainable development of heritage [46].

(3) Historical streets are the sequence and connection of traditional spaces, and historical streets with a high degree of integration and selection are easier to be recognized by people. The development and utilization of traditional villages should focus on protecting the street space in the original settlement, so that the new space and the old space have a similar topological relationship—Topological Isomorphism. In addition, we should focus on the development and utilization of historical streets with a high degree of integration and selection. Tourism activities should be carried out by strengthening the attraction of scenic spots in the streets, the accessibility of the streets, and the uniqueness of landmarks. Hongcun Village makes better use of the original streets as tourist routes and commercial streets in tourism development, which is worth learning for future generations.

## 5. Conclusions

Traditional villages hold immense material and cultural significance and possess distinct advantages when it comes to tourism development. Nevertheless, the journey of developing tourism within these traditional settings has often led to a series of challenges. These include the over-commercialization of tourism, disparities in village development, the degradation of village spaces, and the erosion of intrinsic vitality. Collectively, these issues exert a detrimental influence on the sustainable development prospects of traditional villages.

Researchers and traditional village managers have proposed a series of policies and measures for the protection and utilization of traditional villages. However, most of the relevant research is qualitative research, and the research content is mostly focused on the protection of traditional buildings and historic and cultural elements. There remains a significant gap in research concerning the protection and utilization of traditional villages from the perspective of spatial design and form. The relationship between spatial form and the inner vitality of the village cannot be well explained. The recent outbreak of COVID-19 has caused many traditional villages to face the problem of spatial inactivation. Due to over-reliance on tourism and single tourism activities, these villages cannot meet the needs of tourists or villagers.

In order to analyze the relationship between spatial form and inner vitality, this study combines space syntax and spatial cognitive intention, taking Hongcun Village, a world cultural heritage, as an example. In traditional villages, streets are where residents and tourists interact most. These streets are mostly enclosed by historic buildings on one or two sides and grow together with the village. Due to the long history and diverse historical elements, some of the historic streets have gradually evolved into public places integrating living, social, commercial, leisure, transportation and other functions. By analyzing the spatial integration, comprehensibility, and selectability of the historical streets in the village, the spatial vitality of the streets, and the cognition of the street space by residents and tourists, the internal connection between the three is found：

(1) From the analysis results, there is a positive correlation between the degree of integration, intelligibility and selectability of space, the vitality of space and the degree of human cognition. However, residents and tourists have different perceptions of the same street space due to their different identities. For example, although tourists do not know the Back Streets where a large number of facilities necessary for residents' daily life are located, residents have a high level of awareness of them. When formulating protection and utilization plans, the needs of residents and tourists should be considered reasonably to achieve a reasonable allocation of space.

(2) In Hongcun Village, the three historic streets which have hihg awareness of tourists and residents are also the main dynamic spaces in the village. Among them, Hongcun Street, which is more attractive to tourists, has a high degree of spatial integration and spatial selectivity, a suitable spatial scale, and strong street directionality, but there are angle changes that make it impossible to see the end at a glance. Hubin North Sidewalk is relatively empty and has better natural scenery. It can be seen that each historic street space in a traditional village has its own uniqueness, and its inherent spatial advantages should be fully utilized and strengthened to repair deficiencies. In addition, because modern people＇s needs for village space are different from those of ancient people, the overall understandability of the village should be improved to meet the needs of modern life.

(3) In the post-epidemic era, both tourists and villagers have higher requirements for health and safety. Historic streets in the village with poor understandability and selectability should be improved to meet the emergency evacuation function of people in the event of emergencies. In addition, large health industries can also be appropriately developed based on the existing historical street space, such as health walking, health and wellness Bed and Breakfast. These activities can not only enrich the daily activities of tourists and residents, but also enhance tourists' awareness and understanding of traditional spaces.

This study also has some limitations. Since the number of samples of residents and tourists in the actual survey is not large enough, it cannot fully reflect the cognition of residents and tourists to the street space. In order to improve the reliability of the research results, more residents and tourists will be interviewed in future research, detailed viewshed analysis will be added, and more effective methods will be used for analysis.

## Acknowledgment

## References

[1]     Song L, Lin L, Li W, Yong W, Dong-Dong L, Zhao Y.2004 *Scientia Geographica Sinica* Temporal Characteristics of Tourist Flows to Ancient Villages——A Case Study of Two World Cultural Heritages, Xidi Village and Hongcun Village 250-6

[2]     Langston C, Wong FK, Hui EC, Shen L-Y.2008 *Building and environment* Strategic assessment of building adaptive reuse opportunities in Hong Kong **43** 1709-18

[3]     Xiao-hua C, Xiang-yu B.2018 *Journal of Original Ecological National Culture* Research on the Impact of Tourism Development on the Protection and Development of Huizhou Traditional Village **10** 100-7

[4]     Xin-qiu L, Si-ming W.2015 *Agricultural History of China* Difficulties and Countermeasures of Chinese Traditional Villages Conservation **34** 99-110

[5]     Andereck KL, Valentine KM, Knopf RC, Vogt CA.2005 *Annals of tourism research* Residents' perceptions of community tourism impacts **32** 1056-76

[6]     Song L, Lin L, Ming X, Dong-dong L, Li W, Yong W, et al.2005 *Geographical Research* A research on tourism environmental carrying capacity of ancient villages: a case study of world cultural heritage-Xidi Village **09** 581-90

[7]     Ru-yi Y, Liu-ke L, De-ming L, Hong-bing Z, Sheng-dong Z.2013 *Economic Geography* Tourism Population Invasion, Succession and the Spatial Order Recombination of Ancient Village—A Case Study of Hongcun Village **33** 165-70

[8]     Hillier B.2015 *Space is the Machine: A Configurational Theory of Architecture* Space Syntax)

[9]     Wang J.1999 *City Design* Southeast University Press)

[10]    Feng X, Shi-si L.2012 *Urban Problems* Comparative test on spatial image investigation and syntactic analysis in historical core district of Hengyang City 49-53

[11]    Chi C, Bohua L, Jiali Y, Wen Y.2018 *Economic Geography* Spatial Morphology Cognition of Traditional Village Based on Space Syntax:A Case Study of Qinchuan Village of Hangzhou **38** 234-40

[12]    Lynch K.1964 *The Image of the City* MIT Press)

[13]    Birer E, Çalışır Adem P.2022 *Frontiers of Architectural Research* Role of public space design on the perception of historical environment: A pilot study in Amasya **11** 13-30

[14]    Schroeder HW.2007 *Journal of Environmental Psychology* Place experience, gestalt, and the human–nature relationship **27** 293-309

[15]    Ittelson WH.1974 *An Introduction to Environmental Psychology* Holt, Rinehart and Winston)

[16] Kaplan S.1987 *Environment and behavior* Aesthetics, affect, and cognition: Environmental preference from an evolutionary perspective **19** 3-32

[17] Eben Saleh MA.2001 *Building and Environment* Environmental cognition in the vernacular landscape: assessing the aesthetic quality of Al-Alkhalaf village, Southwestern Saudi Arabia **36** 965-79

[18] Gould P, White R.2012 *Mental maps* Routledge)

[19] Paül i Agustí D, Rutllant J, Lasala Fortea J.2019 *Applied Geography* Differences in the perception of urban space via mental maps and Heart Rate Variation (HRV) **112** 102084

[20] Hillier B.1985 *Geoforum* The nature of the artificial: the contingent and the necessary in spatial form in architecture **16** 163-78

[21] Yamu C, van Nes A, Garau C.2021 *Sustainability (Switzerland)* Bill hillier's legacy: Space syntax—a synopsis of basic concepts, measures, and empirical application **13**

[22] Hillier B, Penn A, Hanson J, Grajewski T, Xu J.1993 *Environment and Planning B: planning and design* Natural movement: or, configuration and attraction in urban pedestrian movement **20** 29-66

[23] Hillier B.1997 *Intelligent Environments* - Cities as Movement Economies 295-344

[24] Hillier B.2009 Spatial sustainability in cities: Organic patterns and sustainable forms

[25] Lieshan F, Jian C, Junlin H.2010 *Chinese and Overseas Architecture* The Origin Mechanism Vicissitude Research of the Urban Space Shape's Syntax Constitution——Take All Previous Zhuzhou City General Planning as an Example 89-91

[26] Zhan Q, Zhou J, Sliuzas R.2009 *Proceedings of SPIE - The International Society for Optical Engineering* Study on spatial structure of large scale retail stores based on space syntax: Case study in Wuhan **7492**

[27] Giannopoulou M, Roukounis Y, Stefanis V.2012 *Procedia - Social and Behavioral Sciences* Traffic Network and the Urban Environment: An Adapted Space Syntax Approach **48** 1887-96

[28] Monokrousou K, Giannopoulou M.2016 *Procedia-Social and Behavioral Sciences* Interpreting and predicting pedestrian movement in public space through space syntax analysis **223** 509-14

[29] El-Darwish II.2022 *Ain Shams Engineering Journal* Enhancing outdoor campus design by utilizing space syntax theory for social interaction locations **13**

[30] Zerouati W.2022 *Digital Applications in Archaeology and Cultural Heritage* Using space syntax analysis in archaeological site: Case of Cuicul (Djemila) in Setif, Algeria **26**

[31] Chengfanga W, Yimina S.2012 *Tropical Geography* Research of Conservation and Renewal of Historic District Based on GIS and Space Syntax **32** 154-9

[32] Wei T, Hongye C, Jieyong L.2013 *Acta Geographica Sinica* Spatial form and spatial cognition of traditional village in syntactical view: A case study of Xiaozhou Village, Guangzhou **68** 209-18

[33] Scheer BC.2020 *J Am Plann Assoc* Historic Infrastructure Left Behind: Should Urban Planners Protect Streets and Blocks? **86** 3-10

[34] Zhu X, Chiou S-C.2022 *Sustainability* A Study on the Sustainable Development of Historic District Landscapes Based on Place Attachment among Tourists: A Case Study of Taiping Old Street, Taiwan **14**

[35] Srinurak N, Mishima N, Fuchikami T, Duangthima W.2016 *Procedia - Social and Behavioral Sciences* Analysis of Urban Morphology and Accessibility Character to Provide Evacuation Route in Historic Area **216** 460-9

[36] Wang L, Ding J, Chen M, Sun Y, Tang X, Ge M.2022 *Buildings* Exploring Tourists' Multilevel Spatial Cognition of Historical Town Based on Multi-Source Data—A Case Study of Feng Jing Ancient Town in Shanghai **12** 1833

[37]    Xu G, Zhong L, Wu F, Zhang Y, Zhang Z.2022 *Buildings* Impacts of Micro-Scale Built Environment Features on Tourists' Walking Behaviors in Historic Streets: Insights from Wudaoying Hutong, China **12**

[38]    Mundher R, Al-Sharaa A, Al-Helli M, Gao H, Shamsul Abu B.2022 *Heritage* Visual Quality Assessment of Historical Street Scenes: A Case Study of the First "Real" Street Established in Baghdad **5** 3680

[39]    Ja'afar NH, Sulaiman AB, Shamsuddin S.2012 *Procedia - Social and Behavioral Sciences* The Contribution of Landscape Features on Traditional Streets in Malaysia **50** 643-56

[40]    Zhang J, Huo X, Zheng W, Zheng X, Zhang M.2017 Research on the positioning of protection and utilization of historic districts under big data analysIis **XLII-2/W5** 731-5

[41]    Xu H, Wan X, Fan X.2014 *Tourism Geographies* Rethinking authenticity in the implementation of China's heritage conservation: the case of Hongcun Village **16** 799-811

[42]    Minghao J.2006 Analysis of the Space in Hongcun Ancient Village of the World Cultural Heritage

[43]    Hillier B.1996 *Urban design international* Cities as movement economies 41-60

[44]    Jinlong C, Lei Z, Xiaohua C.2017 *Journal of Chizhou University* Research on Planning Effect of Huizhou Traditional Settlement Based on Spatial Syntax **31** 64-9

[45]    Xi Z, Zhenyu C.2012 *Huazhong Architecture* Research on Tourism Villages' Spatial Form Transform Based on Space Syntax: Taking Shuhe Ancient Town of Lijiang as an Example **30** 105-9

[46]    Hong-gang X, Xiao-juan W, Xiao-jun F.2012 *Human Geography* Rethinkqing the implementation of authenticity in China's heritage conservation——a case study of Hongcun Village **27** 107-12