Research on the Spatial Pattern of Traditional Villages Based on Spatial Syntax: A Case Study of Baishe Village

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Abstract. Along with the rapid development of today's society, new urbanization has promoted the progress and development of the rural economy, and it has inevitably brought devastating blows to traditional villages, leading to its decline and even disappear. This paper takes the traditional Chinese village Baishe Village as the research object, uses GIS space syntax, constructs the relationship diagram and mathematical model of Baishe village spatial syntax, analyzes the parameter value data, and discusses the village spatial shape and spatial deep structure characteristics based on the analysis results. To provide reference for the protection and development of traditional villages.

1. Introduction

According to the third national survey of cultural relics of China, as many as 20,000 objects have been destroyed as a result of urban and rural construction [1] in the past 30 years. At the same time, the traditional buildings were left idle or abandoned, the original space mechanism was destroyed, and the village space presented a state of chaotic and disorderly development. In response to a series of problems in the current development of traditional villages, experts in various fields, conducted further in-depth studies on village space and proposed effective strategies for protection, planning, and development.

Internationally, studies on rural settlements have a long history. As early as the 19th century, French geographers began to conduct research on rural settlements [2]. Later, German geographers expanded the scope of the study, covering aspects such as agricultural production, land development, and cultural landscape [3]. During the 1950s, in the field of architecture and urban planning in the West, there was an upsurge of research on the rural settlements. Scholars of this period not only studied the constituent elements and geographical features of the rural settlements, but also explored the connotations and causes of regional culture, and formed a relatively complete theoretical system [4]. Hillier B first proposed in 1983 a spatial syntactic theory, and systematically elaborated syntactic theory in the two books "Social Logic of Space" and "Space is Machine". Since then, space syntax theory combined with graph theory has been widely used in research fields such as urban space and rural settlement space [5].

The study of traditional villages in China began in the 1930s and was gradually influenced by Western academic circles to study the villages. After the 1980s, the study of rural settlements was gradually paid attention to. [6-7] After the 21st century, the study of traditional village “things” gradually turned to the study of traditional village “people”. In addition, multidisciplinary
cross-disciplinary research and measurement geography are also reflected in traditional village research. Although the research on the spatial form of the village has been actively pursued in many year and reasonably well developed, many shortcomes still remain. For example, most studies tend to focus on the qualitative study of the village space, lack of strict quantitative research.

In this article, based on the spatial syntactic theory, we select the famous historical and cultural village, Baishe Village, to explore the relationship between the spatial form of the village and the human social activities. It also provides a scientific basis, from a quantitative perspective, for the protection and development of traditional rural spatial forms. Research areas and research methods.

2. Research areas and research methods

2.1 Research Area
Baishe Village, in Sanyuan County, Shaanxi Province is a national historical and cultural village that is shortlisted for the second batch of traditional Chinese villages. It is an ancient village with a large scale, concentrated distribution, relatively well preserved in China. The main architectural form of Baishe Village is divided into pit kiln (dark kiln) and independent ground construction. (Figure 1).

With economic development and urbanization in rural areas, most of the villagers in Baishe Village moved out of the pit kilns many years ago. In general, the ancient village of pits Kiln faces the danger of being abandoned and are disappearing. Therefore, an in-depth analysis of the spatial form of the human settlement environment of the pit kiln in Baishe Village provides a prerequisite for the subsequent rescue protection and sustainable development.

Fig 1. Historical distribution of pit kiln.  
Fig 2. Baishe village axis map

2.2 Research Methods
In this paper, we apply a linear mathematical model analysis method in spatial syntax and Depthmap analysis software to calculate a series of parameters for the village street space. The data obtained are combined with the on-ground survey, and the spatial characteristics of traditional villages are quantitatively studied and the relationship with human activities is analyzed [8] (Figure 2). Computer-assisted generation of new relationship diagrams, by analyzing these new relationship diagrams, it can accurately analyze spatial relationships and human behavior characteristics.

3. A Study on the Spatial Syntax of the Spatial Form of Baishe Village

3.1 Analysis of Integration
The degree of integration can be divided into global integration and local integration according to different radii[9]. Global integration reflects the degree to which an axis is closely related to all other axes. It takes the radius R as n, and the integration in the spatial syntax software Depthmap is Rn: The degree of local integration represents the ease with which a space is in contact with the space within a
few steps in the vicinity. R is generally taken to be 3 because 3 is the closest to the spatial scale of human walking. Among them, the area with the highest global integration value is called the "space core" of this space (Integration value is the top 10% of the total space element). The village’s integrated core is the crowd center of people in the village space grid [10]. Due to its dominant position of accessibility and permeability, its social and economic functions are far higher than other areas, thus becoming the center of the village's social activities. The level of integration value is represented by the warm and cold color in the space syntax [11].

3.1.1 Global integration. As can be seen from the axis analysis of the global integration degree of Baishe Village (Figure 3), the axis with the highest integration Ref Number 300 (Baishe West Street) is the horizontal main road through the village. It is the main road connecting the village to the east and west. It is the region with the strongest accessibility, the largest flow of people and traffic, and the most important activities of people. Secondly, the red axes Ref Number 299, Ref Number 298, and Ref Number 0 have higher integration. The axis Ref Number 299 is the secondary trunk road, 7 meters wide and 1200 meters long. It is surrounded by historical sites such as the Shoufeng Temple Site, the Mawang Temple Site, the Niangniang Temple Site. (Figure 4). According to the analysis of space syntax, this axis has strong accessibility and convenience.

The axis Ref Number 298 and Ref Number 0 are the Sanzhao Highway. The north side leads to Shaolin, and the east side leads to Longwang Village. It is the main passageway into and out of Baishe Village. The two axes are the longest, which means that the most information can be reflected. Other axes with integration value accounts for the top 10% of the overall integration degree are Ref Number 176, Ref Number 179, Ref Number 301, Ref Number 23, Ref Number 297, Ref Number 139, Ref Number 250, Ref Number 251, Ref Number 105, Ref Number 238, Ref Number 38, Ref Number 269, Ref Number 192, Ref Number 225. These axes are orange in color and have a high degree of integration, all intersecting the main axis. It can be seen that the area near the intersection of the axis Ref Number 300 and Ref Number 299 forms the integrated core of the village, which is the center of the crowds in the overall spatial grid of the village, and thus becomes the center of the village's social activities.

3.1.2 Local integration. By comparison, it is found that the axis with the highest global integration degree (Rn) and local integration degree (R3) has a partial overlap. This indicates that the overall structural center and the local structure center of the village are located at the intersection of the Ref Number 300 and Ref Number 299 axes. However, the area with higher local integration is slightly different from the area with higher overall integration (Figure 5). In addition to the highest integration of the axis Ref Number 300, the integration degrees of Ref Number 43, Ref Number 186, Ref Number 76, Ref Number 175, Ref Number 150, and Ref Number 176 are relatively high. Although the
road is a bit tortuous, it also forms a route with better convenience in the local area, sharing the flow of people and traffic on the west street of Baishe (Ref Number300), connecting the space of nearby streets and lanes.

Fig 5. Local integration map of Baishe Village  
Fig 6. Intelligibility map of Baishe Village

3.2 Intelligibility Analysis
Intelligibility measures the difficulty of people's perception of large-scale space, that is, the extent to which local structural features are seen to assist people in building awareness of the entire space system [12]. Linear regression analysis is carried out on the overall integration degree and local integration degree and local integration degree, and obtain the intelligibility of the axis system through the XY scatter plot to measure the relationship between the village and the entire area (Figure 6). In this figure, X represents global integration, Y represents local integration, and R2 represents intelligibility [13]. According to the scatter plot, the intelligibility value R2 of Baishe Village is 0.54. Generally speaking, if the R2 value is above 0.5, the horizontal axis is related to the vertical axis, indicating that it is easier to estimate the spatial shape of the entire road network based on the spatial form of the local street network in Baishe Village. From this point of view, the space with higher local integration and better convenience can be well integrated into the whole system, and the local structure and the overall structure form an efficient interaction. The local integration and overall integration of the area north of Baishe West Street are low, and the accessibility and convenience are poor. This space is not easy to attract people, and it is not easy to form people's spatial cognition, but in general, the community of Baishe Village has better interaction and synergy.

3.3 Analysis of Connection Values
The degree of connectivity represents the visual penetration of a spatial system, that is, the visual breadth of a person. The larger the connection value, the better the permeability of the space, and the worse the opposite. In the connection value map of Baishe Village (Figure 7), it can be seen that only Ref Number300 (Baishe West Street) has a connection value of 10 in the entire axis system. This axis is the central commercial street of Baishe Village. Baishe West Street undertakes most of the functions of the village. It is connected with the main road and connects many branches of the village in close connection with the space. It has a strong influence on the surrounding space, and other space nodes are more likely to reach this space. It is directly connected with the integrated core of Baishe Village, which further proves the importance of this street running through the village. The axis Ref Number 150 and the Ref Number 24 have a connection value of 8, and the axis Ref Number 43 has a connection value of 7, indicating the usage of these roads is also high. Most of the southwest corners of the village are newly built ground buildings, while the southern part of the village is the place where the pits and kiln houses are concentrated. Therefore, several streets connecting the new city and...
the old town have a high degree of connectivity. The rest of the line segments are blue and green, showing a colder color. Correspondingly, the universal connection value is not high.

3.4 Control Value Analysis

The control value represents the degree to which a space is controlled by the space to which it is connected [14]. The relationship between the control value and the connection value is relatively close, and both represent the relationship between a space and the space directly connected to it. The node with a high connection value does not necessarily have a high control value[15]. In the control degree map of Baishe Village (Figure 8), the color of most of the axes is cool, indicating that the mutual control between the various spaces in Baishe Village is not high. However, there are several warm color axes with higher control values distributed in the area connecting the new town and the old town. The local regions of these axis connections are closely related, so we can infer that the development of the village is mainly based on certain roads, and then extend other branches and roads. For example, the roads represented by Ref Number150 and Ref Number43. However, the two axes are branched by the east-west axis connected by Ref Number43, Ref Number186, Ref Number76, Ref Number175, Ref Number150 and Ref Number176. Therefore, this tortuous road has the potential to become a branch road, which in turn can strengthen the connection between the core area in the middle of the village and the southern part of the village. The control range of the central area will be expanded to the south. Ref Number300 (Baishe West Street) has the highest control value, the best accessibility and permeability, once again proves its core space status.

![Fig 7. Connection value map of Baishe Village](image)
![Fig 8. Control value map of Baishe Village](image)

3.5 Selectivity Analysis

The degree of selectivity is to examine the number of times a space is selected as the shortest path between any two spaces in the system. The high degree of selectivity indicates that this space has the potential for greater traffic. From the selection analysis of Baishe Village (Figure 9), it can be seen that the axis with higher selectivity and the axis with higher global integration largely coincide. From the selection map of Baishe Village, it is obvious that the selection of the boundary axis of the periphery of Baishe Village is higher, and the overall color of the internal axis of the village is colder, indicating that people are more inclined to choose a smoother main road. The twists and turns of the village's trails and the irregular distribution of pits and kiln in the village are hazardous to driving and walking tourists who are unfamiliar with road conditions even though local residents may choose these trails, therefore smooth main roads are the best choice.

3.6 Analysis of Average Depth Value

The depth value represents the accessibility and convenience of the space. The fewer the number of spatial transitions to reach a certain area, the smaller the depth value, the better the convenience. On
the contrary, the convenience is poor and the space is deeper. In the space syntax theory, the node space with higher accessibility is called the “integration zone”. On the contrary, that is called “discrete zone”.

It can be found from Figure 10 that the streets with smaller average depth value in Baishe Village are mainly concentrated on the main roads of the village, such as the streets represented by the axes Ref Number300, Ref Number299, Ref Number298. These streets are highly accessible, and it is convenient to reach these spaces, and there is a large degree of coincidence with the axis with high integration value of the village. From the average depth value map, several axes with higher depth values appear: a road in which the axes Ref Number 204, Ref Number 205, Ref Number 206, Ref Number 207, Ref Number 208, Ref Number 209, Ref Number 211, Ref Number 212, Ref Number 213, and Ref Number 214 are connected; Two roads north of the two main village roads connected by the axis Ref Number 226, Ref Number 227, Ref Number 228, and Ref Number 229 provide a path connecting the central axis Ref Number140, Ref Number142, and Ref Number143 into the middle of the village. These three lines show a warm color in the illustration, and the depth value is much higher than the surrounding area, indicating that these areas have poor accessibility and belong to discrete areas.

By observing the average depth value of Baishe Village, we can see that the spatial pattern of Baishe Village is grid-like. Then, the correlation analysis between the average depth of Baishe Village space and the overall integration degree shows that these two variables are negatively correlated (Figure 11). The lower the depth value, the higher the integration of the space, and the higher the depth value, the lower the integration of the space. Therefore, we speculate that the depth of the space affects the intelligibility of the village space.
4. Analysis of spatial morphological characteristics

4.1 Spatial Characteristics of Areas with High Degree of Village Integration

Through the mining of the road and driveway of Baihe Village in the previous section, it can be seen that the Bai nationality street is roughly grid-like, the Zhongnan Road in the village is densely distributed, and the northern road is sparse, irregular. In addition to the smooth flow of Baisha West Street, other straight roads also have a good landscape, distributed around the village, forming a grid-like centripetal layout.

(1) Through the observation of the overall integration of Baishe Village, the integrated core of the village is Baisha West Street that has the highest accessibility and convenience and is also a commercial street of the village as well as a gathering place for social activities. This is also the space with the strongest sense of belonging and it dominates the villagers' consciousness.

(2) According to the analysis of the local integration degree of Baishe Village, there is a well-accessible road running through the east-west direction in the south of Baisha West Street. People also tend to choose this road to walk. But this road is uneven and the road surface is poor, the scale of the street is out of balance, and it needs to be widened as appropriate, so that the traffic of the main street can be shared.

(3) Through the analysis of the connection value and the selection degree, it is known that the connection value and the selection degree of the road near the newly built residential area and the connection between the residential area and the central area are high, and the residents flow greatly. The roads between the residential area and the central area are more convenient and has potential for attracting people.

4.2 Spatial Characteristics of Areas with Low Village Integration

(1) From the perspective of the overall integration of the entire village, the accessibility and convenience of the area north of Baishe Village is poor. The analysis of the average depth value shows that the depth value of the northern part of the village is much higher than that of the middle and the south, the terrain conditions are poor, the pit kiln is concentrated, and the people are sparsely populated, all are characteristics of a typical “discrete area”.

(2) The analysis of the connection degree of the village shows that the universal connection value is not high, and there are many winding paths between the caves in the village. There are many "人" (two-way) and "T" (three-way) shaped intersections. Although this has certain sheltering effect on the residents of the village, it has caused confusion to the outsiders, which has also caused weak links in various parts of the village.

(3) The degree of selectivity analysis shows that the boundary axis of the village has a higher degree of selection and the overall color of the village's internal axis is colder, indicating that people are more inclined to choose a smoother main road, rather than a small road in the village.

5. Conclusion

Based on spatial syntax, this study quantifies Baishe Village with significant regional characteristics and studies the relationship between space and society from a new perspective. Including the overall spatial shape analysis, street space shape analysis and other aspects. It can be obtained that the spatial characteristics of the village and the intrinsic relationship between space and human behavior activities, and the relationship between space and human behavior is explored in a more scientific and humanized way. Adhering to the principle of "people-oriented" and "adapting to local conditions", it can not only protect the original spatial structure of the village space, but also effectively improve the irrational spatial form, and provide a scientific basis for the protection and development of the subsequent village space form.

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