

Quantitative Research on Public Spaces in the Traditional Village Streets and Alleys of Fangshan District, Beijing

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Abstract: This paper conducts a quantitative analysis of the public spaces in the traditional village streets and alleys of Fangshan District in Beijing. It objectively reflects the richness of the spatial form of traditional village streets and alleys, summarizing existing problems. Based on this, and in conjunction with quantitative data and relevant theories, it proposes optimization strategies from the perspectives of overall preservation and spatial renewal. The aim is to improve the environmental quality of streets and alleys in traditional villages, enhance the quality of public spaces, and, while maintaining the authenticity and historical character of the villages, to stimulate their vitality and promote urban-rural development.

1. Introduction

With the accelerating urbanization of Beijing, the traditional villages in the shallow mountain areas of Fangshan District have seen continuous economic development. These villages are increasingly outward-looking, and the villagers' living standards are constantly improving, leading to higher demands for living spaces. Some villagers, catering to their heightened needs, have renovated their homesteads without systematic planning, resulting in architectural forms and courtyard scales vastly different from traditional village norms. Others choose to build new houses around the periphery of the village. Consequently, on the basis of the original village, the spatial layout of the village has gradually expanded, giving rise to new villages. The development of new and old villages together has altered the traditional village street structure. Based on the different topographies, regional cultures, customs, and historical development of ancient trade routes in Fangshan District, the spatial organization structures of traditional village streets and alleys also vary. The spatial layout of traditional village streets and alleys emphasizes the material spatial structure of traditional villages, a key factor affecting space accessibility, and subsequently influences how villagers and tourists use the space. Therefore, this paper focuses on the quantitative analysis of street and alley public spaces in Fangshan District's villages, delving into their intrinsic organizational structures, as one of the effective approaches to protecting and developing traditional villages in Fangshan District.

2. Research Object

Fangshan District serves as the southwestern gateway to Beijing. As the junction of the North China Plain and the Taihang Mountains, it includes a diverse topography of mountains, hills, plains, and depressions. Traditional villages in the mountainous areas are generally built along the contours

of the mountains, developing in accordance with the terrain^[1]. Traditional villages located between the foothills, in contrast, have a gentler terrain than those in the mountains, with a relatively higher elevation on the plains. These geographical advantages make them more suitable for human habitation, resulting in a large number of villages forming in these areas. The varying terrain also leads to significant differences in the spatial layout of streets and alleys. This paper selects three traditional mountain villages in Fangshan District with different street and alley structures for study: Shuiyu Village and Nanjiao Village in Nanjiao Township, and Heilongguan Village in Fozizhuang Township. Through a multi-sample study within a relatively small area, it conducts a comprehensive quantitative analysis of the public spaces in the streets and alleys of Fangshan District's traditional villages, offering direct reference significance for the protection and development of these spaces in Fangshan District.

3. Quantitative Research Methodology for Public Spaces in Traditional Village Streets and Alleys

Current analyses of public spaces in traditional village streets and alleys include both qualitative analyses of the spatial form of streets and alleys and quantitative analyses using methods such as space syntax. Many scholars have conducted in-depth studies on the spatial structure of traditional village streets and alleys, predominantly relying on field survey measurements. Scientifically analyzing the structural characteristics of public spaces in traditional village streets and alleys can be achieved through various quantitative indicators, such as road sinuosity, street and alley interface density, and alignment rate, to provide a comprehensive quantitative analysis of the public spaces in village streets and alleys.

(1) Road Sinuosity: Road sinuosity is characterized by the straightness of the road, i.e., the ratio of the linear distance between the road endpoints to the actual length of the road^[1].

$$T_1 = \frac{l_1}{L_1},$$

(Formula: T_1 represents road sinuosity, l_1 is the linear distance between road endpoints, and L_1 is the actual length between the road endpoints.)

(2) Street and Alley Interface Density: Interface density refers to the overlap rate between the total length of the bases of all buildings on both sides of the street and the total length of the street's boundary line (interpreted as the building red line). (For phenomena such as the red line setback and unclear courtyard boundaries, the street's centerline is shifted 5 meters to the left and right as a reference line for the street's boundary line^[2]).

$$T = \frac{\sum R_i}{L}$$

(Formula: R_i is the base length of the i -th building facing the street; L is the length of the street's boundary line.)

(3) Alignment Rate: The current concept and calculation method of alignment rate in China are not entirely consistent, and they cannot effectively distinguish between different street interface forms. From the perspective of the development timeline, the concept and method of alignment rate represented by the "Shanghai Criteria" is a relatively recent research outcome^[3]. In the "Shanghai Criteria", the alignment rate is the percentage of the length of the building wall facade line that adheres to the total length of the building interface control line, expressed as a percentage, i.e.:

$$\text{Alignment Rate} = \text{Length of Street Wall Facade Line} \div \text{Building Control Line Length} \times 100\%$$

Through comprehensive analysis of these indicators, we can gain a more thorough understanding

of the structural characteristics of public spaces in traditional village streets and alleys, guiding the protection and transformation of public spaces in traditional villages.

4. Quantitative Analysis of Public Spaces in Traditional Village Streets and Alleys in Fangshan District

4.1 Road Classification

Streets and alleys form the backbone of the spatial texture of traditional villages, influenced by natural and social environments, leading to different spatial network systems. Based on the purpose of the roads, the overall space of the streets and alleys is divided into three levels. First-level roads primarily include urban roads and inter-village roads, mainly facilitating vehicular traffic within the entire village and connecting to surrounding villages. Second-level roads are the main streets within the village, serving the internal traffic functions of the village. Third-level roads are mainly lanes and roads in front of houses.



Figure 1: Road Classification in Heilongguan Village

Table 1: Road Quantity Statistics in Heilongguan Village

Road Level	Number	Percentage of Total
First-Level Roads	2	15%
Second-Level Roads	4	31%
Third-Level Roads	7	54%

Heilongguan Village's (Figure 1) first-level roads include Jingkun Road and the G108 expressway. These two urban roads run almost parallel within Heilongguan Village, traversing it. Second-level roads are the main roads within the village and the outer ring road, bearing the internal traffic of the entire village. Heilongguan Village, built before the Yuan Dynasty, has a simple structure due to its environment of backing onto mountains and facing water. The old village, from south to north, has only one street, with residential buildings along it, gradually forming the streets and alleys' spatial skeleton. The newly built village is located on the opposite side of the mountain peak, facing away from the traditional village, generally continuing the old village's streets and alleys' texture. It is also traversed by one main street, with peripheral roads mainly connecting Dashi River and surrounding green spaces. Third-level roads mainly include lanes and roads in front of houses; since most courtyards in Heilongguan Village are arranged around the main street within the village, there are fewer third-level roads. (Table 1)



Figure 2: Road Classification in Shuiyu Village

Table 2: Road Quantity Statistics in Shuiyu Village

Road Level	Number	Percentage of Total
First-Level Roads	1	2%
Second-Level Roads	12	29%
Third-Level Roads	28	69%

In Shuiyu Village (Figure 2), there is only one first-level road, Shuiyu Road, which runs through the village from south to north and connects with Hongnan Road. The second-level roads include the main thoroughfares connecting buildings within the village and the ancient trade route. The roads follow the valley's terrain in a linear extension, forming the East and West Villages of the ancient Shuiyu Village. The West Village has a flatter terrain and a more orderly layout, while the East Village, situated on higher terrain, has residential buildings winding along the S-shaped ancient trade route. Today, most villagers live in the Shuiyu New Village to the north, where the village roads continue the linear layout due to the expansion of external highways. The third-level roads are lanes and roads in front of houses, mostly dirt or stone-paved, with many dead ends. (Table 2)



Figure 3: Road Classification in Nanjiao Village

Table 3: Road Quantity Statistics in Nanjiao Village

Road Level	Number	Percentage of Total
First-Level Roads	1	1%
Second-Level Roads	3	3%
Third-Level Roads	91	96%

Nanjiao Village is located in a basin-shaped valley and has developed in a clustered pattern. (Figure 3) The first-level road is Hongnan Road, which connects the entire village and is situated on the northern side of the village. The second-level roads include the ancient trade route within the village and the main roads along the river on the village's periphery. Nanjiao Village began to take shape about 600 years ago during the Ming Dynasty, gradually giving rise to the ancient Nanjiao commercial street. The existing 1.2 km long ancient trade route in the village runs from west to east through the old village along the southern main street, meandering in a "U" shape following the natural course of the river. The third-level roads mainly include lanes and roads in front of houses, with streets and alleys perpendicular to the ancient trade route, spreading north and south in a fishbone pattern. (Table 3)

4.2 Road Sinuosity

Road sinuosity reflects the degree of curvature in the village's road composition, influenced mainly by the total length of the streets and alleys and the linear distance between their endpoints. The closer the ratio is to 1, the straighter the road.

The lengths of the streets and alleys within the three villages were measured (with urban roads passing through the villages being truncated), and the sinuosity of the roads was calculated by determining the ratio of the linear distance between road endpoints to the actual length of the road. The average values for each level were then compiled and analyzed, as shown in Table 4.

Table 4: Road Sinuosity Statistics

Village	Road Level	Road Sinuosity	Average Level	Average by Village
Heilongguan Village	First-Level Roads	0.59,0.51	0.55	0.91
	Second-Level Roads	0.99,0.98,0.96,0.92	0.96	
	Third-Level Roads	0.98,0.99(4),1(2)	0.99	
Shuiyu Village	First-Level Roads	0.92	0.92	0.92
	Second-Level Roads	0.56~0.99	0.83	
	Third-Level Roads	0.73~1	0.96	
Nanjiao Village	First-Level Roads	0.94	0.94	0.96
	Second-Level Roads	0.86,0.83,0.94	0.88	
	Third-Level Roads	0.61~1	0.96	

4.3 Street and Alley Interface Density

The study of street and alley interface density examines the compactness of the street interfaces. It is determined by the ratio of the width of the buildings' street-facing projection to the length of the street segment. Generally, a higher interface density indicates a denser arrangement of buildings along the street.

The street and alley textures of traditional villages in Fangshan District are simple, respecting nature while maintaining richness. By overlaying the street boundary line and the building baseline in a diagrammatic form, the interface density of village streets and alleys is calculated. The internal main street and alley interface densities of Heilongguan Village, Shuiyu Village, and Nanjiao Village do not reach 100%. Among them, the interface density of the main street in the old part of Heilongguan Village is the highest, while the southern side of the ancient trade route in Shuiyu Village has the lowest interface density. The interface densities of the main streets in the three villages range between 30% and 80%.

The street and alley interface densities for different road levels in the three villages were calculated and averaged, as shown in Table 5. Nanjiao Village exhibits the highest overall street and alley interface density, followed by Shuiyu Village, with Heilongguan Village having the lowest. This reflects the varying degrees of street and alley interface arrangement density across different road levels in each village, indicating a rich structural diversity.

Table 5: Street and Alley Interface Density

Village	Road Level	Street and Alley Interface Density	Average by Level	Average by Village
Heilongguan Village	First-Level Roads	11.98%,18.95%;0%,2.09%	8.26%	29.52%
	Second-Level Roads	79.1%,67.32%;53.67%,54.2%;0%,19.9%;48.01%,0%	40.18%	
	Third-Level Roads	0%~76.47%	29.50%	
Shuiyu Village	First-Level Roads	15.12%,33.68%	24.4%	37.29%
	Second-Level Roads	29%,0%~96.2%,89.6%;	49.39%	
	Third-Level Roads	0%~98.06%	32.57%	
Nanjiao Village	First-Level Roads	64.99%,65.46%	65.23%	52.58%
	Second-Level Roads	58.29%,49.25%;47.35%,69.61%;12.39%,8.89%	40.96%	
	Third-Level Roads	0%~100%	55.49%	

4.4 Alignment Rate

The alignment rate is primarily used to represent the horizontal protrusion and indentation changes of street interfaces. The calculation method from the "Shanghai Criteria" is adopted (which defines the alignment rate as the ratio of the total length of the building wall facade line adhering to the building interface control line to the total length of the building interface control line, expressed as: Alignment Rate = Length of Street Wall Facade Line ÷ Building Control Line Length × 100%).

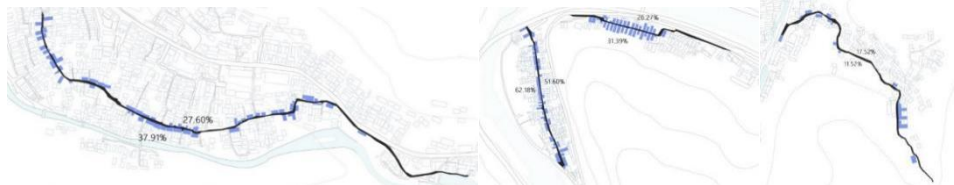


Figure 4: Illustration of Building Alignment Rates for Main Streets and Alleys

In Shuiyu Village, the ancient trade route in the East Village has a complex terrain. It extends linearly along the valley, with higher terrain and residential buildings winding along the S-shaped

ancient trade route. The alignment rates on both sides of the streets are the lowest, at 17.52% and 11.52%, respectively. The ancient trade route in Nanjiao Village, which follows the natural shape of the river in a "U" pattern, has a flatter terrain with numerous historical buildings on both sides, resulting in higher alignment rates of 27.60% and 37.91%. The alignment rate of the main street in the new part of Heilongguan Village is close to that of Nanjiao Village's ancient trade route, but the alignment rate of the main street in the old part of Heilongguan Village is significantly higher than that in the new village. (Figure 4)

Table 6: Alignment Rate

Village	Road Level	Street and Alley Building Alignment Rate	Average by Level	Average by Village
Heilongguan Village	First-Level Roads	0.65%, 2.84%; 0%, 0%	0.87%	15.11%
	Second-Level Roads	62.18%, 51.60%; 31.39%, 26.27%; 0%, 0%; 14.78%, 0%	23.28%	
	Third-Level Roads	0% ~ 50.98%	14.51%	
Shuiyu Village	First-Level Roads	6.61%, 7.53%	7.07%	14.60%
	Second-Level Roads	0%, 0% ~ 67.82%, 56.73%	19.29%	
	Third-Level Roads	0% ~ 87.94%	12.86%	
Nanjiao Village	First-Level Roads	19.39%, 15.01%	17.20%	32.88%
	Second-Level Roads	0%, 3.57%; 17.94%, 35.26%; 37.91%, 27.60%	20.38%	
	Third-Level Roads	0% ~ 100%	33.56%	

Calculations and statistics for the alignment rate of different levels of roads within the three villages were conducted, as shown in Table 6. In these villages, most of the buildings along the streets do not strictly adhere to the alignment, resulting in noticeable protrusions and indentations in the street interfaces. The average alignment rates for Heilongguan Village and Shuiyu Village are similar, while Nanjiao Village is significantly higher than both Heilongguan and Shuiyu Villages. This indicates that the street-facing buildings in Nanjiao Village are closer to the streets and alleys and are more densely packed compared to the other villages.

4.5 Data Analysis

Road sinuosity reflects the winding nature of the village streets and alleys, while street and alley interface density and alignment rate indicate the relationship between village street interfaces, street walls, and the buildings adjacent to the streets and alleys (Table 7). The street and alley structures of

Heilongguan Village, Shuiyu Village, and Nanjiao Village exhibit distinct characteristics. Heilongguan Village, with its relatively flat terrain, has a simpler street and alley structure, harmoniously integrating the layouts of the new and old villages. It has the lowest average values in road sinuosity, street and alley interface density, and alignment rate among the three villages. Shuiyu Village, with its more complex terrain, has the new and old villages adjacent to each other. The ancient trade route extends along the winding terrain, with buildings along the road adapting to the topography, resulting in lower street and alley interface density and alignment rate. Nanjiao Village, with a flatter terrain compared to Shuiyu Village, has its ancient trade route following the river in a U-shape. Its street and alley interface density and alignment rate are both higher than those of Shuiyu and Heilongguan Villages.

Table 7: Data Statistics

Village	Road Level	Number	Road Sinuosity		Street and Alley Interface Density		Alignment Rate	
Heilongguan Village	First-Level Roads	2	0.55	0.91	8.26%	29.52%	0.87%	15.11%
	Second-Level Roads	4	0.96		40.18%		23.28%	
	Third-Level Roads	7	0.99		29.50%		14.51%	
Shuiyu Village	First-Level Roads	1	0.92	0.92	24.4%	37.29%	7.07%	14.60%
	Second-Level Roads	12	0.83		49.39%		19.29%	
	Third-Level Roads	28	0.96		32.57%		12.86%	
Nanjiao Village	First-Level Roads	1	0.94	0.96	65.23%	52.58%	17.20%	32.88%
	Second-Level Roads	3	0.88		40.96%		20.38%	
	Third-Level Roads	91	0.96		55.49%		33.56%	

5. Conclusion

In the context of implementing rural revitalization, planning and protection of these villages should consider the distinct regional characteristics unique to each. The protection and development of street and alley spaces in traditional villages should adhere to the principle of authenticity. Compared to traditional methods of studying street and alley space forms, quantitative research methods offer a more precise and direct description of the spatial characteristics of streets and alleys, enhancing the scientific nature of the research. This paper conducted a survey and mapping of three traditional villages in Fangshan District, calculating and statistically analyzing quantitative indicators such as road sinuosity, street and alley interface density, and alignment rate. Due to differing terrain, cultural backgrounds, and the formation of ancient trade routes, the analysis of quantitative data revealed distinct differences in the street and alley structures among the traditional villages of Fangshan District.

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