



Study on Spatial Optimization Strategies of Old Community Streets Based on Spatial Syntax and PSPL - A Case Study of Garden Hill Community in Grain Road Street, Wuhan City

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Abstract. The old community is an important livelihood project related to the fundamental interests of the residents as an important part of the organic. As an important carrier of urban public space rejuvenation and vitality, community street space is an important part of the development of cities in transportation, environment, vitality, renewal and so on. Therefore, based on the optimization and transformation of the old community street space, this paper selects the Huayuanshan Community of Wuhan Grain Road Street as the research object. This paper tries to analyze the present situation and problems of Huayuanshan Community street space by combining space syntax with PSPL investigation method, and further puts forward the optimization strategy in order to provide some old community renewal and space optimization references.

Keywords: Spatial Syntax · Pspl · Old Community · Street Space · Community Renewal · Spatial Optimization

1 Introduction

Since the industrial revolution, in order to comply with the needs of motor vehicle traffic, the new urban road structure network has shifted from a dense, complex and organic road network structure to a regular and fast hierarchical road structure. As most of the old communities in the urban center did not consider the accessibility and motor vehicle parking at the early stage of construction planning, coupled with the long term disrepair of roads, broken community road surface, lack of maintenance of greenery, and spontaneous unauthorized construction by residents make the old community street space broken and the environment increasingly degraded. In the context of the State Council's promotion of comprehensive management of old neighborhoods, on January 10, 2020, the Wuhan Municipal Government issued the "Wuhan Three-Year Action Plan for the Transformation of Old Neighborhoods (2019–2021)" for the transformation of urban residential neighborhoods built before 2000 with incomplete supporting facilities, imperfect functions, and unsound public and social services. It aims to improve the

overall environment and various infrastructure of old communities. As an important part of urban public space renovation, street space has a great potential to stimulate urban public life while meeting the necessary circulation function requirements [1]. Therefore, strengthening the construction of street space in old communities can provide more convenient services and promote the interaction between community residents, thus promoting the positive development of the community.

2 Basic Analysis of Street Space in Old Communities

The old community in this paper refers to the area built around 1980s–1990s, which consists of one or more groups of neighborhoods with a certain residential population and the existence of common public service facilities such as schools and hospitals. Its street space is the space enclosed by community roads and both sides of building facades, which mainly includes the road traffic system for community residents to travel, as well as the green areas, squares, courtyards and open public sites with attributes such as recreation, fitness and interaction that extend from them [2].

3 Research Area and Method

3.1 Overview of the Research Area

The community of Huayuanshan in Grain Road Street, Wuhan, is located in the historical area of the ancient city north of Snake Hill in Wuchang. The community is bounded by Qipan Street to the east, Rouge Road to the west, Grain Road Street to the south, and Huayuanshan to the north, with a total study area of about 0.16 square kilometers. There are 3,059 households and 7,375 people living in the densely populated area. At present, the community is distributed with residential areas such as Shuangbai District, Hansan Palace, Drum Rack Slope and Shuxiang Yuan, in addition to cultural, sports and medical institutions such as Wuhan High School, Hubei University of Traditional Chinese Medicine and Hubei Provincial Hospital of Traditional Chinese Medicine. The residential areas are divided into three main categories: the unitary housing system of the 70s-80s, the partially blocked shantytown self-built houses and the closed residential neighborhoods after the 90s. It is these three different categories of residential forms that constitute the traditional street texture of the Huayuanshan community. Based on the topographic map provided by the city planning bureau, a three-dimensional morphological model of the Garden Hill neighborhood on Grain Road Street was established, and it was found that the northeast corner and the area near Checkerboard Street had a close and disorganized distribution of residences in contrast to the existing homogeneous distribution of 6–8 story traditional unit residences in the neighborhood; except for social service institutions, the residences were basically bounded by houses and streets, and the first floor along the street side of the buildings were basically ground floor shops, and There is no wall like the present closed settlements, but a certain openness, with open public spaces interspersed among the neighborhoods, such as small gardens and activity areas for public facilities. In recent years, with the development of urban construction, the main roads in the community have been widened, and additional marketplaces and

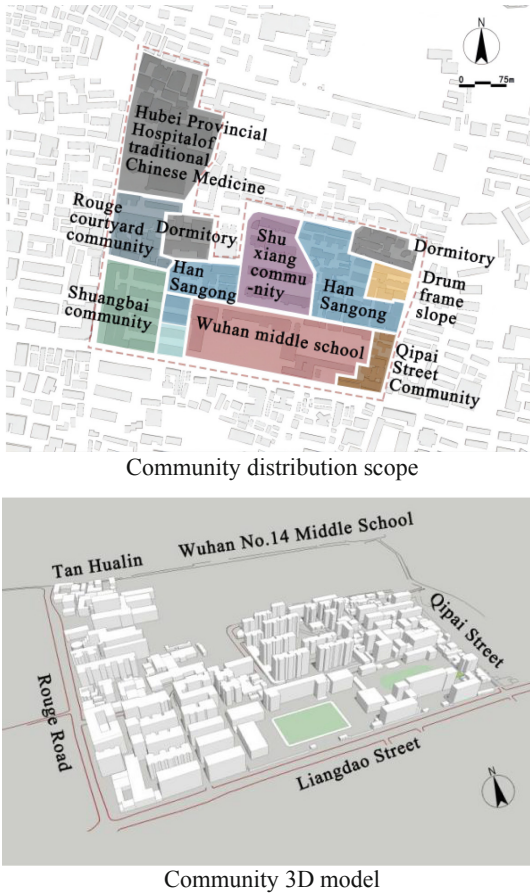


Fig. 1. Analysis on the general situation of huayuanshan community.

commercial supermarkets have been set up, which are the gathering points of the surrounding citizens for shopping and medical treatment, with an average daily flow of about 30,000 people (Fig. 1).

3.2 Research Methodology

This paper mainly uses the following two methods:

- (1) Spatial syntax. The basic idea is to divide the space into scales and spatial partitions, and analyze the topological, geometric and actual distance relationships between spaces [3]. Based on the relevant measurement indexes such as integration degree, connection value, selection degree, synergy degree and understanding degree, the key points of the overall spatial problem are found and the best optimization scheme is formed [4]. In this paper, we will analyze the spatial structure of streets in the community with the help of Depthmap software in terms of axes and view areas, and

propose corresponding optimization strategies for the community street network based on the measured values.

- (2) PSPL research method. By investigating and assessing the quality of urban public spaces and the public living conditions of citizens, the relationship between spatial environment and public activities is explored, and then spatial optimization strategies that better meet public needs are proposed. In this study, the PSPL research method is applied to the street space in the old community, mainly by using the map marking method, field counting method, field observation method and interview method to investigate and evaluate the quality of street space in the community and the current living conditions of the residents in the space, and then propose relevant optimization strategies.

4 Status of Street Space in Old Neighborhoods

As the community of Garden Hill is part of the historical old town area, it is a long time ago, and comparing the maps of the neighborhood parcels in various periods, we can see that the layout of the streets has changed, but the names basically follow the previous naming method. However, because of the late construction of the community and street names were not fully standardized and systematized, the streets in the community were numbered in the order of west to east and top to bottom in order to distinguish them (Fig. 2) The street network, roads, and overall environment of each street space were systematically evaluated based on field surveys and software algorithms.

4.1 Current Status of Street Network System

According to the theory of spatial syntax, the spatial patterns of the streets in the Garden Hill community are abstracted into syntactic topological relations using the axis and view

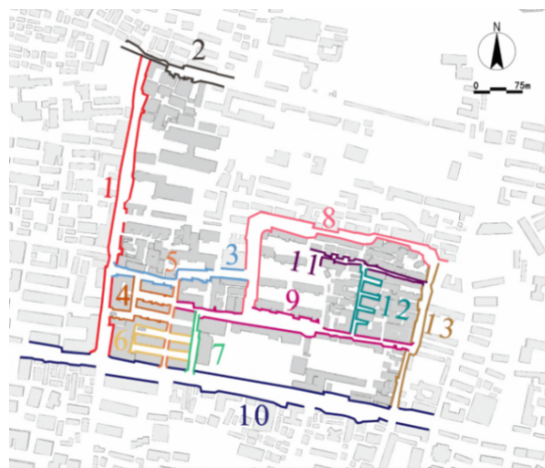


Fig. 2. Diagram of Garden Hill community section zoning.

models, and the spatial characteristics of the community streets are analyzed from the perspective of topological geometry. The drawn axis model is imported into DepthMap software for calculation, and the street integration degree, connection value and selection degree are derived, and the correlation values of the above variables are analyzed to find out the street synergy and pedestrian flow interface.

The axial model focuses on the spatial accessibility of the street, and the warmer the color of the axial line, the higher its integration and the higher its spatial accessibility [5]. According to the results of global integration, the streets around the Garden Hill community have the highest global integration with the warmest linear color in No. 10 Grain Road Street and No. 1 Rouge Road, followed by No. 5 Shuangbai Front Street and No. 3 Shuangbai Back Street, which are close to Rouge Road. This coincides with the field survey, where a large number of commercial supermarkets and farm stores are gathered near Rouge Road, which is a gathering point for the surrounding residents. From the spatial grouping analysis, the street accessibility in the west and south of the community is higher than that in the north and east. In reality, with the opening of the neighboring subway lines 2 and 7, the accessibility of the northeast has improved, and the eastern part shows a negative correlation with the analysis of global integration. From the local integration degree, its value changes are generally consistent with the global integration degree, with the difference that the local integration degree is higher and the accessibility is relatively better in Shuangbaiqian Street, Han Sanguang and Qiepa Street, which indicates that it can play a role in strengthening the interconnection of street spaces and contribute to the improvement of the overall spatial network.

In the spatial syntactic axis analysis, the ratio value of global integration degree (R_n) to local integration degree (R_3) is the synergy degree (R^2), and its higher value indicates the stronger connection between the local and the whole. From the synergy degree, we can see that the synergy degree value of the pedestrian street in the Garden Hill community is 0.566171, which indicates that the spatial network of this street is generally central, and a large number of agglomerative pedestrian flows converge to make the spatial vitality of Rouge Road and Grain Road Street high, but the other street networks in the surrounding area do not play a proper role in functional and spatial decongestion. Compare the degree of integration (R_n) and the degree of choice (Choice), and the comparison value can get the human flow interface R^2 . The higher the value of the human flow interface, the greater the possibility of people gathering and passing through here, and the attractiveness of the space. High, which can tap the potential of its street space nodes as activation points. From the human flow interface, it can be seen that the R^2 value is 0.19303, which is lower than 0.5 as a whole, and the correlation is weak, indicating that the overall network structure has not had a positive impact on the mobility of the internal street space. (Fig. 3).

The visual field model analysis combines the spatial model with the human sight observation, and the visual field integration degree is obtained by parsing the space based on the visual field depth value with the grid square as the basic unit, the higher the value, the warmer the color of the space corresponding to the model and the larger the visible area, and the colder the color is vice versa. From the spatial integration degree of street space (Fig. 4), it can be seen that in the areas with lower building density and wider road width, specifically in the west and south, the color is warm, indicating that the space

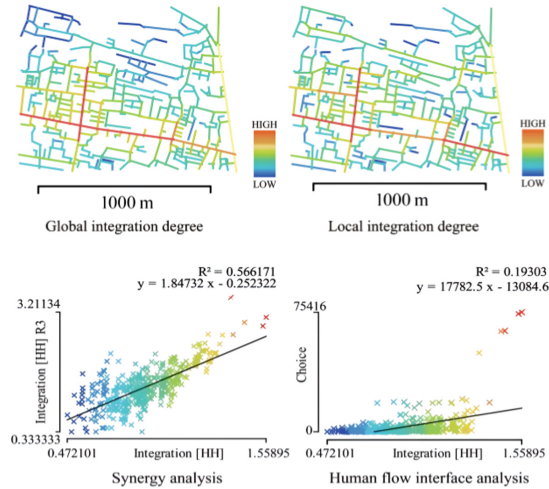


Fig. 3. Data analysis of community street space under spatial syntax.

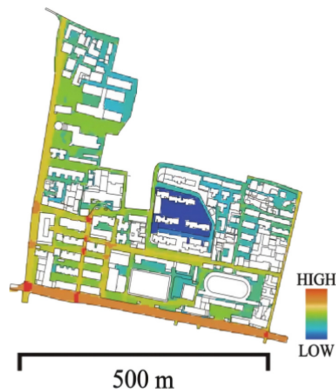


Fig. 4. View integration analysis.

is more feasible, easily perceived and sensed by pedestrians, and they are more willing to approach these places and have more frequent pedestrian activities. On the contrary, in the east, near the area of No. 13 Checkerboard Street and No. 11 Drum Rack Slope, the building density is high and the surrounding interface is visually obscured, making it difficult for pedestrians to penetrate into the interior of the street and the space lacks vitality.

Based on the above analysis, it can be seen that the locations with the highest accessibility, feasibility and mobility within the old community are mainly distributed in the streets where stores gather, and the spatial accessibility and vibrancy are also relatively high, and these streets are densely populated, have a strong concentration, and are also more easily perceived by pedestrians. However, the overall connectivity of the street network in the community is not high, and the space lacks certain connections due to

road blockage, insufficient functions, and visual occlusion, so it cannot effectively play the role of evacuating the flow of people and stimulating the vitality of the space.

4.2 Status of Street Road System

The Garden Hill community is bordered by two major city roads to the north and south, and secondary city roads to the east and west. The roads in the community can be roughly divided into three levels, subdivision-level roads, group-level roads and house front roads. The community-level roads form an inner-loop road with four sections of 3, 5, 8 and 9, and connect two branch roads from east to west, whose width is about 10 m, the widest being 14 m and the narrowest only 6 m. However, due to the early construction age, the roads are now occupied with parking area on both sides, and the roads can only barely achieve two cars staggered, and some of the roads only allow one car to pass and do not separate pedestrian and vehicle traffic. Community 4, 7, 11, 12 for the group road, mainly connecting the Shuangbai District, Han Sangong, Shuxiang Yuan, Drum frame slope four community groups and the main community-level road traffic, the average width of the road is about 8m. The road is narrower, accommodating only one car to pass, and most of the road is unmanned and traffic diversion. As the Garden Hill community building row is more mixed, the road in front of the house also shows different forms, to the west unit system within the residential Shuangbai district, for example, its 4, 6 sections of the road part of the width of up to 12m, the street road is divided into carriageway and sidewalk, equipped with house green space. In contrast, the residential houses in East Drum frame slope and Han Sanguong are relatively densely packed, and the road in front of the house is only about 2m wide, with only pedestrians passing through and no vehicles entering. The roads at the community level are relatively flat, while the roads at the group level and in front of the houses are not maintained, and some of them have slight cracks, damages and potholes. (Table 1).

From the current status of the survey, we can see that the old community did not consider the general development of motor vehicles in the early stage of construction, resulting in the width of the roads in the community does not meet the actual needs of today. Because there are many households, many vehicles and little land in the community, some of the main roads in the community are forced to be occupied as parking area, which causes huge pressure on the ground traffic, and the people and vehicles cannot be separated, and the car and walking paths are mixed and intermingled, which has certain safety hazards.

4.3 Street Environmental Quality Status

The environmental quality of the thirteen sections of the street pedestrian space was organized into three aspects, such as the building façade condition, the number of seats, trees, street lights and fitness equipment (Table 2) for analysis and evaluation based on the field research and photographs taken. From Table 2, we can see that the overall environmental quality of 1, 9, 10 and 13 is better, mainly benefiting from the compact commercial layout along the street, coupled with better street management and maintenance, which makes the space relatively clean and tidy compared to other road sections. On the contrary, the space of 3 and 5 sections is densely packed with stores along the

Table 1. The current status of street roads in the community of Garden Hill on Grain Road Street.

Road Section	Width (m)	D/H	Road height difference treatment	Road paving status
1	18–25	0.8–1.2	stairs	Flattening
2	8–12	0.8–4	None	Flattening
3	6–14	0.4–0.7	slope	More flat
4	12	0.6	stairs	Breakage
5	6–9	0.4–0.6	None	potholes
6	10–12	0.5–0.7	stairs	Damage, dent
7	5–6	0.2–0.3	slope	Flattening
8	4–14	0.4–2	slope	Flattening
9	6–9	0.3–1.5	None	Flattening
10	18–20	0.8–5	stairs	Flattening
11	3–9	0.2–0.5	None	cracks
12	6–12	0.6–1.3	slope	Damage, potholes
13	4–10	0.6–1	slope	Flattening

street, but the stores are badly damaged, no trees are cultivated, and the public facilities are insufficient, leading to a lower overall environmental quality of the space. 4, 6, 11 and 12 basically belong to the community's internal residential sections, with more greenery in front of the houses, part of which belongs to the landscape planning of the community in the early stage, and part of which belongs to the "small garden" built by the residents at a later stage. Garden", but because the greenery is not maintained for a long time, the vehicles are parked in a disorderly manner, leaving less space for walking and serious spatial imbalance. In addition, the No. 2 section belongs to the historical and cultural district, and No. 7 belongs to the section under the jurisdiction of the school, with harmonious and unified building facade, better spatial maintenance and high environmental quality. In general, the street pedestrian space in the Garden Hill community near the western Rouge Road and Grain Road Street is more vibrant and has a higher environmental quality. It is in contrast to the streets near Checkerboard Street in the east.

In the community street space, infrastructure such as signs, lighting, vignettes, rest and entertainment can play a good role in guiding residents to go out, and also provide a comfortable and convenient street travel environment. However, the aging of houses, unreasonable infrastructure configuration, single function of green landscape and confusion of public activity sites in old communities are becoming increasingly prominent environmental problems, leading to poor experience and reduced comfort of residents walking in the street space, thus leading to a lack of community vitality.

Table 2. Analysis of spatial environmental quality elements of the street.

Road Section	Building facade condition	Number of Public Facilities		
		trees	Seats	lights
1	Neat and clean	75	0	8
2	Tidy and harmonious	12	5	2
3	Storefront defacement	0	0	2
4	Serious private construction	7	3	2
5	Part of the facade, pavement defacement	0	0	3
6	Serious private construction	6	4	2
7	Neat and clean	28	0	2
8	Part of the road graffiti, small ads	32	7	6
9	Part of the facade is defaced	46	3	11
10	Dry, neat and clean	147	0	9
11	Facade breakage	0	0	3
12	Facade breakage	2	4	5
13	Part of the facade is defaced	11	0	8

5 Old Community Street Space Optimization Strategy

5.1 Sound Street Evaluation System, Accurate and Straightforward Old Reform Pain Points

With the preparation of street design guidelines around China, street construction has returned to the “people-oriented” model. The transformation of street space in old communities is directly related to the quality of life of residents and promotes the development of urban public space, which means that a more comprehensive evaluation system and more refined planning, design and management are needed, which is also the basis for a long-term mechanism of organic renewal in old communities [6]. This paper explores the method and implementation mechanism of the street space evaluation system in old neighborhoods, using the spatial sentence method to quantify the overall street system and data calculation to clarify the deficiencies of the community street network structure, and at the same time combining the PSPL research method to conduct multivariate data fusion analysis on the environmental indicators of the street space to find the root causes of community-related problems and thus implementing corresponding strategies. In the hope of solving the painful problems of old community old reform and providing certain suggestions for the evaluation system of street space in old communities.

5.2 Optimize the Street Network Structure and Weave and Complement the Road Traffic System

The Garden Hill neighborhood has a good pedestrian base with pleasant street scales. However, due to the development of motorized traffic, the street scale cannot meet the

demand of private motorized traffic, and there are some existing ding-zhi roads and cut-off roads in the community. Network connection does not directly affect the efficiency of street pedestrian space use, and the pedestrian choice is low, the vitality is low, and the pedestrian path shows fragmentation.

Based on the current status of the community street network, determine the currently available paths and use “unclogging”, “connecting”, “weaving” and other related means to encrypt and optimize the network: Sort out the existing paths to retain a good and complete road system in the community; Weaving and patching fragmented paths to increase the network density and restore the street network structure in the community. At the same time, we should focus on the linkage and complementarity of the street network and public transportation network to meet the travel requirements of the community within a short distance, to improve travel efficiency, expand the range of street transportation, and guide a reasonable community travel structure.

5.3 Balance the Functional Layout of the Street and Improve the Pedestrian-Vehicle Separation System

The road traffic pressure to the west of the Garden Hill community is high, and the traffic connection between the north and south streets is insufficient. Except for the main roads, the walking and car space is seriously intertwined, people and vehicles are not separated, the safety of walking is low, and the travel experience is poor.

Combined with traffic stabilization design, the community is divided into a static living area mainly for walking and a dynamic travel area combining car and foot. Living-oriented streets in the community restrict the passage of private cars, encourage slow travel modes, build a continuous slow travel space system, and create a safe street environment. Travel-oriented streets add speed hills and speed tables to reduce the speed of motor vehicle trips; Combine building setback space to sort out sidewalks and non-motorized lanes, as most of the roads in the Garden Hill community are not wide enough to divide the special lanes for multiple uses, because of the adoption of the human and non-human co-panel design, and motor vehicle lanes are separated by guardrails or greenery to improve the safety and comfort of traffic travel. In addition, considering the situation of elderly people living in the community, ramps and lift platforms are used to improve the design of barrier-free access to ensure the orderly organization of residents' life and residential traffic.

5.4 Integrate Broken Space Resources and Connect Public Space Systems in Tandem

Due to the high density of the overall construction of the Garden Hill community, the entire area excluding schools and medical institutions can not form a large area of public open space, while the street space in the vehicle parking occupies most of the space area, residents build their own small gardens make space fragmented and disorderly, space suffered serious squeeze, the overall environment is poor, low walking comfort.

In response to the current situation, the existing landscape vegetation in the space is combined with the refurbishment of tree ponds, integration of greening configuration, rational planning of spatial resources, and increasing the spatial scale area of the

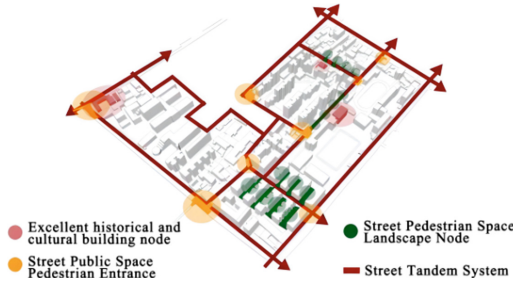


Fig. 5. Schematic diagram of street space cascade system.

street. For example, the landscape fence, drying racks and shelves are unified to save space resources and create an integrated spatial design; the three-dimensional design of greenery is adopted and some lawns and bushes are converted into parking spaces under evergreen trees. On this basis, we adopt the design method of “line with surface” and “point with surface” of urban catalyst theory, and consider the street as a linear open space in the city. Takes the street with green, integrates the scattered and block public space, and uses the scattered space to form small-scale activities in the large space. Without interfering with pedestrian traffic, expanding the range of public space radiation, forming a spatial effect of interpenetration and interpenetration (Fig. 5).

5.5 Improve the Recognizability of the Visual Field and Build a Characteristic Cultural System

The building facade of the roads south of the west in the community is basically dominated by store activities, compared to the roads to the east which are more recognizable and accessible. Identifiable roads will deepen people’s memory of the paths, making them easier to choose and approach, and more likely to induce walking behavior [7]. The community of Huayuanshan is also in the historical district of the old city, where there are excellent historical buildings such as the Wuhan High School founded by Dong Biwu and the “Half Garden” residence inscribed by Tan Yanxian, a calligrapher in the late Qing Dynasty. However, because of the broken road around the recognition is not strong, the accessibility is low, these historical sites are rarely known.

Combined with the above-mentioned catalytic theory, individual cultural attractions or corresponding cultural activities can be used to “lead the way” to link the overall pedestrian path of the community and improve the accessibility of internal roads. In order to activate the whole street space with excellent historical buildings as catalysts, node spaces with different functions, building facade forms and pavements of different materials can be set up in the community to guide pedestrians to enter, and obvious signs can be set up at the entrance of the street as road guides, or different road spaces can be

divided by distinctive colors to improve the sense of visual communication and make the space more recognizable.

6 Conclusion

At present, China's urban planning is transforming from "incremental planning" to "stock planning", and the future renewal mode of urban development is mainly based on "urban repair" [8]. As an important stock, promoting the renovation of old communities is an important engine to promote urban renewal. This paper conducts a field study on the street space of Huashan community in Wuhan City, integrating the spatial sentence method and PSPL research method in the street evaluation system to reveal the problems faced by the community, using the concept of network repair to fill the gaps in the community street network, balance the functional layout of the street, improve the pedestrian and vehicular traffic separation system, and consolidate the safety and convenience of the community street. At the same time, the design concepts of "point with surface" and "line with surface" are applied to improve the recognizability of street space, build streets with cultural characteristics, link public space systems, and other relevant renovation suggestions and targeted renewal strategies, with a view to improving the quality of the streets in the new round of old reform, the volume of the project has increased significantly, so as to provide some reference for similar old urban communities or areas.

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