DOI: 10.53469/jssh.2024.6(11).07

Research on Spatial Elements of Barrier-Free Environment Construction in Urban Livable Streets: A Case Study of Pingguo Yuan Street in Shijingshan District

Jia Wen, Zitong Tian, Yuhan Cai, Yingyu Tao, Jiawei Li, Lei Wang*

School of Architecture and Art, North China University of Technology, Beijing, China
Correspondence Author

Abstract: ***The study uses the Pingguo Yuan Street in Shijingshan District, Beijing as an example to analyze the current situation and problems of barrier-free environment construction in livable streets, and proposes corresponding optimization strategies. The research reveals numerous issues in the construction of barrier-free facilities in Pingguo Yuan Street, such as unreasonable design of paths, uneven distribution of facilities, unreasonable spatial scale, lack of identification systems, and many environmental obstacles. Consequently, the study proposes corresponding optimization strategies, providing useful references for researchers, government departments, and designers in the field of barrier-free environment construction in livable streets.***

Keywords: Livable streets, Barrier-free environment, Spatial elements, Optimization strategies, Special groups.

1. Research Background

Barrier-free environment construction is essential to urban development and has a direct impact on the quality of life for special groups. Promoting the establishment of barrier-free environments and providing more convenient and safe travel conditions for these groups can foster a high-quality living environment and facilitate sustainable urban development. To create an inclusive living space that benefits all members of society while adhering to high-quality living standards, it is crucial to gain a deep understanding of the perspectives of special groups, paying close attention to their needs. Currently, travel difficulties represent one of the primary challenges faced by special groups. Therefore, there is an urgent need to expedite the creation of safe and accessible street spaces while implementing effective policies and measures tailored to meet their requirements. This initiative not only respects and safeguards the basic rights of special groups but also serves as a significant indicator for assessing urban civilization levels and high-quality development.

1.1 Progress and Limitations of Barrier-free Environment Construction System

1.1.1 Progress in the construction of barrier-free environment construction system

As China continues its efforts in promoting barrier-free environments, societal awareness regarding this issue has intensified, leading to ongoing improvements in relevant policies and regulations. The enactment and implementation of the "People's Republic of China Barrier-Free Environment Construction Law" in 2023 signify China's commitment to establishing a legal framework for advancing barrier-free environment initiatives, ensuring that individuals with disabilities and elderly citizens can participate fully, equally, and conveniently in social life. Furthermore, the inclusion of a dedicated plan for barrier-free environment construction within the "14th Five-Year Plan" underscores the government's strong emphasis on this critical work.

During the 13th Five-Year Plan period, Beijing made significant strides in advancing the construction of barrier-free environments. Notably, during the 2022 Winter Olympics and Winter Paralympics, a dedicated initiative for enhancing barrier-free infrastructure was launched, accompanied by the formulation of the "Beijing Municipal Regulations on Barrier-Free Environment Construction." These initiatives have positioned Beijing at the forefront of national efforts to support individuals with disabilities, as evidenced by its inclusion in the "2020 United Nations E-Government Survey Report" regarding online services for people with disabilities. Despite these commendable achievements, several challenges remain. These include low utilization efficiency of urban pedestrian spaces by individuals with disabilities; a lack of comprehensiveness and systematic approach within the service guarantee framework; uneven distribution of resources across different areas; pronounced regional disparities; significant issues related to road occupation; inadequate safety measures; outdated service facilities; inefficient use rates; absence of identification systems; and insufficient directional information.

1.1.2 The current barrier-free environment construction system and its limitations

On one hand, the actual needs of special groups have not been adequately addressed in the policy formulation process. Addressing these needs is paramount in the construction of a barrier-free environment. During a special consultation meeting held by the Beijing Municipal Committee of the Chinese People's Political Consultative Conference in October 2023, Gao Yixuan, a member of the Beijing Municipal Committee and president of Beijing Investment Development Co., Ltd., highlighted that current digital applications primarily cater to individuals with digital technology skills, thereby overlooking the requirements of

special groups such as the elderly and people with disabilities. Bridging the "digital divide" and ensuring that more application scenarios are accessible to those who are less adept at using digital technology is a critical challenge that must be tackled during both construction and operational phases within digital communities. On the other hand, an aging population has resulted in an increase in elderly individuals with disabilities. Due to inadequate management practices, existing barrier-free facilities often fail to meet their actual travel needs. For instance, in Shijingshan District, current regulations remain insufficient to address the growing number of elderly individuals with disabilities; there is both an inadequate supply and subpar quality of barrier-free facilities available.

1.2 The Current Status and Realistic Dilemmas of Barrier-Free Environment Construction in Livable Streets and the Status Quo of Domestic Research

1.2.1 The Current Status and Realistic Dilemmas of Barrier-Free Environment Construction in Livable Streets

Since the promulgation of the Regulations on the Construction of Barrier-free Environment, remarkable progress has been made in the transformation of barrier-free homes in China. From 2016 to 2019, a total of 4.35 million disabled people in China completed home barrier-free renovation, and the coverage rate has improved significantly. The transformation work has gradually changed from standardization to individuation to better meet the differentiated needs of people with disabilities. While the indoor barrier-free environment construction has made remarkable progress, the outdoor barrier-free environment and barrier-free facilities, such as tactile path nodes, ramps, barrier-free elevators, are also increasingly popular in urban construction, which fully reflects the degree of civilization and humanistic care of the city.

However, challenges persist with non-compliant designs and poor maintenance issues. Regional development are nonuniformite, with large cities advancing rapidly, while older residential communities and smaller cities fall behind. Beijing illustrates this with challenges in its old areas. Smaller cities and rural areas are even further behind, often lacking basic facilities due to funding and attention shortages. Although the "Law of the People's Republic of China on the Construction of a Barrier-Free Environment" has been issued, and China is entering a new phase of legalization in barrier-free environment construction, practical implementation still faces issues such as limited enforceability and a lack of specific operational guidelines. Moreover, the specialized legislation for barrier-free environments is not yet comprehensive, and the operability of existing regulations and policies is weak, leading to significant defects in the design, construction, and maintenance of barrier-free facilities in many cities.

In summary, although China has made certain achievements in the construction of a barrier-free environment, it still faces many practical dilemmas. The existence of these problems highlights the limitations of barrier-free environment construction in terms of legal policies, regional development, facility construction, and maintenance. To address these issues, it is necessary to start with multiple aspects such as policy and regulation, planning and design, construction implementation, and maintenance management, to promote the comprehensive development of barrier-free environment construction.

1.2.2 The Status Quo of Domestic Research

Domestic research on livable streets mainly focuses on street space environment [1], pedestrian activities [2], urban security space, and the safety of street pedestrian systems. These studies mainly focus on the needs of pedestrians, reflecting the importance of people-friendly space and the comfort and happiness of people in space. Domestic research on barrier-free environments mainly focuses on universal design [3], safety design, and spatial form [4], with the target groups being visually impaired people and the elderly [5], who have relatively low tolerance for space. In China, the target population for research often focuses on individuals with visual impairments and the elderly. These groups, who have a relatively lower tolerance for the spatial environment, are often chosen as the primary subjects for research. The selection of target obstacle groups in domestic research is relatively limited. Barrier-free environments should be applicable to all special groups, regardless of their state, so that they can enjoy a good space environment. The key areas for barrier-free environment research are mainly old town areas and urban fringe areas with low population vitality. Due to the low population vitality, economic investment, and talent loss in low-vitality areas, the construction of the environment in these areas is significantly different from that in high-vitality areas. There is a lot of information about the current situation of barrier-free environment research, which is convenient for in-depth research. However, there are also many unique problems in the construction of barrier-free environments in high-vitality areas. With the rapid development of cities, the barrier-free environment construction of new areas also needs our attention.

This study starts from the space where people live for a long time, takes the emerging urban area of Pingguo Yuan Street in Shijingshan District as the research location, focuses on the spatial environment elements of high-quality travel in livable streets, and conducts optimization research on the spatial elements of barrier-free environment construction in livable streets for various groups of people with disabilities. By using spatial perception equipment and field research and interviews, this study collects data, analyzes and summarizes the design problems and potential risks of barrier-free environment construction in spatial elements, and aims to propose targeted optimization strategies, providing effective references for the construction of barrier-free environments in China and creating a high-quality living environment for all members of society.

2. Current Status of Barrier-Free Environment Construction in Pingguo Yuan Street

2.1 Basic Information of Pingguo Yuan Street

2.1.1 Location Information:

Pingguoyuan Street is located in the northern part of

Shijingshan District. It borders Haidian District to the east at Xinsipingtai, adjacent to Bajiao and Gucheng Streets to the south along the Jingmen Railway, connects to Jinding Street to the west at the line of Liwangfen and Jinding Mountain, and is separated from Haidian District by the Cuiwei and Qinglong peaks in the north. The jurisdiction area covers 13.13 square kilometers, with 21 communities under its administration and a permanent resident population of over 90,000. [6].

2.1.2 Transportation Information and Regional Positioning:

Pingguo Yuan Street is located in the northern part of the city, featuring a reasonable transportation network layout. The main road, Pingguo Yuan Street, is spacious and connects with surrounding areas, supplemented by multiple secondary roads and branch roads to form a dense road network. The area is adjacent to the expressway Futai Road in the west, offering a quick connection between the city center and the suburbs. Although there is heavy traffic volume and congestion during peak hours, traffic management measures are effective, maintaining orderly traffic. In addition, ample parking facilities provide convenience for residents and visitors, and the overall traffic situation can meet the daily travel needs of residents.

Figure 1: Regional division of Shijingshan District in Beijing

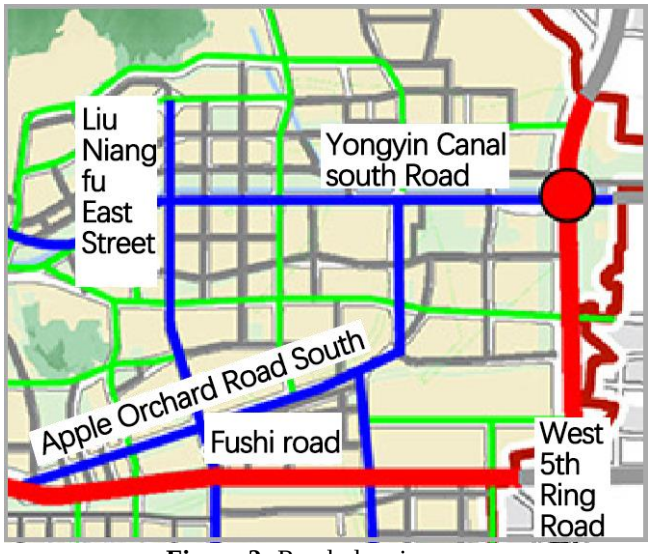

Figure 2: Road planning map

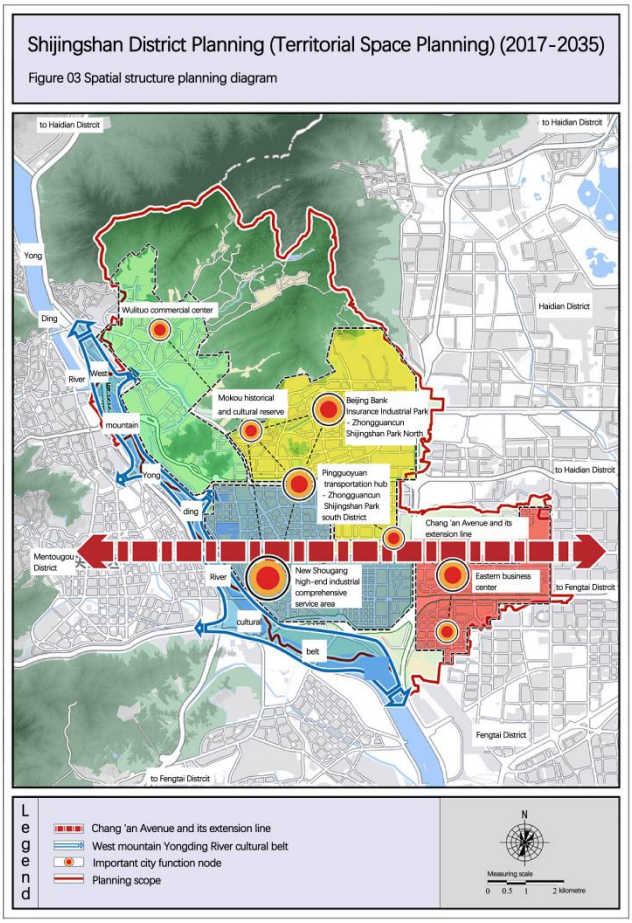

Figure 3: Shijingshan district spatial structure planning diagram

Simultaneously, within the Pingguo Yuan area, there are two significant urban functional nodes: the Beijing Banking and Insurance Industrial Park - Zhongguancun Shijingshan Park North District, and the Pingguo Yuan Transportation Hub - Zhongguancun Shijingshan Park South District, as shown in Figure 3. The area's superior geographical location makes it the core technology industry region and an important transportation hub within the Shijingshan District. As an important transportation hub in the Shijingshan District, the Pingguo Yuan area has consistently adhered to the strategy of prioritizing the development of urban public transportation. The ground public transit network and rail transit network have been established. The mature land function utilization, comprehensive road network, and high coverage of public transportation development provide the most basic conditions for the construction of a barrier-free environment in the Pingguo Yuan area [7].

2.1.3 Public Facilities:

Pingguo Yuan Street boasts numerous kindergartens, primary schools, junior high schools, and high schools, such as Pingguo Yuan First Primary School and Pingguo Yuan Middle School, providing high-quality educational resources for residents. Additionally medical institutions such as the

Plastic Surgery Hospital of the Chinese Academy of Medical Sciences and the Beijing Workers' Sanatorium, providing comprehensive medical services for residents. The area is equipped with supporting facilities to meet the basic needs of residents, yet there is a notable absence of special education schools, and the educational and learning needs of special groups have not been met. However, the area is comprehensive medical system, and people with congenital or acquired disabilities can receive systematic treatment. In terms of cultural facilities, Jinguo Cultural Courtyard is the compre hensive cultural center of Pingguo Yuan Street, with various unique activity venues such as a reading room, calligraphy and painting room, and dance rehearsal room. It also often holds elderly activities and mutual assistance activities, providing rich cultural and entertainment activities for all residents.

2.1.4 Population Structure:

According to the statistics of Pingguo Yuan Street in 2011, the population was 101,800. By the end of 2023, the number of disabled people in Pingguo Yuan Street was 264. In September 2024, there were 11 people receiving subsistence allowances in Pingguo Yuan Street. Although the number of disabled people in the street is small, they receive high attention. Pingguo Yuan Street held a training meeting on the needs assessment of Beijing disabled people's services in 2023[8], thereby increasing attention to special groups. The population structure of the street is relatively balanced, covering all age groups and demonstrating a complex demographic makeup. At the same time, because Pingguo Yuan Street is located in the northern part of Shijingshan District and is close to Zhongguancun Science Park and Shijingshan Park, there are many people engaged in technology, education, and medical work among the residents, contributing to a complex population structure and high regional vitality.

2.2 Xijing Road

2.2.1 Basic Information

1) Location:

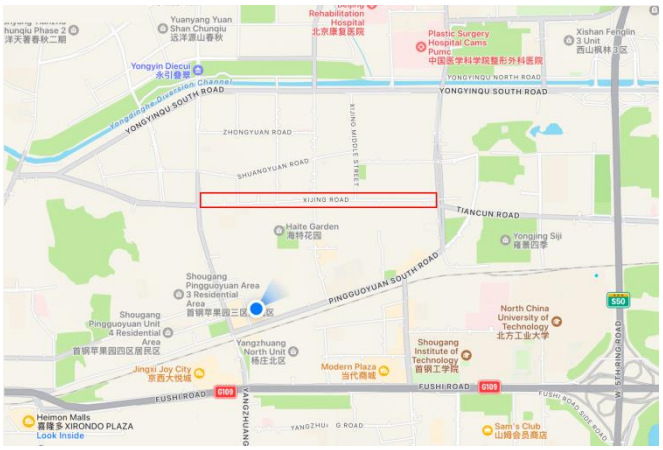

Figure 4: Location analysis diagram of Xijing Road

Xijing Road is located in Shijingshan District, Beijing, near the southern part of Pingguoyuan Road, Badachu Road, Pingguoyuan Avenue, and the southern part of Yongyinqu Road. In terms of public transportation, there are several bus stops along the street, including Haitegarden, Xijing Road, and Xijing Community, allowing passengers to transfer to multiple bus lines such as 663, 958, and 972. We selected the section of Xijing Road west of the intersection with Shixin Avenue as the research area to analyze the spatial elements of barrier-free space.

2) Surrounding Environment:

Functional Analysis of Xijing Road:

Figure 5: Functional partition diagram

We have selected the areas north and south of Xijing Road as the primary research areas. The northern side of Xijing Road is a commercial district, where the commercial real estate types primarily consist of ground-level shops, including categories such as catering, lifestyle services, convenience stores and supermarkets, as well as financial services like banks. The southern side of Xijing Road, stretching from west to east, is populated with a catering commercial area, community service centers and police stations which serve as public management and service facilities, educational land for kindergartens and primary schools, and extensive residential areas. The diversity of service types around Xijing Road not only generates stable economic returns for businesses but also meets the living needs of residents and employees, thus providing convenience for the daily lives of the community members.

From the perspective of spatial environmental organization, the residential areas are distributed on the southern side of Xijing Road, with community service centers and police stations located on the same side, ensuring the convenience and safety of the residents' lives and providing a relatively comprehensive public service. Moreover, the commercial district on the northern side is separated from the residential areas by Xijing Road, which reduces noise and ensures a certain quality of life for the residents. The proximity of the commercial district to the residential areas, coupled with a variety of business formats, facilitates daily shopping and consumption for residents while injecting vitality into the regional economic development.

Analysis of the Traffic Flow around Xijing Road:

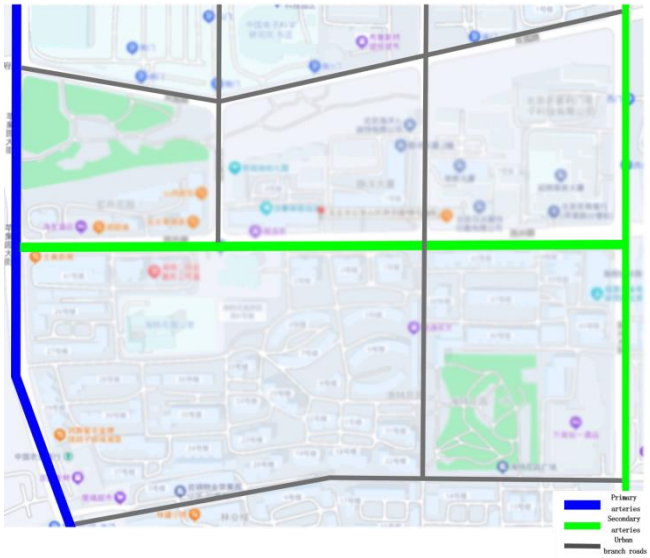

Figure 6: Traffic flow diagram

Xijing Road serves as a secondary trunk road and is a major thoroughfare within the region, connecting the Pingguo Yuan neighborhood with its surrounding areas. The road is bidirectional with a significant volume of traffic. Concurrently, Xijing Road links to Pingguo Yuan Street, and heading south along this street leads to Fushi Road, which is an urban expressway connecting the city center of Beijing with other outlying areas. Moreover, the vicinity of Xijing Road is surrounded by multiple secondary roads and side streets, forming a dense network. These roads, of various sizes, offer convenient travel options for residents, be it for journeying to the distant city center or accessing nearby supermarkets and shopping centers.

2.2.2 Spatial Elements

1) Spatial Organization

Spatial organization includes functional and circulation aspects. In the functional organization of living streets, the division, connection, and proximity relationships between different functional areas influence the circulation patterns of people through the street. For individuals with disabilities, an appropriate circulation organization is essential. This study has conducted research on the behavior flow of special groups along the selected Xijing Road.

Xijing Road is divided into vehicle lanes and pedestrian pathways. The pedestrian pathways have a maximum effective width of 2.5 meters, with no significant changes in width on either side of the road. The width of the tactile paving for the visually impaired is 0.4 meters and is medium-yellow in color. The tactile paving shows no significant damage or occupation by manhole covers and is continuously distributed along the street, connecting various functional areas such as residential communities and educational and commercial public service facilities. The overall spatial circulation organization is reasonable, but the layout of the circulation paths in some details of the tactile paving needs further attention.

As shown in Figure 7, at the Haite Garden bus station, the tactile paving passes through the bus stop but does not have special alerts for the visually impaired, and its location at the back of the bus station waiting area is unreasonable. The tactile paving is not connected to the waiting area. The Xijing Road bus station lacks tactile paving, and the bus station is not connected to the pedestrian pathway, making it impossible to establish a smooth circulation path for the visually impaired.

Figure 7: Haite Garden (left) and West Jing Road (right) bus stops

As shown in Figure 8, the entrance and exit of the western district of Haite Garden residential area lack special alert tactile paving. Walking along a straight thoroughfare, like Xijing Road, the absence of alert tactile paving leads to a high degree of regional similarity, making it difficult for individuals with disabilities to locate specific destinations.

Figure 8: (left) Gate 1 North of the West District in Haite Garden Residential Area; (right) Gate 2 North of the West District in Haite Garden Residential Area

As shown in Figure 9, accessible facilities are clustered at the entrance of the community service center and the police station, located on the western side of the road to the south of Xijing Road. This is in close proximity to the North Gate 1 and 2 of the western district of Haite Community. These facilities are also situated along the main circulation route, which enables individuals with disabilities to access them quickly and conveniently for comprehensive consultation and assistance services. This facilitates the rapid resolution of real-life issues they may face, thereby enhancing their quality of life. However, it is apparent that the distribution of accessible facilities within the area is too concentrated, and the range of accessible facilities is limited, with the absence of essential public services such as accessible restrooms. Consequently, the overall implementation of accessibility in the area is still inadequate.

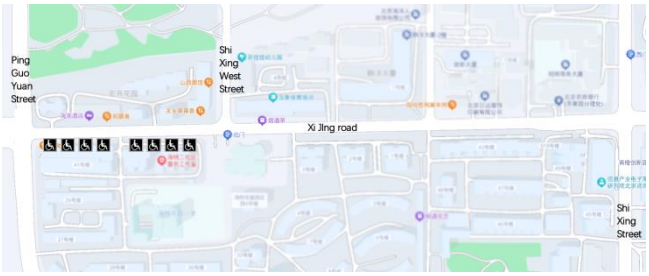

Figure 9: Distribution map of barrier-free facilities

2) Spatial Form

In terms of spatial morphology, it is particularly crucial for people with disabilities to have an appropriate spatial scale and consistent spatial shape. For example, an overly large indoor space can affect the length of the route that visually impaired individuals need to navigate, making it difficult to find their way and posing potential safety risks. Similarly, overly long and wide traffic spaces also impact the spatial awareness, of visually impaired individuals. The shape of the space, whether it is circular or rectangular, provides different directional judgments and perceptions of safety for visually impaired individuals [4]. The same principles apply to external spaces. In terms of horizontal spatial scale, the effective width of the Xijing Road pedestrian pathway is 2.5 meters, which is moderate in width, sufficiently long, and straight, making it suitable for the passage of individuals with non-visual impairments. However, the tactile paving for the visually impaired is excessively winding in some areas. A winding linear space can negatively impact the sense of security in navigation and lead to difficulties in finding the way. Visually impaired individuals require direct and short traffic routes and need clear indications of direction changes.

As indicated in Table 1, the linear space of the tactile paving is too winding, and when the direction changes, it does not form right-angled turns or include special tactile paving to provide alerts. This can lead to disorientation for visually impaired individuals, making it unclear where they are when changing directions, and thereby reducing their sense of security and confidence in navigating. It is essential to design tactile paths that are straightforward with clear markers for direction changes to enhance the safety and ease of navigation for visually impaired users.

Table 1

Table 1	Current Photo	Current Conditions
The Intersection		A blind path at a bend is a reminder blind path that is curved and has no special protrusion.
Manhole Cover		The linear space of the tactile paving is too convoluted and lacks special raised alert strips.
Manhole Cover		The linear space of the tactile paving is too convoluted and lacks special raised alert strips.

Regarding the vertical spatial scale, the majority of shops situated on the northern side of Xijing Road exhibit a discrepancy in height in relation to the sidewalk where tactile path nodes are positioned. As shown in Figure 10 and 11, The sidewalk is connected to the shops by stairs and there is no stone ramp or barrier-free ramp. The only ramp on the road has too steep an angle, so making it inaccessible for people with physical disabilities . It directly cuts off the possibility of people with physical disabilities wishing to engage in commercial activities on the north side of Xijing Road, making the road only a simple passing passageway for such people with physical disabilities, and does not promote economic development and enrich the life and entertainment of special groups. Simultaneously, the tactile path nodes on the northern side are also encroached upon by both motorized and non-motorized vehicles, indicating a deficiency in parking space in the area, which consequently leads to a reduction in barrier-free space.

Figure 10: Overview of the Space on the North Side of Xijing Road

Figure 11: Motor Vehicles Occupying the Road

3) Spatial Node

Spatial nodes are categorized based on function into those related to spatial orientation and those related to route selection.

In this section of the road, nodes related to spatial orientation primarily refer to the entrances and exits of residential areas, while nodes related to route selection mainly involve intersections. Although the physical conditions of individuals in special groups, lead to different difficulties encountered during wayfinding, in the wayfinding process for special groups, the entrances and exits of residential areas, as essential locations in their daily living routines, are high-incidence locations for wayfinding difficulties. Typically, only residents who have lived there for a considerable time and are familiar with the routes can find the

entrances and exits smoothly. Entrances that are not clearly marked, lack accessible facilities, and have spaces that are inconvenient for walking can cause difficulties for people with disabilities when entering and exiting their living spaces.

As shown in Figure 12, the pedestrian entrance and exit positions are not obvious and lack accessible signage. The pedestrian pathways at the entrances and exits of the residential area are relatively narrow and lack accessible facilities such as handrails. During peak morning and evening times, this can lead to congestion, which is not conducive to the smooth comings and goings of residents living their daily lives.

Figure 12: The North Gate of the West District in Hite Garden Residential Area

Similarly, at crossroads, which are key locations for path selection, traffic lights, road signs, and volunteer guides provide vital route choice information for individuals with disabilities. As shown in Figure 13, this section of the road is equipped with complete signage and pedestrian crossing facilities that include voice prompts and audible signals, effectively ensuring barrier-free passage for the visually impaired and safeguarding the travel safety of special groups as they navigate intersections.

Figure 13: Intersection of Xijng Road and Shixing Street

2.2.3 Environment Elements

1) barrier-free Signage System

When there are no distinctive accessibility signs and no volunteers or comprehensive accessibility maps to provide adequate guidance, special groups will be unable to accurately determine their current location or the direction in which they need to travel. Additionally, the absence of an emergency call device prevents them from reaching their destination correctly, posing potential safety risks and an inability to ensure the personal safety of people with disabilities. In the area under investigation, there is a serious lack of essential important components in the signage system. Apart from directional signs at intersections, there are no other signage systems in the environment, which means that the smooth travel and safety of individuals with special groups in the area cannot be reasonably guaranteed.

2) Barrier-free environment

For individuals with disabilities, in addition to universal accessible facilities, factors such as obstacle-free pathways, sound environment, light environment accessibility, road interface materials, and building colors are also crucial. An excessive number of environmental barriers can impact the daily living of people with disabilities. Ensuring the smoothness of road surfaces, the openness of pathways, and the cleanliness and aesthetics of the street environment, as well as its hygiene, are all essential. The condition of roads and space interfaces affects the mobility of individuals with disabilities. Street hygiene, the presence of unpleasant odors, and the state of street greening not only impact the health of people with disabilities but also affect their perception of the surrounding space, increasing the risks they face in their environment.

On West Jing Road, obstacles on the road can be roughly categorized into fixed and movable obstacles. Fixed obstacles that permanently block the passage of individuals with disabilities are a result of poor design. Movable obstacles, primarily consisting of vehicles, are due to human factors and can be improved through notification and proper management. Currently, West Jing Road has many obstacles that hinder mobility and affect the diverse living experiences of people with disabilities. As shown in Table 2.

Table 2

Table 2	Current Photo	Current Conditions
Fixed obstacles		A single side handrail with a barrier at the end of the path blocking pedestrian traffic.
Movable obstacles		The tactile paving for the blind is occupied by motor vehicles and non-motorized vehicles, affecting pedestrian traffic.

As shown in Figures 14-19, Xijing Road has excellent road smoothness and architectural style, but a poor degree of road openness, with relatively narrow spaces and a serious street odor problem. The road's sanitation is generally average; although the colors in the image are dark, they mostly range between 0.61-0.8, which is not considered excellent. Additionally, the distribution of green spaces in the area is uneven. Overall, the Xijing Road area has a poor barrier-free environment. It requires further management and rectification

of sanitation issues, as well as reasonable planning for the distribution of green spaces, to widen the field of view and ensure an open traffic space in the area.

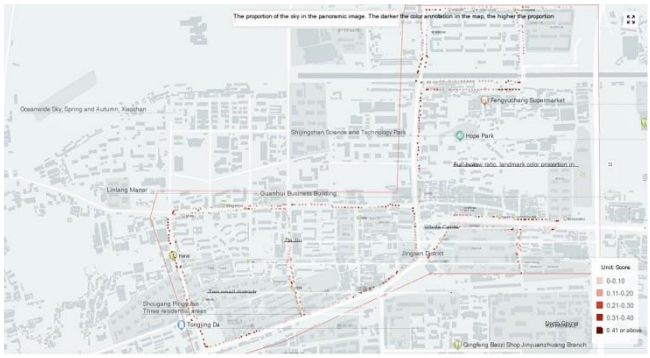

Figure 14: Analysis Report on the Degree of Road Openness (Survey area general map)

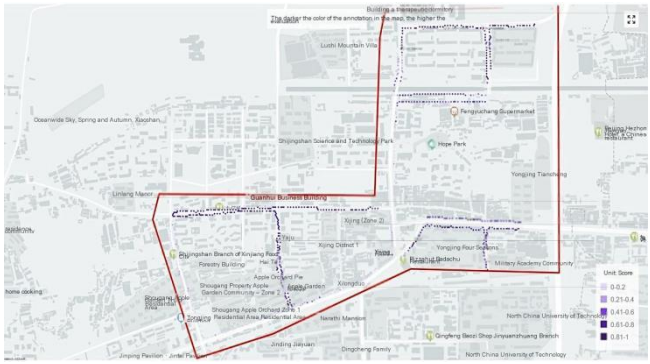

Figure 15: Architectural Aesthetics Evaluation Report (Survey area general map)

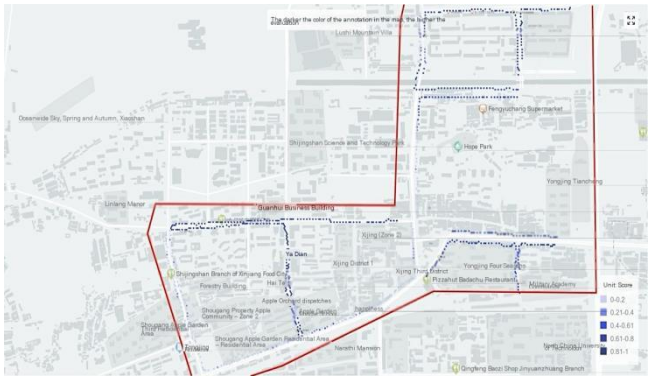

Figure 16: Street Environmental Sanitation Evaluation Report (Survey area general map)

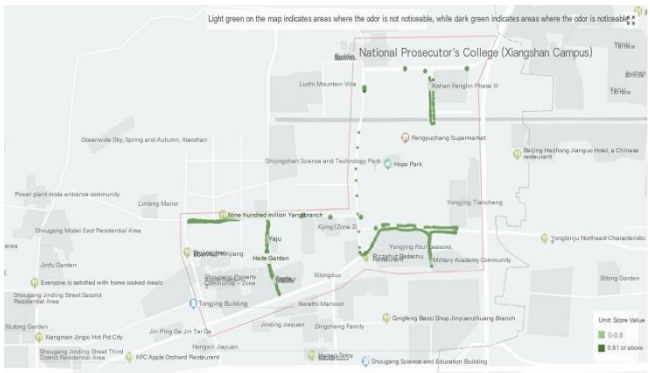

Figure 17: Odor Monitoring and Analysis Report (Survey area general map)

Figure 18: Roadside Green Belt Distribution Analysis Report (Survey area general map)

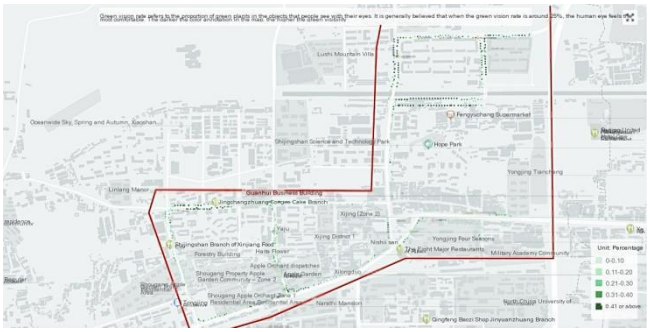

Figure 19: Green View Index Analysis Report (Survey area general map)

3) Community service

The community service center in the Xijing Road area serves the residents of the Hite Garden Second Community. The overall construction of accessibility facilities in the community is relatively comprehensive, with accessibility ramps installed at the entrance of both the community service center and the police station. However, the variety of accessibility facilities is limited, and the maintenance and management of these facilities in the community are still insufficient. It is common to see the obstruction of blind paths, and the community management services still need to be further strengthened.

3. Analysis of the Current Spatial Element Issues in the Construction of Barrier-Free Environments in Livable Streets

3.1 Spatial Organization Aspects

Tactile Paving Issues: The design of certain details of the tactile paving is flawed, such as the lack of alert strips at turning points and sections that are too winding, which impacts the safety and efficiency of wayfinding for individuals with visual impairments.

Uneven Distribution of Accessibility Facilities: Accessibility features are concentrated near community service centers and police stations, with a shortage of public service facilities like accessible restrooms, failing to cater to the diverse needs of people with disabilities.

Lack of Accessibility Facilities in Some Areas: For example, at Xijing Road bus station and the entrances and exits of some residential areas, the mobility needs of individuals with physical disabilities are not adequately addressed.

3.2 Spatial Form Aspects

Inappropriate Spatial Scale: The width of sidewalks is moderate, but some tactile paths are too winding, affecting the spatial cognition and sense of safety in wayfinding for individuals with visual impairments.

Unclear Spatial Shape: Some tactile path turning points lack right-angle turns or distinct alert strips, leading to confusion in direction for individuals with visual impairments and reducing the sense of safety in wayfinding.

Height Difference Issues: There are height discrepancies between some commercial shops and the sidewalks with tactile paths, with a lack of accessible ramps, impeding the movement of individuals with physical disabilities.

3.3 Spatial Node Aspects

Inconspicuous Residential Area Entrances: Some residential area entrances lack accessible signage, and the entrances themselves are narrow, which is inconvenient for people with disabilities.

Insufficient Facilities at Intersections: Some intersections lack traffic lights, road signs, voice prompts, and other facilities, which affect the route selection and safety of individuals with disabilities.

3.4 Environmental Element Aspects

Missing Accessibility Signage System: The environment lacks an accessible signage system, making it difficult for individuals with disabilities to identify their location and direction, and posing safety risks.

Numerous Environmental Obstacles: The presence of fixed and movable obstacles on the roads hinders the movement of individuals with disabilities, such as vehicles occupying tactile paths and narrow sidewalks.

Road Interface Issues: The degree of openness of the roads is poor, street cleanliness is average, and the distribution of greenery is uneven, affecting the travel experience and physical and mental health of individuals with disabilities.

3.5 Community Service Aspects

Inadequate Maintenance of Accessibility Facilities: The maintenance and management of accessibility facilities in the community need to be strengthened, such as the common issue of tactile paths being obstructed.

4. Barrier-free Construction Design Strategy for Livable Streets

4.1 Optimized Node Design

This study finds that there is a lack of accessible alert functions at points where road conditions change, at corners, and at key nodes leading to major buildings along Xijing Road. To address this issue, the following optimization strategies are proposed: Firstly, enhance the identifiability of nodes. It is suggested to differentiate the paving materials at tactile path nodes to distinguish between different functional areas; adjust the colors of accessible facilities such as tactile paths and ramps at key nodes, for example, changing the traditional yellow to red, to enhance the visual cues for individuals with visual impairments. At the same time, optimize the tactile sensation wave level of the tactile path to improve recognizability. Secondly, add visual prompt lights and dynamic indicators. Install visual prompt lights and dynamic indicators around key street nodes and public facilities, with special attention to the inconsistency of accessible facilities at bus stations on Pingguoyuan Street. Pay particular attention to areas with inconsistent accessible facilities, such as bus stations on Pingguoyuan Street. Thirdly, retrofit bus stations for accessibility: Firstly, popularize electronic station signs that provide real-time voice announcements of vehicle information to serve individuals with hearing impairments; secondly, set up wheelchair paths with ramps and anti-slip edges to ensure the safety and comfort of wheelchair passengers; thirdly, optimize waiting areas, divide queuing areas by route, and set up handrails with Braille and vehicle information for the identification and use by individuals with hearing and visual impairments; fourthly, install touch screen information query terminals, equipped with touch screens, to provide real-time traffic information and route guidance, supplementing the lack of audio signals, and better serving individuals with various disabilities.

4.2 Introduction of Digital Road Signage System

Establish prominent road signs and digital maps at major intersections, using vividly colored text and arrows for easy identification. Additionally, add Braille to the bottom of the signs and provide a one-button voice system activation for easy access to information by individuals with visual impairments. The digital maps will not only indicate nearby accessible facilities but will also specially plan an accessible route, providing more convenient travel guidance for individuals with disabilities. The survey shows that although accessible infrastructure such as curb ramps, straight stairs, and accessible restrooms is becoming more common in daily life, accessible information is still not well communicated, and individuals with special needs lack digital accessible information guidance, facing difficulties in travel. An advantage, just a step a few centimeters high, can become a significant obstacle for wheelchair users.

4.3 Installation of Voice Broadcast for Traffic Lights

In response to the insufficient traffic light prompt function at the intersection of Pingguoyuan Street, this study suggests adding a voice broadcast function and flashing indicator lights to the traffic light system at major intersections to alert individuals with special needs to changes in traffic signals. The system can prompt the remaining time of the traffic lights based on sound frequency and regularly broadcast the current status of the traffic lights to ensure the safety of individuals with visual impairments crossing the road. For individuals with hearing impairments, visual prompt lights can be set up near the traffic lights to compensate for the lack of audio reminders.

4.4 Increase in Accessible Signage and Directional System

Currently, there is a significant lack of accessible signage on both sides of Pingguoyuan Street, which causes inconvenience for individuals with disabilities. In light of this, the study suggests adding accessible signage to clearly indicate the specific locations of accessible facilities (such as accessible restrooms, elevators, service centers, etc.) and to enhance public awareness of the importance of an accessible environment. To ensure the effectiveness of the signage, the content design must follow the principles of clarity and intuitiveness, making it easy for individuals with various disabilities to quickly identify and obtain the necessary information. Additionally, accessible signage should be organically integrated with digital road signs and maps to collectively build a comprehensive and coherent accessible guidance system. The establishment of this integrated accessible guidance system will greatly enhance the convenience and autonomy of individuals with disabilities traveling on Pingguoyuan Street, further promoting the improvement and development of an accessible environment.

4.5 Establishment of Emergency Assistance System

Pingguoyuan Street lacks emergency assistance facilities for individuals with special needs in emergency evacuation paths and important safety prompt areas. An emergency assistance system should be added, using eye-catching colors, patterns, and sounds to quickly attract the attention of individuals with disabilities. In addition to visual and tactile prompts, a vibration feedback system should be set up to alert individuals with hearing impairments that the assistance system is activated, ensuring that individuals with special needs can quickly identify and take action in an emergency. In public service areas such as hospitals, supermarkets, and bus stations, information boards with simple sign language illustrations should be set up to allow volunteers to provide simple guidance and information to individuals with hearing impairments. The information boards should use internationally recognized sign language symbols and be accompanied by brief written explanations to facilitate effective communication among individuals.

5. Conclusion

The construction of a barrier-free environment in livable streets is an indispensable part of urban development planning. This study deeply analyzes the problems existing in typical residential streets from two dimensions: spatial elements and environmental elements, including spatial layout, form design, key nodes, accessible signage, and the overall accessible environment. The research findings show that there are many deficiencies in the current construction of the barrier-free environment in livable streets. These issues are specifically manifested as unreasonable design and severe damage to tactile paths, occupation of tactile paths, and imperfect accessible signage and facilities. These problems urgently need to be effectively addressed. Based on efforts to solve the lack or insufficiency of basic accessible infrastructure, this study further proposes strategies to optimize the accessible environment, offering more detailed and inclusive design plans for members of society, including people with special needs and the elderly. Through these measures, we expect to ensure that they can equally enjoy the rich fruits of the nation's material and cultural progress and promote the overall development and advancement of society.

Funding

Sponsored by the Innovation and entrepreneurship training program for College Students of NCUT, (Project No.10805136024XN139-94) and the Yuxiu Innovation Project of NCUT (Project No.2024NCUTYXCX115).

References

[1] Dai, J., Chen, X. L., Chen, L. L., et al. (2024). Evaluation of the barrier-free environment in living streets based on the needs of visually impaired people: A case study of the historic city area of Harbin. Science and Technology Review, 42(17), 130-143.

[2] Cui, Z. H., Luo, Q. M., Yang, S. W. (2023). Evaluation of pedestrian safety in urban living streets: A case study of some blocks in Nanjing. China Ancient Cities, 37(12), 72-78. DOI: 10.19924/j.cnki.1674-4144.2023.012.010.

[3] Liu, Y. (2024). Research on barrier-free design strategies for the external public space of old communities. Urban Architecture, 21(14), 95-98. DOI: 10.19892/j.cnki.csjz.2024.14.22.

[4] Zhou, P. B., Ma, H., Wang, M. H. (2024). Study on the spatial environmental elements affecting the wayfinding of visually impaired patients in general hospital outpatient departments. Journal of Human Settlements in West China, 39(04), 7-16. DOI: 10.13791/ j.cnki. hsfwest.20240402.

[5] Zhou, H., Ao, T. J. (2023). Reconstruction of the edge space of living streets in historic districts based on age-friendliness: A case study of Tongji Gate area in Xiangtan City. China Ancient Cities, 37(04), 22-28. DOI: 10.19924/j.cnki.1674-4144.2023.004.003.

[6] Zhu, L. (2023). Research on the optimization of the barrier-free environment in urban street spaces [D]. North China University of Technology. DOI: 10.26926/d.cnki.gbfgu.2023.000239.

[7] Pingguoyuan Street. (2023). Beijing Municipal People's Government. Shijingshan District Government Service Administration. Retrieved from https://www.beijing. gov.cn/renwen/bjgk/sjsgk/sjsjd/202302/t20230221_2921249.html

[8] Pingguoyuan Street. (2023). Beijing Shijingshan District People's Government Official Website. Retrieved May 18, 2023, from https://www.bjsjs.gov.cn/ gongkai/ pgyjdbsc/ywdt_2179/202309/t20230901_73644_sjs.shtml