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Evaluation and discussion on Beijing Huilongguan-Shangdi Cycling Superhighway

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Abstract: The construction of cycling superhighway has demonstrative and leading significance in building a bicycle-friendly city, promoting green transportation, and enhancing urban resilience. Taking Huilongguan-Shangdi cycling superhighway in Beijing as the research object, this paper comprehensively evaluates the planning, construction and use of cycling superhighways based on field research and data analysis. By comparing travel by bicycles on cycling superhighways and non-motorized lanes in the city, the results show that cycling superhighways are more attractive than non-motorized lanes. By analyzing the impact of construction methods on cities, this paper points out that the cycling superhighway system should improve the top-level design, explore new construction models, drive the improvement of regional non-motorized networks by superhighway lines, and focus on humanized design in planning and construction. The cycling superhighway planning and construction model that can be promoted and replicated is developed to provide a reference for improving the bicycle transportation environment and facility level in Beijing.

Keywords: road engineering; cycling superhighway; non-motorized traffic; green transportation; resilient city; Beijing

Introduction

Cycling serves as a reliable means of transportation for short-to-medium travel for urban residents. Unfortunately, in the wake of rapid urban expansion, the growing number of motor vehicles, and the biased allocation of road space to motor vehicles, the rights of cyclists to the road are inadequately protected. Upholding walking and cycling as the key components of future transportation development, Beijing has rolled out a series of pedestrian and cycling planning in various districts over the past decade. However, Beijing has met with problems for fully implementing its planning, including parking on the roads, interference from public transit stations, and difficulties in implementing land use.

Compared to the conventional traffic design that non-motorized lanes are merely set along urban roads, cycling superhighway, a kind of specialized traffic design, is a breakthrough. Beijing is seeking a point-to-point commute solution by building cycling superhighways independent of urban roads. It is stipulated in The Beijing Municipal Master Plan (2016–2035) [1] that the city should be built into a pedestrian and bicycle-friendly city. The initiative aims to address the challenging problems of Huilongguan-Shangdi traffic jams and poor cycling experience. At the same time, the municipal government is fostering awareness of green travel, and reshaping the value and joy of riding among its citizens, thereby setting a national example for bicycle commuting.

In this paper, the planning and the use of cycling superhighway in Beijing are studied, factors influencing ridership and the promotion of cycling superhighway are looked into, and key issues in the planning and construction of cycling superhighway are set forth.

1 Overview of the cycling superhighway

1.1 Objective

The objective is to address the serious Huilongguan-Shangdi commute problem. Cut off by the Jingzang Expressway (Beijing–Xizang Expressway), Huilongguan housing group, Longyu housing group and Shangdi housing group suffer from inconvenient cycling between each other, forcing their residents to detour [2–3]. Before the cycling superhighway was built, residents in Huilongguan and Shangdi used to rely on public buses and trolleybuses, Subway Line No. 13, and cars. Given that Huilongguan is densely populated and most of its residents work in Shangdi, the two places are plagued by congested metro and road traffic, slow-moving public buses and trolleybuses, dangerous cycling and chaotic parking.

1.2 Route description

The 6.5 km-long Huilongguan-Shangdi cycling superhighway stretches across the Changping and Haidian districts, linking the residential areas of Huilongguan, Longyu, and Shangdi. Officially opened on May 31, 2019, it stands as Beijing's inaugural cycling superhighway. The route begins at the crossroads of Wenhua Road and

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Tongcheng Street in Changping and continues to the junction of Houchangcun Road and Shangdi West Road in Haidian (See Fig. 1). This cycling superhighway boasts a combination of elevated and at-grade pathways, featuring a dedicated 5.5 km stretch free from urban traffic and a 1 km segment that merges with existing non-motorized lanes. The exclusive section, which runs alongside Subway Line 13 within the Huilongguan and Longyu communities, is primarily constructed atop the rail transit's isolation green belt. This segment includes entrances to city streets and is monitored around the clock by security staff to ensure exclusive bicycle access.

1.3 Connectivity between the cycling superhighway and surrounding areas

The cycling superhighway, complete with starting and ending points, boasts a total of 10 entrances, ensuring seamless integration with adjacent urban streets. The Huilongguan area, primarily residential, features five entrances at each at-grade intersection, facilitating the merging of bicycle traffic onto the superhighway. Since the stretch from Wenhua Road to the Jingzang Expressway is an overpass, all entrances, except for the starting one, are constructed with a gentle 2.1% incline and a ramp extending 304 meters. To aid cyclists, bicycle auxiliary power devices are installed, simplifying the uphill push and guaranteeing a safe descent. Entrance No. 6 is specifically designed to solve the challenge of pedestrians and non-motorized vehicles crossing the Jingzang Expressway, significantly improving road connectivity. Between Longyu East Road and Xierqi North Road, the superhighway runs at ground level, with entrances No. 7 and No. 8 directly joining the surrounding roadways. In the industrially-focused Shangdi area, the exclusive section ends at Xierqi North Road. Beyond this point, the path merges with existing bike lanes, aligning its purpose with that of the cycling superhighway.

Entrances from No. 3 to No. 7 are frequently used, with the highest traffic volume at entrances No. 6 and No. 7. Many cyclists cross the Jingzang Expressway via the superhighway. As Houchangcun Road is connected to Longyu and Shangdi housing groups, entrances No. 8 and No. 9 in the Longyu housing group have less traffic volume, with the majority of cycling traffic concentrated at entrances from No. 6 to No. 8 (see Fig. 2).

2 Operation and the maintenance of the cycling superhighway

2.1 Cycling traffic volume

2.1.1 Overview

The main data observation points were located at the intersection between the cycling superhighway and the Jingzang Expressway. From June 1, 2019 to April 9, 2022, the service has accommodated over 4.7 million trips in total, with an average annual cycling traffic volume of approximately 1.57 million trips. During the peak months, the traffic volume reached 187 000 trips or so, while during the off-peak months, the traffic volume stood at about 97 000 trips. The daily traffic volume ranged from 4 000 to 5 000 trips. The monthly traffic volume in the first year of operation was unstable, but the traffic volume from 2020 to 2022 was relatively stable. The traffic volume was higher in August and September, and lower in January and February. The daily traffic volume remained steady each year. As data was only available for the first four months of 2022, the daily traffic volume was relatively low (see Fig. 3).

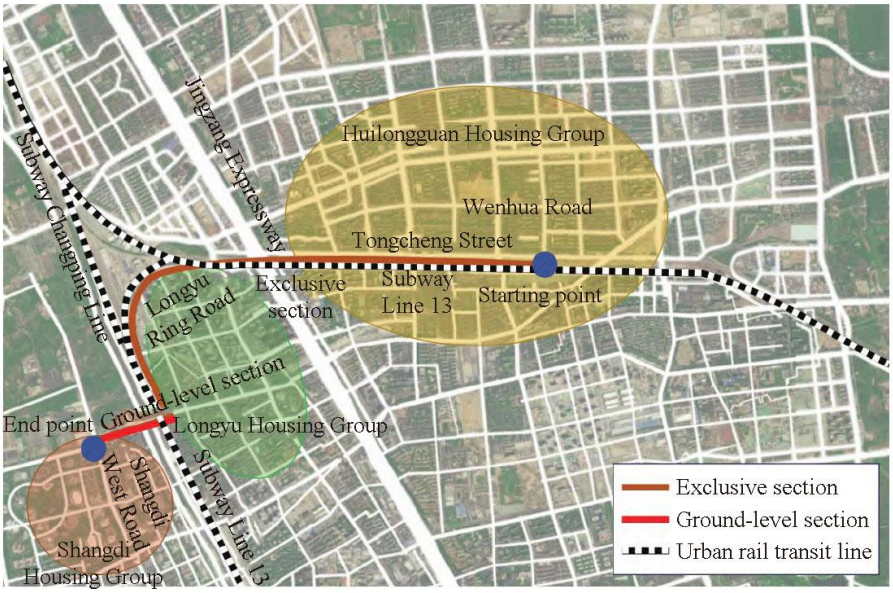

Fig. 1 Route of the cycling superhighway

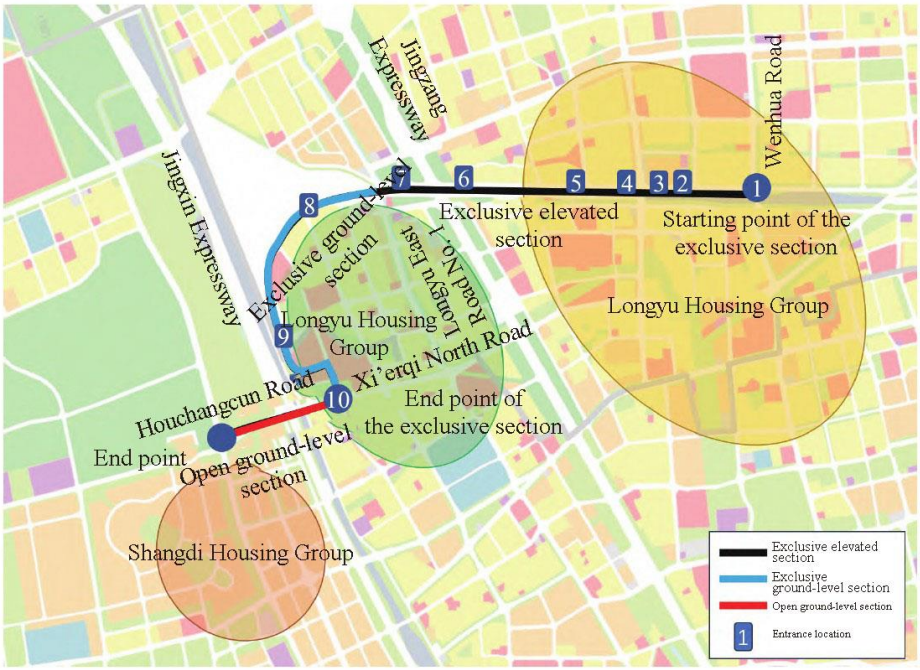

Fig. 2 Entrance locations and construction forms at different sections of the cycling superhighway

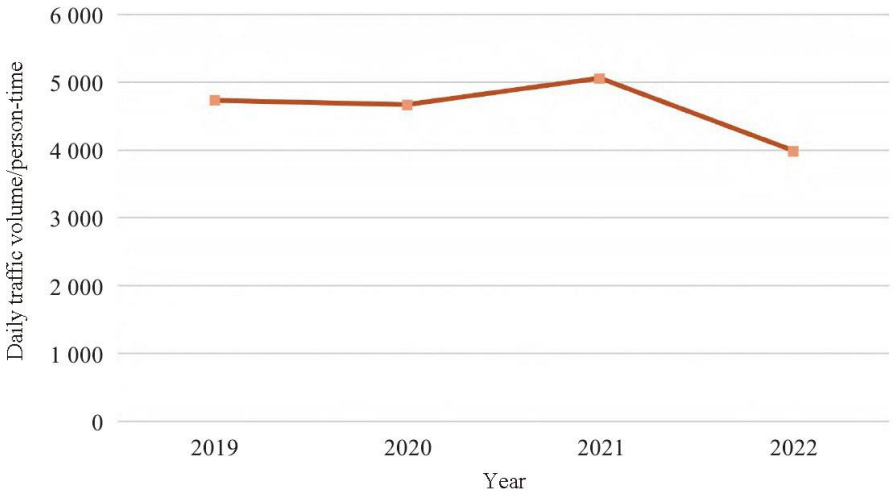

Fig. 3 Annual changes of daily traffic volume on the cycling superhighway

The distribution of shared bicycle trip distances was studied. The results show that the average cycling distance on the cycling superhighway during morning and evening peak hours is 4.8 km. On workdays, the average cycling distance is 3.5 km, while on weekends, it is 3 km. Given the total 6.5 km length of the cycling superhighway, it can be inferred that most cyclists only use certain sections of the cycling superhighway, and fewer riders cycle the entire superhighway.

2.1.2 Cycling on workdays and weekends

The traffic volumes of the typical workday (August 4, 2021) and the weekend (August 1, 2021) were compared and contrasted. The results show that the traffic volume on workdays (7 500 trips) is twice that of weekends (3 700 trips). The commuting on workdays clearly display "tidal" characteristics, with high traffic volume mainly in the Huilongguan-Shangdi direction during peak commuting hours and the Shangdi-Huilongguan direction during evening rush hours. Cycling on weekends is concentrated in the evening, and the difference in traffic volume between the two directions is small (see Fig. 4).

2.1.3 Effects of temperature and the COVID-19 pandemic

Temperature is the chief factor that affects cycling traffic volume. Traffic volumes will drop when temperature is either low or high. From November to March the next year, as the

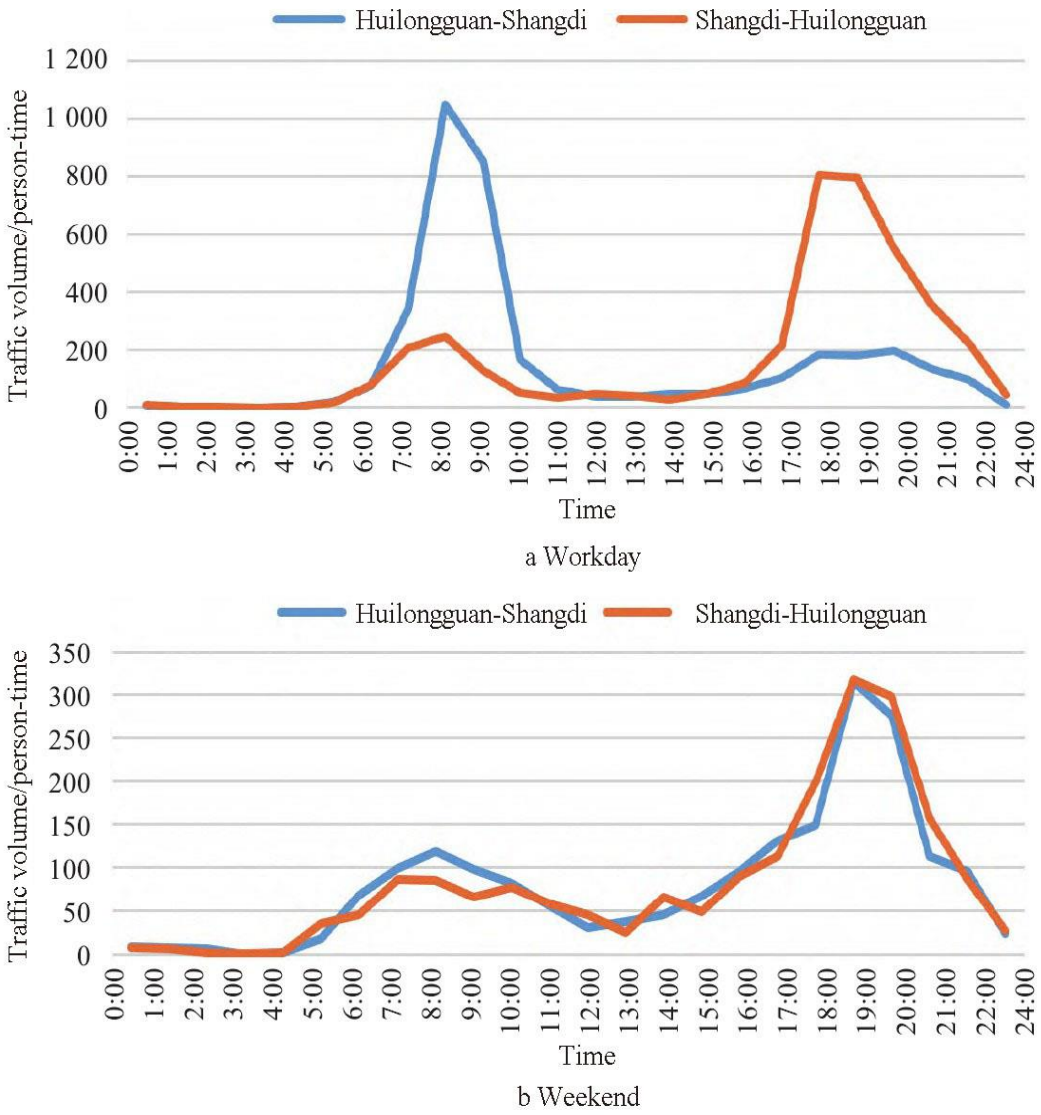

Fig. 4 Traffic volume on the cycling superhighway in different time periods

temperature is lower than 10 ℃, cycling traffic volume decreases, which is testified to by monthly average traffic volume of 97 000 trips. In contrast, as the temperature from April to October is above 15 ℃, traffic volume increases, with monthly average traffic volume of 187 000 trips (see Fig. 5). All things considered, the optimal temperature for cycling is over 15 ℃.

In February 2020, the COVID-19 pandemic led to a decrease in cycling traffic volume, yet certain committed cycling groups continued to ride. By April of that year, cycling traffic volume had quickly rebounded.

2.1.4 Comparison of traffic volumes between the cycling superhighway and urban roads

In 2019, non-motorized traffic volumes were surveyed on 68 urban roads, comprising 36 auxiliary roads, 24 arterial roads, 4 secondary trunk roads, and 4 branch roads. The daily average non-motorized traffic on auxiliary roads was 8 751 trips, with electric bicycles making up 5 769 trips (65.9%) and bicycles 2 982 trips (34.1%). On arterial roads, the daily average was 9 181 trips, with electric bicycles at 5 524 trips (60.2%) and bicycles 3 657 trips (39.8%). Secondary trunk roads saw a daily average of 8 392 trips, with electric bicycles at 4 912 trips (58.5%) and bicycles 3 480 trips (41.5%). Branch roads had a daily average of 3 296 trips, with electric bicycles at 2 130 trips (64.6%) and bicycles 1 165 trips (35.4%). Overall, electric bicycles represented 62.3% of the total non-motorized traffic, outnumbering bicycles.

The traffic volume of the cycling superhighway is higher than that of bicycles on arterial and secondary trunk roads and is much higher than that of bicycles on branch roads. It indicates that the cycling superhighway, which is separated from electric bicycles and motor traffic, has a greater capacity to accommodate and attract bicycle traffic.

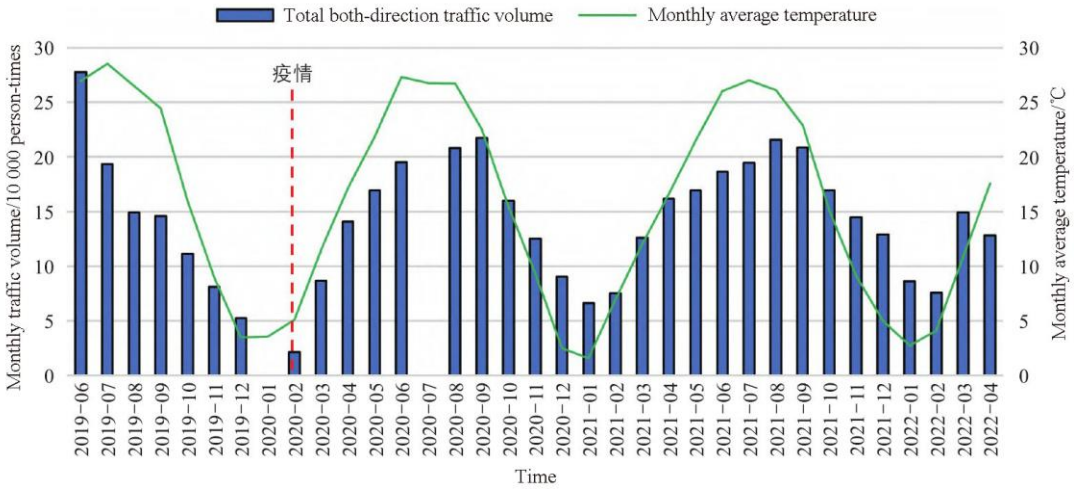

Fig. 5 Monthly traffic volume on the cycling superhighway

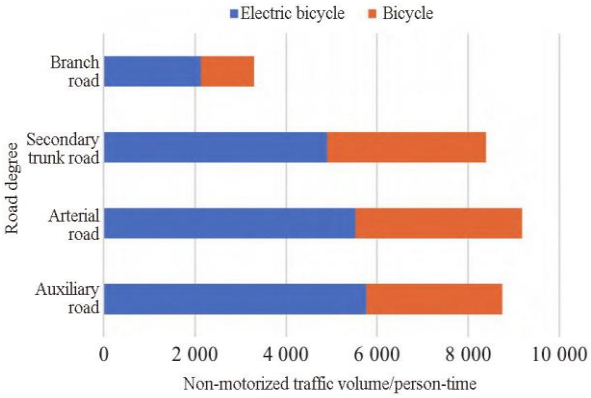

Fig. 6 Non-motorized traffic volume on roads of various levels in 2019

2.1.5 Actual serving number

The data of the section of the cycling superhighway adjacent to the Jingzang Expressway and 10 entrances from April 18 to 19 (workdays) and on April 23 (weekend) in 2022 were analyzed to count the number of cyclists.

On workdays, the average daily total traffic volume on the entire superhighway is around 51 400 trips. The Jingzang Expressway section contributes approximately 8 100 trips to this total, representing 15.8%, while the 10 entrances account for about 43 300 trips (84.2%). During weekends, the superhighway's total traffic volume drops to roughly 41 200 trips, with the Jingzang Expressway section making up around 6 600 trips (16.0%) and the 10 entrances contributing about 34 600 trips (84.0%). The traffic volume for the Jingzang Expressway section only captures the movement between Shangdi and Huilongguan, whereas the volume at the 10 entrances includes traffic entering and exiting the superhighway. When considering the symmetry of commute patterns, the actual number of superhighway users on workdays is estimated to be 21 600 trips.

2.1.6 Shift of traffic from alternative transportation modes to the cycling superhighway

Metro tapping data from the month surrounding the launch of the cycling superhighway were analyzed to examine the shift from metro to bicycle commuting. Following the cycling superhighway's introduction, there has been a 7.8% decrease in commuter traffic on the urban rail transit between Huilongguan and Xierqi stops during morning peak hours. Meanwhile, usage data of subway passes for the urban rail transit route has remained relatively stable during this period, suggesting that the cycling superhighway has successfully attracted a portion of the metro's commuter traffic upon its activation.

2.2 Operation management

2.2.1 Blocking situation

As of April 2022, cycling superhighways had blocked a total of 30 600 trips by electric bicycles, 2 400 trips by tricycles, 67 800 trips by pedestrians, and 5 000 trips by children aged below 12. Following sustained public awareness campaigns, the frequency of such blocking has shown a year-by-year decline (see Fig. 7). Tricycles and electric bicycles have since been rerouted to adjacent roads.

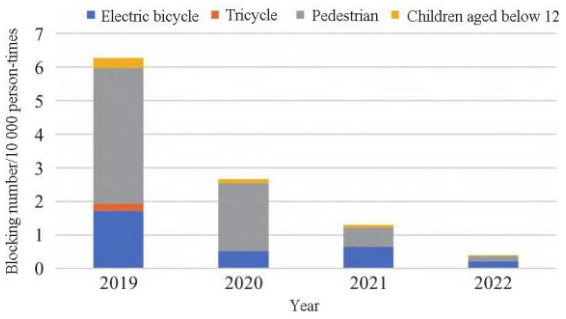

Fig. 7 Blocking situations

Despite the explicit ban on vehicles and pedestrians, other than bicycles, from using the superhighway, a handful of electric bicycles continue to make their way through. When considering the ratio of electric bicycles, the daily traffic volume at all 10 superhighway entrances, once fully open, can amount to 56 000 trips.

2.2.2 Complaints

Since July 23, 2020, the 12345 official complaint hotline has primarily received complaints in four key areas regarding the cycling superhighway. Firstly, there have been reports of road damage and malfunctioning electromechanical equipment. Secondly, the conduct of public order enforcement officers has been criticized, with some objections being unfounded. For instance, complaints have been made about officers preventing electric bicycle riders from forcefully entering the superhighway. Thirdly, grievances have been expressed over the prohibition of children and electric bicyclists on the superhighway. Lastly, there have been suggestions to enhance service quality, including better management, concerns about pedestrian and electric bicycle encroachment, and recommendations to minimize the elevation gap at temporary entrances where steel plates are laid.

Overall, there is a certain demand for children to ride and for electric bicycles to use dedicated lanes. At the same time, incidents of pedestrians and electric bicycles intruding have always been occurring.

2.3 Achievements

The cycling superhighway boasts a higher traffic volume than both urban arterial and secondary trunk roads, thereby encouraging cycling along its routes and serving as an exemplary model. By diverting riders from the metro, the superhighway alleviates congestion within the metro system at peak hours.

2.3.1 Raising cycling awareness

The cycling superhighway project is designed to tackle the challenges of difficult and substandard travel in Huilongguan and Shangdi, responding to the public's strong demand for enhanced travel experience. It leverages supply-side reform of bicycle infrastructure as an effective means. By implementing policies and partnering with non-governmental organizations, it fosters a societal consensus on "prioritizing green travel by revitalizing bicycle transportation". Owing to technological advancements and a shift in public attitudes, the project turns dots into lines and lines into fields. It has holistically enhanced cycling conditions in the Huilongguan area. The project's promotional efforts have advanced the development of a city-wide cycling transportation system, thereby endorsing green values and redefining the prestige and significance of cycling.

2.3.2 Promoting regional development

The cycling superhighway project has significantly helped surrounding areas overcome their road traffic bottlenecks and increase associated benefits. Residents' 15-minute accessibility range of the Huilongguan and Tiantongyuan communities now extends southwest, reaching as far as Zhongguancun Software Park. The superhighway has primarily enhanced cycling access for communities north of Tongcheng Street and in the southwest near Huilongguan New Village. A comparison of cycling accessibility rates before and after the superhighway's inception reveals that Rongze Home Community Phase I and Phase II have seen the most improvement, with their 15-minute cycling accessibility range tripling in size. The 15-minute range for the eastern and western zones of the Longzeyuan Community has increased by 1.8 times, and for Zones 4 and 6 of the Longtengyuan Community by 1.6 times (see Fig. 8). Calculations indicate that the annual benefits include: CNY 100 million from

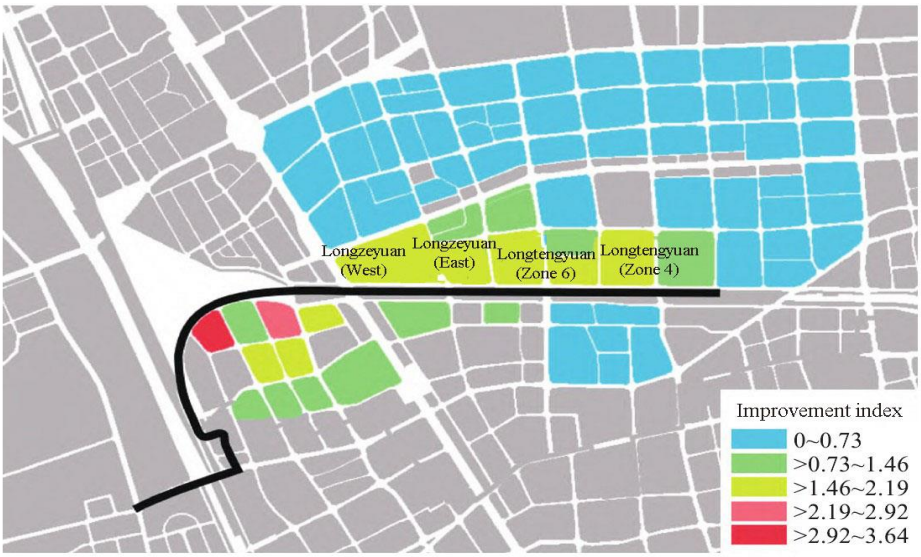

Fig. 8 Degree of improvement in the range of cycling accessibility

reduced commuting time, CNY 150 million from health improvement, CNY 40 million from spatial governance, and CNY 78 million from social impact.

2.3.3 Enhancing urban resilience

The development of the cycling superhighway has created a new commuting corridor linking employment and residential areas. It reshapes the 15-minute living radius for those residing along its route, encouraging individuals to embrace cycling as a healthy and relaxing form of transportation. In the aftermath of COVID-19, the cycling superhighway has seen a steady increase in usage, establishing itself as a vital means to maintain fitness, practice social distancing, reduce pressure on public transit, and support the green transportation initiative. Moreover, it exemplifies the effective use of transport infrastructure to bolster urban resilience and adapt to pandemic conditions.

3 Prospect of the cycling superhighway

3.1 To improve top-level design

The development of the cycling superhighway showcases Beijing's expertise in urban culture, advancing urban development strategies, rejuvenating cycling culture, pioneering planning innovations, achieving technological breakthroughs, and modernizing operations and management. Catalyzed by the planning exchange programs initiated in 2019 between Beijing and its sister cities along the Belt and Road, these robust and methodical standards and practices have been disseminated to an increasing number of cities and countries.

In the upcoming phase, emphasis should be placed on enhancing the network layout for the cycling superhighway. The goal is to establish an internal commuting system within the capital's core functional areas supported by a network of urban service roads, greenways, and riverside paths, meeting the increasing demand for cycling routes. This system's development will rely on careful observation and data analysis to identify corridors with high potential for cycling traffic, as well as surveys of residential and employment patterns. With the support of auxiliary roads alongside high-speed thoroughfares, these corridors will connect burgeoning new towns, significantly improving the efficiency of both internal and external commutes. Beyond the core areas, a cycling bridge will be constructed based on specific needs and local conditions, ensuring safe and convenient passage through challenging terrain, including overpasses and riverbanks.

In collaboration with the Beijing Municipal Commission of Planning and Natural Resources, the Beijing Municipal Commission of Transport, and the Beijing Traffic Management Bureau, each expressway will be assigned a unique number and corresponding cycling signage. Upgrades to the road sections designated for the cycling expressway are necessary; the implementation of three carriageway roads should take precedence; and barriers must be installed between the motorized and non-motorized lanes to guarantee safety. At the same time, the enforcement of motor vehicle regulations must be strengthened. Motor vehicles are prohibited from parking on roads reserved for the cycling expressway, ensuring an unobstructed path [4].

3.2 To explore a new mode integrating the cycling superhighway and urban space

It is rather difficult to build another completely independent and enclosed cycling superhighway akin to the Huilongguan-Shangdi one in Beijing. The success of the Huilongguan-Shangdi cycling superhighway is attributed to two factors. First, its proximity to the ground segment of Subway Line 13 of the urban rail system allows it to utilize the adjacent protected greenbelt; at the same time, the elevated tracks keep a considerable distance from nearby residential areas, thereby reducing disruptions to the daily lives of inhabitants. Second, the issue of highways obstructing non-motorized lanes is undeniable; however, this can be mitigated by the planning team through the strategic construction of a cycling superhighway. Such problems are not present on typical urban service roads; at the same time, there is a lack of space for constructing such independent infrastructure.

In addition, the project faced significant challenges in planning, construction and operation. The project also entailed a substantial investment of manpower in managing electric bicycles, tricycles, motorcycles, children's cycling, pedestrians, etc. At the same time, it invested considerable material resources in repairing road surfaces and bridge structures, and purchasing snow removal equipment. As a result, annual maintenance costs amounted to tens of millions of yuan. The project had to go through various approval processes, which were obstacles to be overcome. With the proactive support from the Municipal Party Secretary and the collaborative efforts of Beijing Municipal Commission of Planning and Natural Resources, Beijing Municipal Commission of Transport, Changping District Commission of Urban Management, and Beijing Municipal Commission of Development and Reform, the elevated cycling superhighway was finally accomplished.

For future planning, it is essential to thoroughly assess the challenges associated with cycling superhighways and strive to seamlessly incorporate them with urban service roads, greenways, and waterfront promenades. In addition to ensuring cost-effectiveness and cohesive spatial design, the construction of bicycle bridges is crucial to link road segments, thereby guaranteeing cycling connectivity and fostering an inviting environment for cyclists.

3.3 To promote the development of surrounding road networks

In pace with the planning and construction phase, the Huilongguan area launched a three-year action plan to bolster its bicycle infrastructure. At the heart of this initiative is the creation of cycling superhighways, which form the backbone of efforts to enhance non-motorized traffic flow along the route. The focus is on improving the quality of intersections between cycling superhighways and roadways, addressing long-standing traffic challenges, deeply involving the community, and encouraging a shift towards more sustainable modes of transport. The aim is to nurture a culture of eco-friendly travel and to broaden the scope of pedestrian and cyclist-friendly zones by turning dots into lines and turning lines into fields.

Seizing the chance to transform and upgrade the adjacent roads of the superhighway, this action plan will integrate spatial resources including bus stations, public parking lots, and pedestrian bridges, and coordinate the space within and beyond the road's red line through an integrated design approach. By merging traffic, urban, and landscape designs, the action plan aims to improve the spatial governance along the route and promote regional revitalization.

Measures are to be taken to enhance the environment for non-motorized vehicles, which involve: (1) implementing embedded on-street parking in motorized lanes to minimize disruption from motor vehicles (see Fig. 9); (2) smoothing out the surface of non-motorized lanes and promptly fixing any damage to increase riding comfort; (3) installing signs that prioritize non-motorized vehicles to underscore the precedence of cycling; (4) ensuring adequate shading and establishing fully tree-lined avenues [5].

Fig. 9 Schematic diagram of the embedded on-street parking space

3.4 To offer better humanized design

Efforts should be made to adjust the signage of entrances and along the route to foster a healthy, happy, and civilized cycling culture. Measures should be taken to avoid prohibitive language like "Forbidden" and "Not allowed" along cycling superhighways, and to communicate traffic management directives while showing respect to cyclists. The essence of cycling superhighways is to show respect to cyclists, which should be mirrored in their operational management in harmony with a healthy, happy, and civilized cycling culture. [6–7]

Endeavors should be made to enhance micro-design, install bicycle traffic volume detection devices, and boost a sense of engagement in cycling; to upgrade the quality of the space along the route, add rest areas and repair stations; to clear up visual pollution and design cycling-themed cultural landscapes; and to conduct regular inspections and maintenance of small-scale facilities, including pavement, guardrails, ramps, steps, and lighting.

Steps should be taken to enhance the promotion of walking and cycling by organizing themed activities aligned with the fitness and leisure needs of residents; to establish a civilized model area to activate the cycling vitality in the surrounding areas; to prioritize public involvement in management to make decisions understood and accepted by the public, thereby enhancing residents' consciousness in complying with regulations; and to actively respond to users' feedback to foster a positive culture of mutual oversight.

A children's cycling park should be set up along the superhighway, allowing the green transportation concept to take root and flourish in the next generation. Accompanied by parents, children should be allowed to practice cycling in the park on the condition that they wear appropriate safety gear.

4 Conclusions

The Huilongguan-Shangdi cycling superhighway has invigorated cycling vitality along its route, enhanced people's cycling consciousness in nearby areas, and improved the cycling infrastructure on surrounding roads. However, it is difficult to further promote the current design of this cycling superhighway. So, it is necessary to find a form of cycling superhighway that suits the commuting environment of Beijing's residents. (1) An optimal cycling superhighway system should strengthen top-level design, coordinate multiple departments, and map out a cycling superhighway network. (2) The optimal cycling superhighway system should move beyond its current isolated state and integrate the superhighway spatially with other roads for joint development. The optimal cycling superhighway system should prioritize bridging gaps over rivers and on highways to ensure the continuity of cycling routes and should leverage existing structures to improve feasibility. (3) With the cycling superhighway network as the framework, the optimal cycling superhighway system should upgrade the walking and cycling conditions on surrounding roads to build an urban city friendly to cyclists and pedestrians in all respects. (4) The optimal cycling superhighway system should broaden cultural outreach, organize theme-based promotion events, and mobilize more people to endorse it.

The paper overlooks the impacts of cycling superhighways on the redistribution of car traffic and the use of electric bicycles. For future research, it is essential to further refine the research by integrating pertinent data.

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