Journal of Landscape Research 2026, 18(3-4): 1-4

Research on Current Parking Conditions of Non-motor Vehicles and Optimization Strategies at Pingguoyuan Comprehensive Transportation Hub in Shijingshan District, Beijing City

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Abstract The parking order of non-motor vehicles at a comprehensive transportation hub is a critical factor affecting transfer efficiency and travel experience. In this paper, the parking conditions of non-motor vehicles at all entrances and exits of Pingguoyuan Comprehensive Transportation Hub were studied through field observation and photographic documentation, and the parking issues and root causes at three typical access points (E, H, and B) were thoroughly discussed. It is found that non-motor vehicle parking at the hub faces three universal constraints, such as unbalanced supply and demand, uneven provision of supporting facilities, and weak parking order management. Each of the three entrances shows distinct challenges. Entrance E suffers from insufficient parking space and inadequate signage; entrance H lacks overhead shelters despite adequate basic supporting facilities; entrance B faces overloaded parking capacity and deficient on-site management. In response to these issues, differentiated improvement schemes were put forward, including expanding parking zones, installing overhead shelters, tapping underutilized space to increase parking capacity, and establishing standardized regular management mechanisms. The research findings can serve as a reference for improving the parking management of non-motor vehicles at Pingguoyuan Hub and other analogous comprehensive transportation hubs.

Keywords Parking of non-motor vehicles, Pingguoyuan Transportation Hub, Parking facilities, Optimization strategies

DOI 10.16785/j.issn 1943-989x.2026.3-4.001

The accelerated advancement of urbanization and the improvement of people's living standards have raised their demands for public spaces beyond basic transportation functions. Citizens now expect comfortable, safe, and convenient environments integrated with artistic and cultural elements to enrich their spiritual lives. As vital traffic nodes and pedestrian gathering hubs, rail transit transfer stations require upgraded public space quality to meet multifaceted modern urban demands covering transportation, culture, economy, and livability[1]. With the improvement of urban transportation systems, comprehensive transportation hubs have become core nodes connecting diverse travel modes, and their planning, construction, and operational management directly determine urban traffic efficiency. Against the backdrop of urban stock renewal and refined urban governance, enhancing the coordination and connectivity of various travel modes within hubs has become a key research priority.

In recent years, the green travel concept has gained widespread recognition, leading to a steady rise in non-motor vehicle trips in Beijing. Conventional bicycles and electric two-wheelers have become primary daily commuting tools, while shared bicycles play an increasingly important role in delivering last-mile feeder connections to rail transit. Beijing has issued special slow travel system plans and non-motor vehicle management regulations to upgrade supporting facilities and improve slow travel quality, and has incorporated parking order governance into refined urban administration agendas. Nevertheless, pervasive problems such as insufficient non-motor vehicle parking facilities and chaotic parking around comprehensive transportation hubs remain prominent bottlenecks limiting overall service capacity.

Located in Shijingshan District, Pingguoyuan Comprehensive Transportation Hub is one of the largest and most functionally integrated passenger transport hubs in the west of Beijing, sustaining massive daily passenger flows. At present, the parking conditions of non-motor vehicles vary drastically across its entrances and exits, and inadequate facilities and disorderly parking prevail in certain zones, calling for systematic sorting and targeted remediation.

Existing domestic research on comprehensive transportation hubs largely concentrates on macro-level planning and passenger flow organization, leaving substantial room for in-depth exploration of non-motor vehicle parking management within hubs. In this paper, the causes and features of parking issues of non-motor vehicles at the entrances and exits of Pingguoyuan Hub were studied via field surveys to provide references for parking governance at similar hubs nationwide.

This study aims to systematically understand the parking status of non-motor vehicles at all entrances and exits of the hub, analyze the characteristics and root causes of the issue at three typical access points (E, H, and B), and propose actionable and targeted optimization strategies aligned with on-site hub conditions and relevant national specifications, thereby laying a solid foundation for the improvement of parking management at the hub.

1 Overview of Pingguoyuan Comprehensive Transportation Hub

1.1 Basic profile of the hub

Pingguoyuan Comprehensive Transportation Hub sits at the intersection of Pingguoyuan Road and South Pingguoyuan Road in Shijingshan District, Beijing, as well as along the west section of Chang'an Avenue. As the largest integrated passenger transport hub in western Beijing, it is approximately 18 km away from Tiananmen Square in the east, and is adjacent to Shougang Industrial Park and the Yongding River Ecological Corridor in the west. Its prime geographic location enables critical passenger

Received: May 8, 2026 Accepted: June 12, 2026
Sponsored by the Special Program for Postgraduate Education and Teaching Reform of North China University of Technology in 2026.

distribution services for residents of Shijingshan District and Mentougou District.

The hub currently accommodates three rail transit lines: Metro Line 1, Line 6, and Maglev Line S1, forming a three-line interchange network. It is additionally served by multiple bus routes originating from or passing through the site, creating an integrated transfer system combining rail transit, ground bus services, and slow travel modes. Line 1 serves the east-west corridor of Chang'an Avenue; Line 6 extends eastward toward Beijing's sub-center; Line S1 facilitates inbound commuting for Mentougou residents. The convergence of the three lines establishes Pingguoyuan Hub as the most vital rail transfer node in western Beijing. It sustains heavy daily passenger volume, and passenger volume peaks during morning and evening rush hours. Dense residential neighborhoods surround the hub, generating robust demand for cycling-based rail feeder trips.

1.2 General profile of each entrance and exit

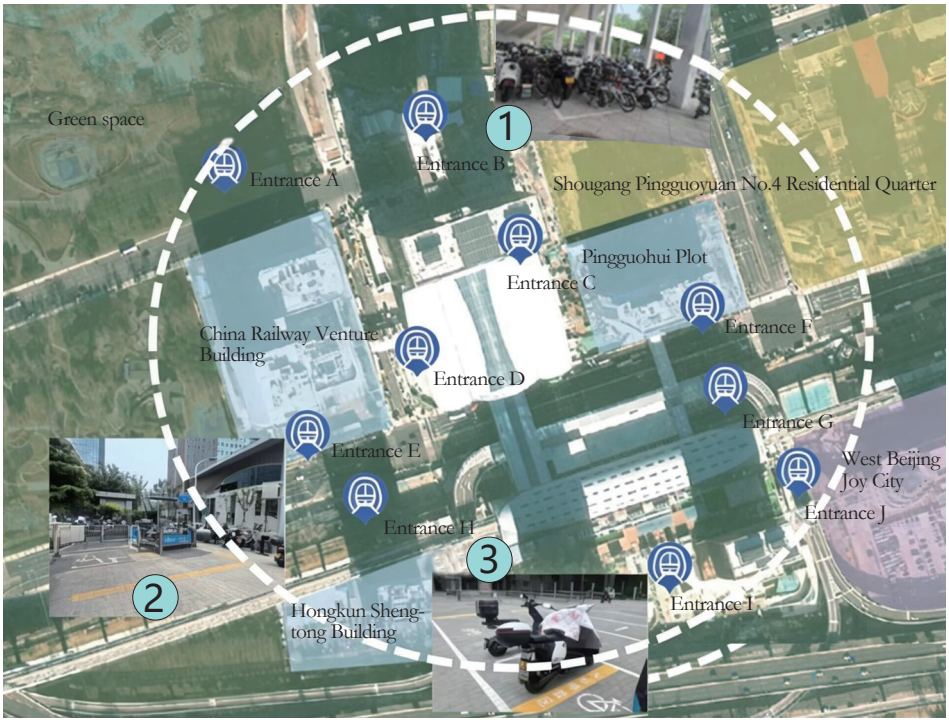
Entrances and exits are distributed around the perimeter of the hub (Fig.1), and connect to adjacent arterial roads, commercial districts, and residential communities, undertaking differentiated passenger evacuation functions. The entrances and exits around major thoroughfares and residential blocks record higher pedestrian volumes and greater demand for non-motor vehicle transfers.

Parking facility configurations differ widely across the entrances and exits: some feature marked parking bays, overhead shelters, and complete signage systems, while others only possess basic ground markings or lack dedicated parking infrastructure without systematic planning. This research focuses on entrances E, H, and B, which represent three typical scenarios of the parking issue of non-motor vehicles due to distinct parking scale, facility provision, and daily management status.

2 Field surveys and problem analysis of non-motor vehicle parking

2.1 Field surveys

Field surveys were conducted on workdays during daylight hours. By using on-site observation and photographic recording, the parking conditions of non-motor vehicles at all major entrances and exits of the hub were surveyed from the aspects of parking zones, vehicle quantity and classification, supporting facility completeness, and real-time parking order. Three representative access points (E, H, and B) were selected for detailed recording and targeted comparative analysis.



Note: ① Occupation of pedestrian passages by non-motor vehicle parking at entrance B; ② Occupation of pedestrian passages by non-motor vehicle parking at entrance E; ③ Occupation of pedestrian passages by non-motor vehicle parking at entrance H.

Fig.1 Research scope of areas surrounding Pingguoyuan Comprehensive Transportation Hub

2.2 Severe congestion caused by insufficient external parking space at entrance E

Entrance E serves as a primary cycling access route for local residents and office staff from adjacent northern commercial buildings, with a high volume of parked non-motor vehicles dominated by electric two-wheelers, alongside mixed conventional bicycles and shared bicycles at high density.

The designated parking zone occupies a limited ground area with only basic ground markings, yet actual parking volumes far exceed designed capacity, with vehicles spilling outward toward both sides of the entrance and pedestrian corridors. Three prominent congestion phenomena are observed: firstly, parked non-motor vehicles occupy non-motor vehicle lanes and pedestrian walkways; secondly, severe road occupation creates mixed pedestrian and vehicle traffic during peak hours; thirdly, disorganized vehicle alignment with misoriented, stacked, and toppled vehicles drastically narrows the effective width of pedestrian corridors.

Parking deficiencies at entrance E stem from multiple overlapping factors. On the one hand, the allocated parking area fails to match actual travel demand. High transfer passenger flow contrasts sharply with undersized marked bays, generating an immediate supply-demand gap that forces vehicle overflow. On the other hand, surrounding land use exacerbates spatial competition. Only a tiny dedicated parking plot exists within the northern commercial precinct, prompting commercial employees to park their non-motor vehicles near entrance E and further straining already limited parking resources.

2.3 Ample parking space without overhead shelters at entrance H

In contrast to entrance E, entrance H boasts spacious and regularly demarcated marked parking zones with clear directional signage; nearly all vehicles dominated by electric two-wheelers and conventional bicycles are parked within designated boundaries without widespread overflow.

Nevertheless, a prominent functional shortcoming persists, that is, the entire parking area lacks overhead shelter infrastructure, leaving vehicles fully exposed to outdoor weather with no sun or rain protection for both vehicles and riders. The absence of shelters undermines parking attractiveness and overall user experience. Intense summer solar radiation and unshielded rainfall in Beijing accelerate the aging of vehicle

bodies and electric batteries while severely reducing rider comfort. When alternative parking locations are available, unsheltered zones become less desirable, pushing some users to park in unregulated informal spaces and exacerbating disorder at other entrances.

2.4 Complete shelters and signage but overloaded parking capacity at entrance B

Entrance B features the most sophisticated supporting facilities among the three entrances, with installed overhead frame shelters, distinct ground markings, and comprehensive directional signage that meets standardized hardware requirements.

However, complete infrastructure cannot resolve the core conflict: parking demand vastly outstrips facility capacity. On-site observations reveal fully saturated marked bays, with large numbers of vehicles spilling beyond shelter edges, onto adjacent passageways, and even fire exits. This narrows pedestrian clearance and creates congestion bottlenecks during peak hours, introducing significant safety hazards. This entrance boasts excellent cycling accessibility. Combined with superior supporting facilities that can shield riders from sunlight and rainfall compared with other entrances, it exerts a strong attraction on cycling feeder passengers, making it one of the entrances with the most concentrated parking demand. Due to the underestimation of travel demand during the planning phase, there is a persistent mismatch between built capacity and real-world usage volume.

2.5 Cross–site comparison and generalized shared deficiencies

While each entrance exhibits unique localized problems, three shared core deficiencies emerge across all entrances (Table 1). Firstly, there is a persistent imbalance between parking supply and travel demand, that is, insufficient space at entrance E, quality defects at entrance H, and overloaded capacity at entrance B all reflect a fundamental failure of supporting facilities to accommodate cycling transfer demand, which constitutes the primary cause of parking issues at the hub. Secondly, the distribution of supporting facilities is uneven, and stark disparities exist across the three entrances in the provision of signage, overhead shelters, and standardized ground markings. Thirdly, daily parking order management is weak, because disorganized parking is prevalent at all three entrances with limited on-site maintenance mechanisms and passive emergency responses rather than proactive daily regulation.

3 Optimization strategies

3.1 Mitigating severe congestion at entrance E

The core challenge at entrance E lies in a substantial gap between parking space supply and real travel demand, with space expansion as the top remediation priority.

Firstly, it is necessary to systematically survey idle paved ground, marginal lots, and underutilized hardscape areas surrounding entrance E to map available space locations, dimensions, and boundary constraints. Based on measured cycling transfer passenger volume, the boundaries of existing parking zones should be redrawn and moderately extended toward suitable peripheral areas. Besides, physical dividers and green buffer strips are installed to demarcate separate travel corridors for different transport modes, with colored pavement and ground markings applied for clear visual guidance[2]. Meanwhile, spontaneously formed informal overflow parking areas are integrated into standardized regulated zones, namely converting unplanned spillover into guided ordered expanded parking to increase effective parking supply.

Furthermore, surrounding land is categorized into residential, commercial, office, and public service zones, and the number of parking bay quotas is determined according to their development intensity, building floor area, and functional attributes. Meanwhile, total parking capacity is controlled to prevent mismatched supply-demand ratios across different functional districts[3].

3.2 Completing supporting infrastructure at entrance H

Entrance H already features ample marked parking space and coherent signage systems, forming a solid baseline infrastructure. Optimization priorities center on addressing the critical absence of overhead shelters to drastically elevate service quality with minimal investment. The primary task involves erecting continuous overhead frame shelters covering the main parking zones. The shelters are engineered to suit Beijing's climatic conditions, such as sloped roof panels for facilitating rainwater drainage and UV-resistant surface materials for extending service life. Vertical clearance must enable unobstructed movement of electric two-wheelers. If site conditions permit, a small number of charging sockets should be installed along shelter frames to provide basic power supply services for electric two-wheelers, thereby expanding the multifunctional value of the parking zone.

3.3 Implementing capacity expansion and order governance at entrance B

Entrance B possesses complete supporting facilities yet suffers from capacity shortages paired with inadequate on-site management, requiring dual interventions of space expansion and standardized regulatory oversight.

3.3.1 Tapping underutilized space to boost parking capacity. Idle paved lots and low-efficiency peripheral areas adjacent to entrance B should be surveyed, and eligible spaces are incorporated into unified non-motor vehicle parking planning to increase total parking supply. The marking layout of expanded parking zones shall be coordinated with the coverage of existing overhead shelters. Newly added parking areas should be prioritized for inclusion within sheltered zones to maintain consistent supporting facility configuration.

3.3.2 Exploring the applicability of three-dimensional parking facilities. Given the limited expandable space in the surrounding area, double-decker vertical parking racks should be introduced to boost parking density without increasing land occupation. Vertical racks are suitable for conventional bicycles and lightweight electric two-wheelers, and gentle ramp gradients and intuitive operation should be prioritized to avoid low utilization stemming from cumbersome vehicle access.

3.4 Comprehensive recommendations

Within the framework of urban renewal, refined design for rail station precincts extends beyond the optimization of spatial form to holistic upgrades of functional performance and environmental quality. By systematically designing and optimizing the road network, traffic microcirculation, signage system, travel convenience, and parking layout, efficient traffic organization, human-oriented travel experience, and environmental quality can be simultaneously improved[4].

Based on differentiated targeted measures, comprehensive improvement measures should be promoted from the overall perspective of the hub. To alleviate overcrowding at entrance

Table 1 Comparison of deficiencies at the three entrances

Entrance	Parking scale	Signage condition	Shelter facility	Primary deficiencies
E	Extremely large	Inadequate	Absent	Severe congestion and road occupation
H	Moderately large	Clear	Absent	Lack of shelters and low service quality
B	Overloaded	Clear	Installed	Capacity shortage and corridor occupation

B and improve the utilization rate at entrance H, electronic real-time parking occupancy display screens should be installed at major entrances and exits to display their remaining parking capacity in real time and guide cyclists to achieve rational passenger diversion. To tackle the disorderly parking of shared bicycles at the three entrances, it is recommended that the hub management department should strengthen cooperation with operating enterprises (Meituan, Hello, and Didi Qingju) to define the boundaries of electronic fences, implement responsibilities for vehicle dispatching and violation disposal, and incorporate shared bicycle management into the overall governance framework of parking order. Besides, relevant competent authorities should prioritize the systematic improvement of non-motor vehicle parking facilities in the follow-up renovation work of the hub. In accordance with the *Code for Urban Parking Planning*, they should re-verify the facility allocation demand for each entrance, resolve the problem of insufficient supporting facilities at the planning source, and promote the overall upgrade of the slow transit connection service capacity of the hub. This optimized design fully complies with the principles of modern urban renewal and effectively elevates the standard of urban travel services[5].

4 Conclusions

4.1 Core conclusions

In this paper, the parking conditions of non-motor vehicles across all entrances and exits of Pingguoyuan Comprehensive Transportation Hub were studied through field surveys. Meanwhile, the parking issues and root causes at three typical access points (E, H, and B) were thoroughly analyzed, and differentiated targeted optimization proposals were proposed. It is concluded that non-motor vehicle parking at the hub faces three universal constraints, such as unbalanced supply and demand and uneven provision of supporting facilities, which jointly hinder the advancement of parking service quality[6]. Each of the three entrances exhibits distinct localized challenges. The core conflict of entrance E is disorganized parking triggered by severe space shortages; entrance H boasts sufficient space and complete signage yet suffers from low-quality service due to the total absence of overhead shelters; entrance B is equipped with complete standardized facilities but generates severe corridor occupation caused by excess demand paired with lax on-site management. As the three entrances have distinct types of problems, targeted differentiated governance measures shall be adopted respectively.

4.2 Research limitations

Field observations are limited to workday daylight hours, excluding parking status under rainy, snowy, or extreme weather conditions. The existing dataset lacks dynamic representativeness across variable weather scenarios, requiring multi-period supplementary surveys to fully validate the research conclusions[7]. This research relies primarily on on-site observation and informal short interviews, without systematic quantitative data tracking passenger origins and demographic classification. This limitation reduces the analytical depth of parking problems.

4.3 Research outlook

Subsequent research can be deepened analysis from the three aspects. Firstly, follow-up surveys should be conducted across multiple time periods and under various weather conditions to obtain dynamically representative parking data, so as to lay a more reliable demand foundation for the scale calculation of parking facilities. Secondly, questionnaire surveys and in-depth interviews with cyclists should be introduced to deepen the understanding of parking behavior patterns and the priority of facility improvement from the perspective of end users, and enhance the pertinence of the optimization strategies. Thirdly, the analytical framework of this research can be applied in studies on non-motor vehicle parking at other similar comprehensive transport hubs in Beijing. Relevant conclusions can be verified and perfected through multi-case comparison, providing broader references for the systematic upgrading of slow transfer facilities at urban comprehensive transportation hubs[8].

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