Evaluation of Spatial Matching Between Non-motorized Vehicle Parking Facilities and Public Service Facilities in Rail Micro-centers: A Case Study of the Pingguoyuan Rail Micro-center in Beijing

MA Xiaoyun, LI Daoyong, LIU Yuhao, CHAI Jing

(School of Architecture and Art, North China University of Technology, Beijing 100144, China)

Abstract Under the background of the "dual carbon" strategy and the integration of station and city construction, rail transit stations are shifting from single transfer nodes to composite spaces that combine transportation connections, public services, and community life functions. Non-motorized vehicle parking facilities are a key link in the travel chain of "community-cycling-parking-rail station/public service facilities", and their layout directly affects the operational efficiency and usage experience of rail micro-centers. In this paper, the Pingguoyuan rail micro-center of Beijing is taken as the research object. Based on on-site research, parking locations, and Gaode POI data, using classification statistics, circle analysis, nearest distance calculation, service radius coverage discrimination, and convenience evaluation, the spatial matching relationship between parking facilities and public service facilities is analyzed from three dimensions: accessibility, coverage, and convenience. The results show that there are a total of 1,601 public service facilities within a range of 1,000 m in the study area, with commercial service facilities accounting for 65.2%, and there is a significant agglomeration in the circle of 500-800 m. There are 10 non-motorized vehicle parking spots with a total capacity of approximately 1,160 vehicles. The actual parking capacity is about 937 vehicles, with an average utilization rate of 80.8%. However, the parking spots are mainly concentrated within a radius of about 200 m around the rail station. The existing parking facilities provide good support for rail transfer, commerce, and leisure recreation, but have insufficient coverage for science, education, culture, healthcare, and some community service facilities. There are also shortcomings in canopy, charging, guidance, and parking order. Based on this, it is proposed to construct a graded parking system of "rail station level-public service facility level-community level", and synchronously optimize the supporting facilities and slow traffic connection.

Keywords Rail micro-center, Non-motorized vehicle parking facilities, Public service facilities, Spatial matching, Slow connection

DOI 10.16785/j.issn 1943-989x.2026.5.003

Driven by the strategy of "dual carbon" and the goal of high-quality urban development, the coordinated development of public transportation and green travel has become an important direction for optimizing transportation in big cities. Rail transit stations not only undertake commuting and transfer, but also gradually become comprehensive nodes connecting residence, commerce, public services, and community life[1]. With the advancement of the construction of the rail micro-centers in Beijing, the functions within the walking and cycling reach of the stations have become more complex, and residents' travel has shifted from a single commuting of "community-rail station" to a continuous process that includes transfer, shopping, medical treatment, office work, and leisure activities. In this process, non-motorized vehicle parking facilities serve as a link between "cycling arrival-vehicle parking-pedestrian transfer", and their spatial location and usage conditions could affect the efficiency of rail transfer and the actual accessibility of public service facilities. The Pingguoyuan comprehensive transportation hub integrates subway lines 1, 6, S1, and multiple bus routes, with continuous concentration of surrounding commerce, community service, and leisure functions, exhibiting typical characteristics of a rail micro-center. On site observation shows that the existing parking facilities are relatively concentrated in the core area of the station, while the parking support around the peripheral public service facilities is relatively insufficient. Therefore, it is necessary to evaluate their matching status from the perspective of the overall spatial relationship of the rail micro-center.

Existing research mainly focuses on three aspects. First, TOD and node-place studies emphasize the synergy between the transportation attributes of rail stations, place functions, and walkability[1], while living circle research of station area further focuses on the composite configuration of rail stations and public service facilities and their walkable accessibility[2]. Second, rail transit travel chain studies treat rail travel and its connecting links as an integrated system, analyzing transfer mode choices and facility demands[3]. The study on slow-moving transfer space in the Pingguoyuan Street incorporates bicycle parking, traffic signage, and barrier-free facilities into satisfaction evaluations[4]. Third, the research on public service facility configuration examines the spatial matching of supply and demand as well as the impact of the slow-moving environment[5], and utilizes POI data to identify spatial clustering characteristics of different facility types[6]. Spatial coupling studies of rail stations and public service facilities further analyze their spatial connections from perspectives such as relative and absolute coupling[7], functional mix degree, facility service efficiency, and coupled facility density[8]. Overall, existing research provides a foundation for understanding station functions, transfer behaviors, and facility layouts, but how parking nodes can connect rail transit and public service facilities still requires scenario-specific analysis. Based on this, this paper regards non-motorized vehicle parking facilities as a transition node between rail transit and public service facilities. Combining on-site research, parking locations,

Received: September 12, 2026 Accepted: October 30, 2026
Supported by Graduate Education Teaching Reform Research Project (217051360026XN098-09).

and POI data, spatial matching is evaluated from three dimensions: accessibility, coverage, and convenience, and optimization strategies are proposed accordingly.

1 Theoretical framework and research methods

1.1 Theoretical logic and analytical framework

The rail micro-center is a spatial organization model centered around rail stations, emphasizing functional complexity, convenient accessibility, and the integration of stations with surrounding urban spaces[1]. Its operation requires both efficient transportation distribution and continuous connection between the station and surrounding living services. TOD and node-place related research emphasizes the synergy between station traffic attributes, place functions, and pedestrian environment[1], while research on the accessibility of station living circles and public service facilities focuses on whether residents can easily access daily services[2,5]. Therefore, this paper constructs an analytical framework for "rail transit–non-motorized vehicle parking facilities–public service facilities": rail stations undertake passenger flow distribution, parking facilities undertake cycling arrival, vehicle parking, and walking conversion, and public service facilities constitute residential activity destinations. The three together form a travel chain of "community–cycling–parking–rail station/public service facilities".

1.2 Research scope and data

The Pingguoyuan rail micro-center is located in Shijingshan District, Beijing. Referring to existing circle analysis research[1-2], the Pingguoyuan Station is divided into 3 circles: 500, 800, and 1,000 m in this paper, to analyze the distribution of facilities in core area of the station, surrounding pedestrian contact range, and larger scale. The research data includes the location, capacity, actual parking volume, and supporting conditions of parking spots obtained from on-site surveys, parking spot tables, and Gaode POI data. POI data can be used to analyze the spatial distribution of different types of public service facilities[6]. Combining the research objectives, public service facilities are classified into six categories: commercial service, transportation service, community service, leisure and recreation, science, education, and culture, and healthcare.

1.3 Evaluation methods

Spatial matching evaluation includes three dimensions: accessibility, coverage, and convenience. Accessibility is reflected by the closest distance from each parking point to six types of public service facilities, to determine the spatial proximity of different facilities after parking. Coverage setts two analysis radii of 300 and 500 m centered around the parking point, and the coverage rates of various POIs at different distance thresholds are compared. The above threshold is set for the analysis in this paper and is not intended as a universally applicable standard for walking comfort or acceptable distance. Convenience evaluation refers to the attention paid to bicycle parking, traffic signs, and supporting facilities in the study of slow traffic connecting spaces[4], combined with on-site information such as parking capacity, utilization rate, rain shelters, charging facilities, parking order, and directional signs for judgment. Ultimately, the three dimensions are integrated to identify the matching level of various public service facilities. It should be noted that the distance calculation in this paper is based on point coordinates, mainly reflecting spatial proximity relationships, and cannot be completely equivalent to walking or cycling distances in real road networks.

2 Current situation and spatial matching evaluation

2.1 Current situation of public service facilities and parking facilities

Within a radius of 1,000 m in the research area, a total of 1,601 public service facility POIs are identified, including 1,044 commercial service facilities, accounting for 65.2%, which are the main types. According to the circle statistics, there are 550, 743, and 308 facilities within the range of 0–500, 500–800, and 800–1,000 m, respectively. The clustering is most obvious in the circle of 500–800 m, with commercial and scientific, educational, and cultural facilities extending more prominently to the periphery (Fig.1, Table 1).

A total of 10 non-motorized vehicle parking spots are identified on site, with a total capacity of approximately 1,160 vehicles. During the investigation period, approximately 937 vehicles are actually parked, with an average utilization rate of 80.8%. Among them, there are 7 cen-tralized parking spots, 3 roadside and open parking spots, and only 2 have rain shelters. No centralized charging facilities have been found. The parking spots are mainly concentrated within a range of about 200 m around Pingguoyuan Station, with the main parking pressure borne by the elevated bridge and the square in front of the station. There are relatively few parking spots around the surrounding communities, medical and educational cultural facilities. From this, it can be seen that there is a significant spatial mismatch between the expansion of public service facilities outside the circle of 500–800 m and the aggregation of parking facilities in the core area.

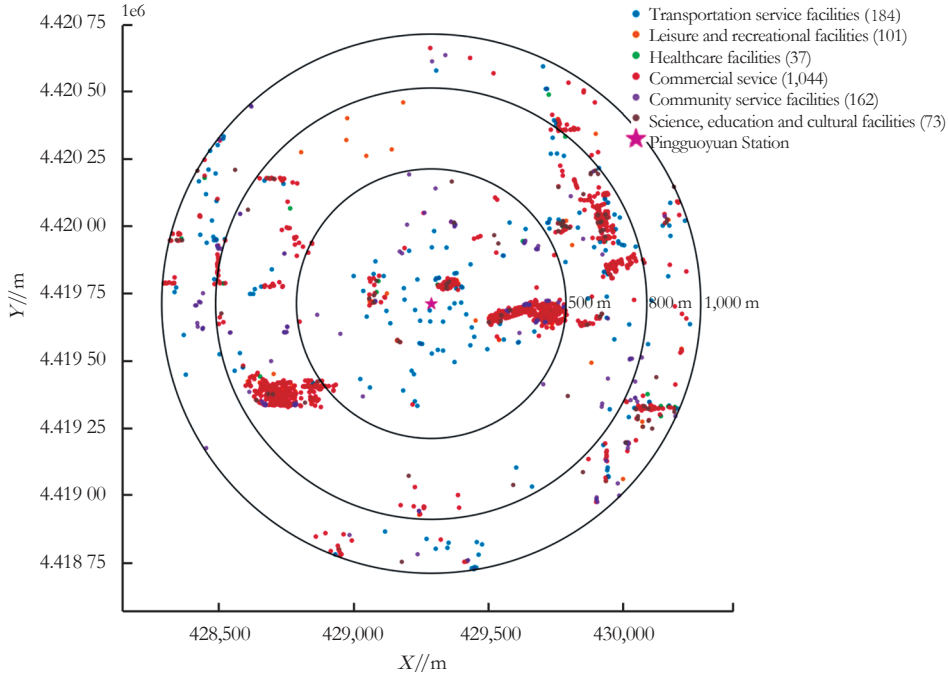

Fig.1 POI distribution of public service facilities in the Pingguoyuan rail micro–center

2.2 Accessibility and service coverage

The closest distance calculation shows that the average closest distance between parking spots and transportation service facilities is the shortest, at 25.5 m. The average closest distance between parking spots and commercial service facilities is 67.0 m, and the average closest distance between parking spots and community service facilities is 148.6 m, with relatively weak spatial connections. Under a service radius of 500 m, the coverage rates of leisure and recreation, community services, and commercial services facilities are 65.3%, 53.7%, and 52.8%, respectively, while the coverage rates of science, education, and culture, and healthcare facilities are only 37.0% and 35.1% (Table 2). This indicates that the existing parking system can better support rail transfers, commercial consumption, and some leisure activities, but lacks support for public service facilities such as science, education, and culture, and healthcare.

2.3 Convenience and comprehensive evaluation

From the perspective of convenience, the parking facilities in Pingguoyuan have a certain foundation in terms of capacity supply, with a high average utilization rate. The transfer service function of the core parking area is strong, but there are still shortcomings in the quality of the facilities. Most parking spots are open-air, with only 2 having good shelter conditions. No centralized charging facilities have been found at all 10 parking spots. There are phenomena such as mixed parking of vehicles, unclear boundaries, and occupation of slow-moving space at commercial entrances and roadside points, and some point guidance signs are not clear enough. Based on the comprehensive assessment of accessibility, coverage, and convenience, the overall matching of transportation, commerce, and leisure facilities is good, while the matching of community service facilities is average. The matching of scientific, educational, and cultural facilities is generally weak, and the matching of medical and healthcare facilities is insufficient. Pingguoyuan has formed a non-motorized vehicle parking system with rail transfer as its core, but has not yet formed a balanced and graded service network for public service facilities.

3 Optimization strategies

3.1 Building a graded and classified parking system

Based on the spatial mismatch between the core agglomeration of parking facilities and the peripheral expansion of public service facilities, a three-level parking system of "rail station level–public service facility level–community level" is constructed, which respectively serves transfer, public service facility use, and daily community travel. The parking supply is moderately extended from the core area of the station to the functional agglomeration area of 500–800 m and the community living space (Table 3).

3.2 Strengthening the connection and supporting of public service facilities

Different public service facilities should adopt differentiated supplementary methods: short-term parking areas should be set up around commercial facilities with clear boundaries; it should supplement parking spots near the entrance of medical facilities and take into account accessibility needs; science, education, and culture facilities alleviate pressure through time-sharing parking, separation of people and vehicles, and peak management; community service facilities are equipped with small-scale parking spots around the community entrance and service center; it should improve entrance parking and guidance for leisure and recreational facilities. At the same time, rain shelters should be appropriately installed in the station square, commercial entrances, and main centralized parking areas. Safety charging facilities should be piloted in larger parking areas[4], and parking boundaries should be standardized through ground markings, guardrails, green restrictions, and clear signage.

3.3 Improving slow network and collaborative management

Non-motorized vehicle parking points should be embedded in a slow traffic network among rail stations, bus stops, community entrances, and public service facilities. The traffic modes around Pingguoyuan Station are obviously intertwined. It is necessary to optimize the pedestrian connection between subway entrances and exits,

Table 1 Types and circle distribution of public service facilities in the Pingguoyuan rail micro-center

Type of public service facilities	Number	Proportion//%	0–500 m	500–800 m	800–1,000 m
Commercial service facilities	1,044	65.2	352	548	144
Transportation service facilities	184	11.5	64	52	68
Community service facilities	162	10.1	63	46	53
Leisure and recreational facilities	101	6.3	45	46	10
Science, education, and cultural facilities	73	4.6	16	37	20
Healthcare facilities	37	2.3	10	14	13
Total	1,601	100.0	550	743	308

Table 2 Results of spatial matching between non-motorized vehicle parking facilities and public service facilities

Type of facilities	Average closest distance//m	Coverage rate of 300 m//%	Coverage rate of 500 m//%	Accessibility	Comprehensive evaluation
Business service	67.0	23.0	52.8	Better	Better matching
Transportation service	25.5	33.7	44.6	Better	Better matching
Community service	148.6	32.7	53.7	General	General matching
Leisure and recreation	77.7	33.7	65.3	Better	Better matching
Science, education, and culture	88.0	20.5	37.0	Better	Generally weak
Healthcare	94.8	21.6	35.1	General	Insufficient matching

Table 3 Classification optimization strategy for non-motorized vehicle parking facilities

Parking facility level	Main service targets	Suitable layout location	Optimization focus
Rail station level	Transit crowds	Subway entrances and exits, bus transfer areas, spaces under bridges, and station squares	Guidance, order, and turnover efficiency
Public service facility level	Commercial, medical, educational and cultural, and leisure users	Entrance to commercial and public service facilities, park entrance	Small and medium-sized dispersed distribution points to enhance accessibility
Community level	Daily travel of surrounding residents	Residential area entrance, community service center, and residential road nodes	Connecting community travel and improving convenience of life

bus stops and parking areas, improve sidewalks, street crossing facilities, barrier free passages and night lighting, and reduce the occupation of tactile paving and pedestrian spaces by vehicles[4]. Subsequent updates should also synchronize the configuration of parking spaces with public service facilities, and differentiated management should be implemented based on different scenarios such as commerce, medical treatment, science, education, and culture, and community, to achieve collaborative maintenance by streets, communities, property management, and operational entities.

4 Conclusions

From three dimensions: accessibility, coverage, and convenience, this paper evaluates the spatial matching relationship between non-motorized vehicle parking facilities and public service facilities in the Pingguoyuan rail micro-center. The main conclusions are as follows: firstly, the public service facilities in the study area have obvious circle diffusion characteristics. Among the 1,601 POIs, commercial services dominate, and the facilities at the circle of 500–800 m are the most concentrated. In contrast, the 10 non-motorized vehicle parking spots are mainly concentrated within a range of about 200 m around the station, forming a spatial difference of "public service expansion-parking supply cohesion". Secondly, the accessibility and matching degree between existing parking facilities and transportation, commerce, and leisure facilities are relatively good, but the coverage rates of science, education, and culture, and healthcare facilities within 500 m are only 37.0% and 35.1%, respectively. There is also insufficient local connection in community service facilities, indicating that the parking system is still mainly based on rail transfer. Thirdly, the overall parking capacity can support the existing demand, but the rain shelter, charging, guidance, and parking order still need to be improved. Based on this, a hierarchical system of "rail station level-public service facility level-community level" should be constructed, and the parking layout, facility quality, and slow traffic network should be optimized in coordination. This paper uses point coordinates to measure spatial proximity relationships, but has not yet taken into account real road networks, time-sharing passenger flow, and differences in behavior among different groups. Further testing can be conducted by combining path data and time period surveys.

References

[1] Wang, J., Lu, X. Q. & Lu, H. P. (2024). Evaluation of the coordination between TOD development level and urban vitality at urban rail transit stations: A case study of rail transit micro-centers in Beijing. *Urban Transport of China*, *22*(6), 40-50.

[2] Lu, L. N. (2023). *Configuration optimization of public service facilities in residential rail transit station area based on TOD and life circle coupling* (Master's thesis). Retrieved from China National Knowledge Infrastructure.

[3] Guo, Y. X. (2015). *Research on the connection mode of rail transit based on travel chain*: *A case study of Beijing* (Master's thesis). Retrieved from China National Knowledge Infrastructure.

[4] Qin, S. H., Li, D. Y. (2024). *Evaluation of user satisfaction with slow travel shuttle space at urban rail transit stations*: *A case study of Pingguoyuan Street*, *Shijingshan District*, *Beijing City*//2024 China Urban Planning Annual Conference.

[5] Feng, J. M., Li, C. & Sun, Y. X. et al. (2023). Spatial matching between supply and demand of public service facilities: A case of Huilongguan-Tiantongyuan area in Beijing. *City Planning Review*, *47*(5), 75-85.

[6] Liu, Z. F., Guo, P. & Sun, Y. L. et al. (2023). Clustering analysis of public service facility in central urban area of Zhuhai City based on POI data. *Areal Research and Development*, *42*(2), 73-79.

[7] Gu, J. C. (2021). *Research on spatial coupling between rail transit stations and public service facilities*//2020 China Urban Planning Annual Conference.

[8] Zhong, T. Y. (2025). *Research on spatial coupling between rail transit stations and public service facilities*: *A case study of Wuhan City*//2025 China Urban Planning Annual Conference.

****

(Continued from P11)

to a deeper proposition, namely that the contemporary value of regionality lies neither in the museum-style preservation of traditional culture nor in the helpless distant observation of the natural climate, but in transforming the "local wisdom" embodied in local predicaments into a design grammar oriented toward the future. The environmental landscape design of the river island is no longer merely a single tourist reception place, but a holistic and systematic composite environmental design system of "climate regulator", "culture generator" and "ecological filter". In other words, as humanity pursues high-quality development today, the core competitiveness of regional landscape lies precisely in its creative response to "limiting conditions" or certain predicament states. The practice of environmental landscape design for the river island in Nawei Village, Tiantang Temple, Tianzhu, Gansu shows that when design takes root in the land, climate and ethnic memory beneath our feet, marginal places are fully capable of providing a unique approach, reference and lesson from northwest China for global environmental and cultural crises.

References

[1] Zhang, J. (2009). *Research on regional architectural creation in Northeast China* (Master's thesis). Retrieved from China National Knowledge Infrastructure.

[2] Wang, X.L. (2015). Theoretical research based on regional landscape design. *Today's Massmedia*, *23*(6), 115-116.

[3] Wu, L.Y. (2002). Basic concepts, regional culture and the mode of the times: an exploration of the development path of Chinese architecture. *Architectural Journal*, (2), 6-8, 65-66.

[4] Yang, X. (2009). *Theoretical research on regional landscape design* (Master's thesis). Retrieved from China National Knowledge Infrastructure.

[5] He, X.N. (2025). *Research on multi-ethnic interaction and exchange in the Datong River Basin* (Master's thesis). Retrieved from China National Knowledge Infrastructure.

[6] Bao, Z.P. (2018). *Research on the countermeasures for tourism development in Tianzhu Tibetan Autonomous County* (Master's thesis). Retrieved from China National Knowledge Infrastructure.