Journal of Global Change Data & Discovery. 2023, 7(1): 48-55
www.geodoi.ac.cn

Accessibility Evaluation 1-km Ruster Dataset Development of Public Charging Stations for New Energy Vehicles in Beijing (2020)

Huang, J.[1, 2*] Gao, Y.[1, 2]

1. Institute of Geographic Sciences and Natural Resources Research & Key Laboratory of Regional Sustainable Development Modeling, Chinese Academy of Sciences, Beijing 100101, China;
2. College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100049, China

Abstract: Accessibility represents the ease or difficulty of reaching a particular location and overcoming spatial distances and is a commonly used indicator in the study of public service facilities. Based on the spatial distribution of public charging station sites, population distribution data, point of interest data, and other relevant information of the Sixth Ring Road of Beijing in 2020, we used the two-step floating catchment area, cumulative opportunity, and spatial clustering methods to calculate the accessibility of public charging facilities for car travel at the kilometer grid level, as well as the cumulative opportunity count for walking activities after charging completion. Consequently, we developed a dataset for evaluating the accessibility of public charging stations within the Sixth Ring Road of Beijing in 2020. The dataset includes the following: (1) accessibility data for electric vehicles to reach public charging stations from the center of each 1 km grid; (2) the cumulative opportunity count of various types of public service facilities reachable by each vehicle owner from the center of each 1 km grid; and (3) comprehensive evaluation results of accessibility for both car travel and foot travel. The dataset was archived in .shp format, consisting of eight data files with data size of 963 KB (compressed into one file, 153 KB).

Keywords: residential travel; accessibility; public service facilities; electric vehicles

DOI: https://doi.org/10.3974/geodp.2023.01.07

CSTR: https://cstr.escience.org.cn/CSTR:20146.14.2023.01.07

Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2023.04.02.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2023.04.02.V1.

1 Introduction

In the context of industrial transformation and carbon neutrality, the layout of new types of infrastructure is important for socioeconomic development[1]. As a strategically supported

Received: 03-02-2023; **Accepted:** 20-03-2023; **Published:** 25-03-2023

Foundation: National Social Science Fund Major Project (20&ZD099)

***Corresponding Author:** Huang, J. CVH-4108-2022, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, huangjie@igsnrr.ac.cn

Data Citation: [1] Huang, J., Gao Y. Accessibility evaluation 1-km ruster dataset development of public charging stations of new energy vehicles in Beijing (2020) [J]. *Journal of Global Change Data & Discovery*, 2023, 7(1): 48–55. https://doi.org/10.3974/geodp.2023.01.07. https://cstr.escience.org.cn/CSTR:20146.14.2023.01.07.

[2] Huang, J., Gao Y. Accessibility evaluation dataset of public charging stations of new energy vehicles in Beijing [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2023. https://doi.org/10.3974/geodb.2023.04.02.V1. https://cstr.escience.org.cn/CSTR:20146.11.2023.04.02.V1.

emerging industry, megacities are gradually increasing their market share of new energy vehicles[2]. Public charging stations for new electric vehicles represent a new type of urban infrastructure. The suitable allocation, quantity, and layout of charging stations can support new energy vehicle users, improve charging convenience, and increase the popularization and adoption of new energy vehicles, thus playing a crucial role in sustainable urban development and the construction of suitable transportation systems.

Recently, the development, planning, construction, and layout of charging stations have become popular research topics. Related studies have focused on policy making[3], charging technology, charging capacity allocation[4], optimization of algorithms for energy conservation and emission reduction[5], as well as power load and charging time[6]. Accessibility is an essential indicator of the public service nature of new energy charging stations. Studies on accessibility include the evaluation of spatial coverage, equality, and the efficiency of public service facilities from a geographical perspective. At the technical and methodological level, various studies have been conducted using gravity model (which consider spatial distance and facility quantity), cumulative opportunity model, isochrone model, distance-based model[7–9], balance coefficient model (that consider supply-demand relationships), or the two-step floating catchment area (2SFCA) model[9,10]. Results from previous studies indicate that, by introducing distance decay, the cumulative opportunity method can effectively increase the accuracy of facility accessibility measurements[11]. The 2SFCA model, with a variable effective service radius, can effectively reflect regional accessibility influenced by supply, demand, and distance[10].

At the practical level, after the proposal of the "new infrastructure" and "dual-carbon" goals in 2020, the market share of new energy vehicles in China has increased significantly, and local governments have begun to pay more attention to the construction of public charging stations. However, the assessment of public charging-station accessibility is often based on community-based capacity planning, which lacks precise evaluations at the city level and, from a detailed perspective, makes it challenging to accurately assess the service level of charging stations.

Thus, a fine-scale evaluation of the accessibility of public charging infrastructure is of great significance for the further development of the new energy vehicle industry. Within this context, the developed dataset provides quantitative results of public charging station accessibility at the kilometer grid scale within the Sixth Ring Road of Beijing and resolves the issue of mismatched supply and demand in charging infrastructure services and provides scientific support for optimizing the layout of public charging facilities for new energy vehicles.

2 Metadata of the Dataset

The metadata of the Accessibility evaluation dataset of public charging stations of new energy vehicles in Beijing is summarized in Table 1[12]. It includes the dataset full name, short name, authors, year of the dataset, temporal resolution, spatial resolution, data format, data size, data files, data publisher, and data sharing policy, etc.

3 Methods

3.1 Data Sources

The developed dataset has a 1 km × 1 km grid and covers the area within the Sixth Ring Road of Beijing. The following data sources were used for the dataset development.

Table 1 Metadata summary of the Accessibility evaluation dataset of public charging stations of new energy vehicles in Beijing

Items	Description
Dataset full name	Accessibility evaluation dataset of public charging stations of new energy vehicles in Beijing
Dataset short name	AccessibilityofBeijingchargingpile_2020
Authors	Huang, J. CVH-4108-2022, Institute of Geographic Sciences and Natural Resources Research, huangjie@igsnrr.ac.cn Gao, Y. GSM-9571-2022, Institute of Geographic Sciences and Natural Resources Research, gaoyang212@mails.ucas.ac.cn
Geographical region	Within the sixth ring road of Beijing city
Year	2020 Spatial resolution 1 km × 1 km
Data format	.shp Data size 153 KB (after compression)
Data files	AccessibilityofBeijingchargingpile_2020
Foundation	National Social Science Fund Major Project (20&ZD099)
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	***Data*** from the Global Change Research Data Publishing & Repository includes metadata, datasets (in the *Digital Journal of Global Change Data Repository*), and publications (in the *Journal of Global Change Data & Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the 'ten per cent principal' should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[13]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEO

(1) Vehicle ownership, public charging station construction, and residential travel destinations were obtained from the 2021 Beijing annual report on transportation development[14].

(2) Socioeconomic statistical data, such as the total population and vehicle ownership, were obtained from the Beijing Statistical Yearbook 2021[1], and administrative boundary data were sourced from the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences[2].

(3) Point of interest (POI) data was obtained from the Amap Application Programming Interface (API), including categories such as healthcare, schools, dining, entertainment, residential areas, companies, and charging stations. Data fields included the name, time (August 16, 2021), latitude, longitude, and POI category. Subsequently, we referred to mobile applications such as State Grid and Xingxing Charging to screen and verify the distribution of the charging stations.

(4) Road network data was downloaded from the OpenStreetMap[3] website and pre-processed using geospatial information technology. Roads were classified into different levels, and speed limits were set based on road types, including local roads (20 km/h), secondary roads (40 km/h), main roads (60 km/h), and motorways (80 km/h). Travel time was used as a cost in the dataset creation process.

(5) The 2020 population distribution data, obtained from Worldpop[4]. Using integrated household surveys, microdata, satellite, and other data sources, population estimation values were generated through a random forest algorithm.

[1] https:// nj.tjj.beijing.gov.cn/nj/main/2021-tjnj/zk/indexch.htm.

[2] https://www.resdc.cn/.

[3] OpenStreetMap. https://www.openstreetmap.org/.

[4] Worldpop. https://hub.worldpop.org/geodata/summary?id=49919.

3.2 Data Processing

Charging and travel activities primarily involved the following two processes: vehicle owners driving to search for charging stations near their destinations, and vehicle owners walking to charging stations during the charging process. To search for charging stations while driving, a Gaussian distribution function with distance decay was used. The center point of the grid was considered the starting point, while the charging station was considered the endpoint. Using a two-step movement search algorithm, the number of reachable charging stations during the travel chain process was calculated to obtain evaluation results of charging station accessibility. For walking activities, a third-degree polynomial function was used for distance decay. The charging station was considered the starting point, with the center point of the grid being the endpoint. A cumulative opportunity algorithm was used to calculate the number of reachable facilities of various types during the walking part of the travel chain process, yielding evaluation results of walking activity accessibility. Finally, based on the principle of equal intervals, the evaluation results of the two steps were divided into nine categories to provide numerical and categorical outputs for charging station accessibility.

3.2 Technical Roadmap

We developed a technical roadmap for creating a dataset to evaluate the accessibility of public charging stations within the Sixth Ring Road of Beijing and to analyze the spatial distribution characteristics of public charging stations (Figure 1). The technical roadmap included the following steps:

(1) We obtained, drew, and integrated basic data such as administrative districts, ring road boundaries, population distribution, POIs, and graded road network data in Beijing.

(2) Divide the smallest evaluation unit. Our dataset uses a 1 km × 1 km grid as the smallest evaluation unit, allowing for the aggregation of spatial data, such as population distribution and POI, into the evaluation grid. The facility supply and demand of each grid were adjusted using the total number of cars, total population, facility size, and total data quantity.

(3) A vector network dataset was created, and calculations were performed using ArcGIS.

(4) Distance decay functions were developed for the driving and walking stages and the POI at different distances.

(5) A two-step mobile algorithm and cumulative opportunity model were used to calculate the accessibility of charging stations within the evaluation grid.

(6) Equi-frequency binning was used to divide the two-stage evaluation results into high, medium, and low levels and to connect the results of the two steps to obtain the dataset for evaluating the accessibility of public charging stations.

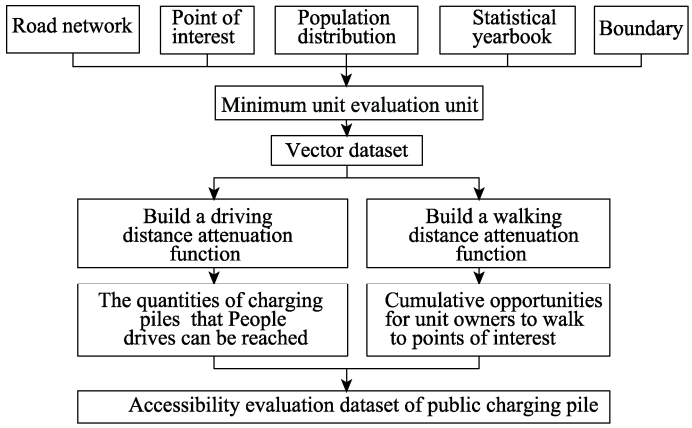

Figure 1 Technology roadmap for the dataset development

4 Data Results and Validation

4.1 Data Composition

The accessibility evaluation dataset of public charging stations of new energy vehicles in Beijing consists of a single dataset based on the accessibility evaluation 1 km grid vector data (.shp). The attribute fields of the dataset included (1) data on the accessibility of public charging piles for each electric vehicle within the Sixth Ring Road of Beijing, departing from the 1 km grid, with the field name PA; (2) the cumulative opportunity count of various public service facilities reachable by each vehicle owner departing from the 1 km grid within the Sixth Ring Road of Beijing, weighted by the different proportion of Beijing residents' travel purposes and calculated as the Z-score, with the field name comprehensive cumulative opportunity (OA); and (3) a comprehensive evaluation of accessibility across the two stages of driving and walking by vehicle owners, including a total of nine levels, such as low-low, low-medium, and low-high, with the field name Combi1_2.

4.2 Data Results

Based on the 2020 population distribution and stock of new energy vehicles (NEVs) in Beijing, we calculated a total of 312,400 NEVs within the Sixth Ring Road. The results of the developed dataset show a significant variation in the overall accessibility patterns of charging stations across different areas (Figure 2). In the region with the highest accessibility to public charging stations in Beijing, each vehicle, on average, had access to 0.148 public charging stations, whereas in the lowest accessibility region, this decreased to 0.004 stations per vehicle, with an average of 0.09 charging stations available per vehicle. From a citywide perspective, the spatial distribution of charging stations in Beijing aligns with the hierarchical structure of the city's transportation network, forming various concentric circles[15]. The characteristics of the concentric circles in terms of charging station accessibility per vehicle are as follows: (1) The first concentric circle corresponds to the area within the Fourth Ring Road. The average number of accessible charging stations within the Fourth Ring Road is 0.135, which is higher than that areas outside the Fourth Ring Road, while the variation within this region is relatively small. (2) Charging station accessibility per vehicle significantly decreased beyond the Fourth Ring Road, with an average value of 0.11 between the Fourth and Fifth Ring Roads. The second concentric circle appears between the Fourth Ring Road and the edge of the Fifth Ring Road, with accessibility ranging from 0.09 to 0.12. (3) Beyond the Fifth Ring Road, accessibility values rapidly declined, forming a three-tiered concentric circle pattern. Within the region between the Fifth and Sixth Ring Roads, the average number of accessible charging stations was 0.07. Furthermore, compared with the western side, there was a slight increase in charging station accessibility per vehicle on the eastern side of the Fifth Ring Road.

In this study, data were obtained from the 2020 Beijing Resident Travel Survey data[14]. Travel purposes was categorized based on facility attributes, including commuting, shopping, dining, leisure, and other primary activity facilities. Furthermore, based on the travel frequency of the total population[14], the accessibility of charging

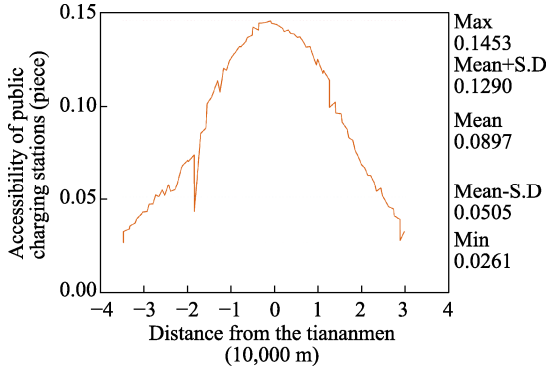

Figure 2 Distribution map of the accessibility of charging stations in Beijing city

stations to activity facilities was accumulated and weighted according to the proportion of trips, resulting in the calculation of OA for pedestrian activities. The spatial distribution data of OA (Figure 3) revealed the following: (1) A global Moran's I value for OA of 0.83 with a Z-score of 56.41 indicates a significant clustering pattern of OA within the Sixth Ring Road in Beijing at a 99% confidence level. (2) A mean OA value of 0.41, with a minimum of 0 and a maximum of 11.41. OA exhibited a distribution pattern in which the central area had higher values than the peripheral areas, and the northern region had higher values than those of the southern region. High-value clusters were concentrated in the northeast region within the Fourth Ring Road in Beijing, whereas low-value clusters were found outside the Fourth Ring Road in areas with lower urban road density. (3) At the municipal level, the eastern and western urban districts of Beijing had the highest mean OA values, followed by Chaoyang, Haidian, and Fengtai, whereas Shijingshan and Mentougou had the lowest values. (4) At the street level, areas within the Second Ring Road such as Taoranting, Temple of Heaven, Shichahai, Jingshan, and Donghuamen had lower OA values than those of the surrounding areas. Conversely, areas such as Xincun, Dongtiejiaying, Shangjie, Wangjing, and Qinghe had higher OA values than those of the surrounding areas[15].

Based on previously calculated Potential Accessibility (PA) and comprehensive cumulative opportunity (OA), we divided the results into three categories (low, medium, and high) using equal-frequency partitioning. The two-step results were then combined to create nine comprehensive evaluation categories. The combined evaluation results represent different levels of vehicular and pedestrian accessibility, with the “low-high” region indicating low vehicular accessibility and high pedestrian accessibility, while the “high-low” region indicates the opposite[15] (Figure 4). (1) The “high-low” region was distributed around the Fifth Ring Road, while the “low-high” region appeared in the peripheral areas near the Sixth Ring Road. This indicates that in the region between the Fifth and Sixth Ring Roads in Beijing, certain areas have formed regional centers for employment and life services; however, the supply level of charging facilities cannot match the increased demand resulting from the growth of activity facilities. (2) The “low-low” region of the comprehensive evaluation value corresponded closely to the cluster of low pedestrian values, while the “high-high” region overlapped with the high-value areas of pedestrian cumulative opportunities. This indicates that the central area of the city is supplemented with both public charging piles and various types of POI facilities, whereas the outer ring area exhibits an imbalance in the distribution of these facilities. (3) The overall evaluation results indicate that high-value areas exhibited central clustering and an axial radiating distribution. In the outer ring area (between the Fifth and Sixth Ring Roads), the distribution of public service facilities is relatively sparse, with the majority of public charging piles concentrated around urban motorways with a low density of installations. Therefore, in areas without charging station coverage, it is inconvenient for residents with new energy vehicles to access public service facilities. However, in the inner ring area (within the Fourth Ring Road), there was no significant difference between the two stages of charging facility

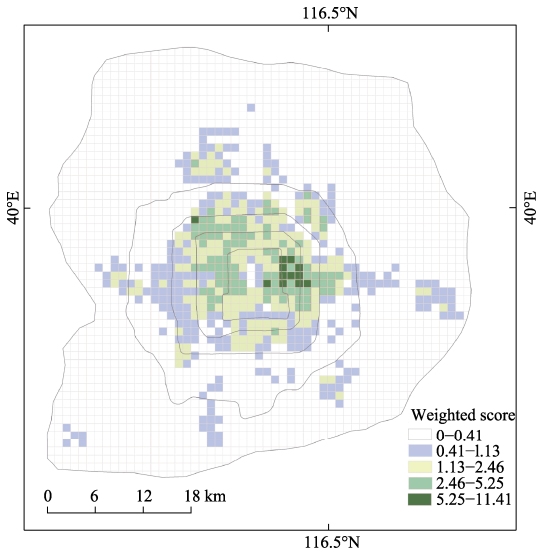

Figure 3 Map of cumulative opportunity score distribution in Beijing city

accessibility results owing to the higher density of residential and commercial facilities within the Fourth Ring Road in Beijing, which has more integrated public charging stations.

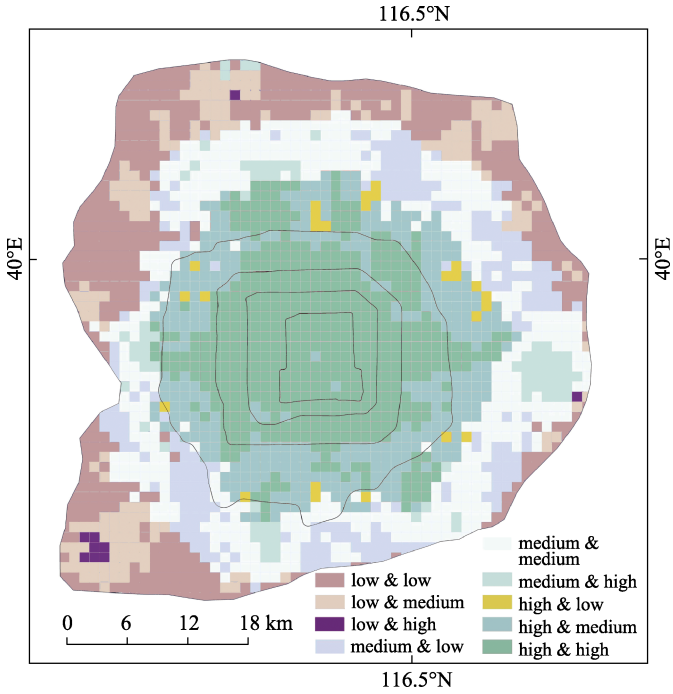

Figure 4 Map of accessibility of public charging piles in Beijing city

5 Discussion and Conclusion

The requirements for industrial structure upgrading and improvement of living environment quality are clearly defined in the 14th Five-Year Plan and the "Dual Carbon" goals. The layout of public charging stations, as a fundamental element of the new energy vehicle industry, directly affects the convenience of using new energy vehicles through factors such as spatial distribution, service coverage, and accessibility, thereby influencing the commercialization of new energy vehicles. The developed dataset is based on the complete travel chain of vehicle owners charging their vehicles and analyzes the spatial correlations between public charging stations, driving destinations, and pedestrian activity destinations to calculate the fine-scale spatial accessibility of charging facilities in Beijing. In terms of methodology, we used a two-step mobile search method and the cumulative opportunity method for analysis to accurately reveal the spatial distribution patterns of charging facilities. To some extent, the developed dataset improves the methodological system for studying the spatial accessibility of public charging piles and provides new research material and data support to assist in the layout and optimization of new infrastructure in Beijing. Notably, considering the varying proportions of new energy vehicle travel in different regions together with the wide distribution of private charging stations, the combination of different modes of transportation, and different travel periods, all of which affect the charging pattern, this dataset does not fully explore and analyze all relevant influencing factors. Instead, it provides a basic description of the spatial accessibility distribution of public charging piles within the Sixth Ring Road in Beijing, based on the supply-demand balance and the weighted adjustment of charging pile accessibility according to multipurpose travel.

Therefore, this dataset provides a foundation for further research on optimizing the layout of new energy charging piles. However, future related studies and data development still need to further collect and develop the spatial distribution of charging pile accessibility under complex travel conditions. In addition, future research avenues should include in-depth investigations of the spatial and temporal mismatch between new infrastructure and residents' needs in major cities in China and propose targeted optimization and simulation schemes. This will serve as fundamental research for the design and optimization of new infrastructure in China and contribute to the achievement of the "Dual Carbon" goals.

Author Contributions

Huang, J. designed the overall development of the dataset; Gao, Y. collected and processed the charging station evaluation data and drafted the data paper; Huang, J. reviewed, supervised, edited, and improved the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Lin, B., Liu, X. China's carbon dioxide emissions under the urbanization process: influence factors and abatement policies [J]. *Economic Research Journal*, 2010, 45(8): 66–78.

[2] Ma, J., Liu, X., Chen, Y., *et al*. Current status and countermeasures for China's new energy automobile industry and technology development [J]. *China Journal of Highway and Transport*, 2018, 31(8): 1–19.

[3] Tang, B., Wang, X., Wang, B., *et al*. Analysis and prospect of the development level of China's new energy vehicle industry [J]. *Journal of Beijing Institute of Technology*: *Social Sciences Edition*, 2019, 21(2): 6–11.

[4] Pantelidis, T. P., Li, L., Ma, T. Y., *et al*. A node-charge graph-based online carshare rebalancing policy with capacitated electric charging [J]. *Transportation Science*, 2022, 56(3): 654–676.

[5] Zhang, D., Jiang, J., Zhang, W., *et al*. Optimal configuration of charging piles for electric taxis [J]. *Transactions of China Electrotechnical Society*, 2015, 31(18): 181–188.

[6] Fang, Z., Zhang, J., Sun, Y., *et al.* Study on quantity planning of charging piles considering multi-objective constraints [J]. *Power System Technology*, 2020, 44(2): 704–712.

[7] Wang, F. Measurement, optimization, and impact of health care accessibility: a methodological review [J]. *Annals of the Association of American Geographers*, 2012, 102(5): 1104–1112.

[8] Wang, F., Wang, S., Li, M. Dynamic evolution and function optimization of green open space system in Luoyang [J]. *Geographical Research*, 2012, 31(7): 1209–1223.

[9] Wu, H., Levinson, D. Unifying access [J]. Tr*ansportation Research Part D*: *Transport and Environment*, 2020, 83: 102355.

[10] Zhao, P., Luo, J., Hu, H. Spatial match between residents' daily life circle and public service facilities using big data analytics: a case of Beijing [J]. *Progress in Geography*, 2021, 40(4): 541–553.

[11] Mora, R., Truffello, R., Oyarzún, G. Equity and accessibility of cycling infrastructure: an analysis of Santiago de Chile [J]. *Journal of Transport Geography*, 2021, 91: 102964.

[12] Huang, J., Gao, Y. Accessibility evaluation dataset of public charging stations of new energy vehicles in Beijing [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2023. https://doi.org/10.3974/geodb.2023.04.02.V1. https://cstr.escience.org.cn/CSTR:20146.11.2023.04.02.V1.

[13] GCdataPR Editorial Office. GCdataPR data sharing policy [OL]. https://doi.org/10.3974/dp.policy.2014.05 (Updated 2017).

[14] Beijing Transportation Development Research Institute. Annual report of Beijing transportation development in 2021 [EB/OL]. https://www.bjtrc.org.cn/List/index/cid/7.html, 2021-10-08.

[15] Huang, J., Gao, Y., Fu, Xiao, *et al*. Accessibility of public electric vehicle charging stations based on trip chains: a case study in Beijing [J]. *Geographical Research*, 2022, 41(12): 3305–3317.