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Big Data Analysis of Park and Green Space Serviceability for Elderly Population—Case Study of Core Area of Beijing

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Green spaces and parks play an important role in the urban ecosystem and are vital in improving the urban ecology, beautifying the environment, and maintaining the physical and mental health of urban residents. Beijing has been facing various challenges, such as the rapid growth of the elderly population. Parks and green spaces, which play an important role in citizens' daily lives, provide a place for senior residents to exercise, make friends, and communicate with others. As the threat of the pandemic is still present, too many visitors to parks and green spaces will hamper pandemic prevention efforts. In this study, data sources, including Baidu Map Huiyan and four-dimensional traffic data from Navinfo; surveying and mapping of geoinformatics spatial and statistical data; big data analysis; GIS spatial analysis and network analysis; and a normalization algorithm were used to assess the comprehensive capacity of parks and green spaces in the core area of Beijing to serve the elderly population in terms of demographic characteristics, accessibility, and the intensity of population mobility.

1. Introduction

Parks and green spaces are becoming increasingly important in urban planning as they provide spaces for leisure, recreation, communication, exercise, and relaxation. The report delivered at the 19th National Congress of the Communist Party of China proposed to pursue green development and increase attempts to solve significant environmental problems. Under the guidance of the Beijing Municipal Party Committee and Municipal Government, the spaces saved from the "decentralization of non-capital functions" will be primarily dedicated to "leaving empty spaces and increasing green spaces".(1) The "Implementation Opinions on Organizing and Implementing the Special Campaign of Relocation and Governance to Promote Improvement During the 14th Five-Year Plan Period" report points out that Beijing is planning to "leave empty and increase green" by 8.6 km^2 in the next five years by building several new urban parks in the central urban area. Worldwide, there are three typical classification systems of urban parks. The American National Park Service divides parks into three categories: national

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parks, national historical parks, and national recreational parks.[2] The Japanese park classification system classifies parks into natural parks and urban parks, which include children's parks, neighborhood parks, and regional parks.[3] The Standard for Classification of Urban Green Space (CJJT85-2017) of China divides parks and green spaces into four categories: comprehensive parks, community parks, theme parks, and gardens.[4,5]

According to the Development Report of the Beijing Municipal Undertakings for the Aged (2020), the elderly population of Beijing increased from 3.133 million in 2015 to 3.677 million in 2019. By the Seventh Population Census in 2020, the elderly population had further increased.[6] The elderly population have physical and mental particularities: their physical strength and immunity are weakening, they have fewer social interactions after retirement, and their children are usually busy at work. Therefore, there are various threats to their physical and mental health. With the improvement of living conditions, elderly people have begun to pursue a higher quality of life and spiritual satisfaction. Well-designed parks and green spaces provide a place for exercise, communication, socialization, and interaction with society, which contribute to social connectivity and reduce loneliness. Some experts believe that the importance of parks and green spaces is second only to housing for elderly people.[7–9] The accessibility[10–13] and availability of parks and green spaces as well as the density of tourists during the pandemic have affected the experience of elderly people visiting such spaces.

To address the above-mentioned concerns, in this study, we analyzed the serviceability of parks and green spaces for elderly people in the core area of Beijing, considering their common means of transportation as well as regular pandemic prevention and control measures. The demographics of the elderly population, accessibility of parks and green spaces, coverage rate, convenience, and population mobility were evaluated comprehensively. Big data analysis, GIS analysis, and a normalization method[14] were applied to geoinformatics spatial data, data of theme parks, and statistical data.

2. Materials and Methods

2.1 Materials

This study targeted the old urban area of Beijing, including 32 streets across the Dongcheng and Xicheng Districts. The results of the seventh national population census showed that the resident populations in Dongcheng and Xicheng Districts are 708829 and 1106214 and their administrative areas are 41.90 and 50.58 km^2, respectively. The official website of the Beijing Municipal Bureau of Landscaping and Afforestation listed a total of 68 green spaces affiliated with the municipal districts,[14] with Dongcheng District and Xicheng District each having 32. There are two municipal parks in Dongcheng District and four in Xicheng District, among which one is graded a 5A tourist attraction and five are graded 4A, with entrance prices ranging from 2 to 20 Chinese yuan depending on the season. In terms of district-affiliated parks, there are 32 in Dongcheng District and 30 in Xicheng District, most of which have free entrance.

The big data used in this study were from Baidu Map Huiyan population data, including the resident population, floating population, and passenger mobility. They were collected in 30 m ×

30 m grids over 24 h a day from July 22 to August 5, 2020. The four-dimensional traffic data we analyzed consisted of 24 h road speeds per day from July 22 to August 22, 2020.

The traditional surveying and mapping of geoinformatics data we used included Beijing's vehicle and pedestrian road traffic network, bus stops, bus lines, subway lines, and subway stations. Data related to parks were obtained from the official website of the Beijing Municipal Bureau of Landscape and Afforestation, and spatial data were obtained through Baidu Maps text and location searches and included park entrance and exit areas. The base map data, such as the administrative division, used in this study were obtained from the public version of the Tianditu standard map [mapping inspection number: No. Jing S (2021) 023].

Parks and green spaces are open to the public for recreational purposes. They also perform ecological, landscape, cultural, educational, and emergency risk aversion functions, being equipped with recreation and service facilities.[15,16] Parks and green spaces are generally divided into four types: comprehensive parks, community parks, theme parks (zoos, botanical gardens, historical gardens, etc.), and gardens (Table 1).

The main functions of parks are visitor recreation, ecological value, disaster prevention and mitigation, and public science education.[17,18] According to official statistics, the total areas of parks and green spaces in Dongcheng and Xicheng Districts are 5.82 and 4.32 km^2, respectively.[18] For senior residents aged 60 and above, a major benefit is that the entrance to parks and green spaces is either free or half price. Overall, 10 of the 64 parks charge an entrance fee, among which six are free for senior citizens aged 60 and above and four are free for those aged 65 and above. According to the classification of parks and green spaces, community parks and gardens in Dongcheng and Xicheng Districts account for 41 and 65% of the total number of parks. There are 17 community parks in Xicheng District, 2.8 times that of Dongcheng District.

Table 1
Classification standard of parks and green spaces.

Classification code		Classification name	Content
Division	Group		
G1		Parks and green spaces	Open to the public, serve a recreational purpose, perform ecological, landscape, cultural, educational, and emergency risk aversion functions, and offer recreation and service facilities
	G11	Comprehensive parks	Rich in content, suitable for a wide range of outdoor activities, offering green spaces with comprehensive infrastructure and facility management for recreational services
	G12	Community parks	Dedicated land use with basic recreation and service facilities aimed at offering green space for residents of a certain community to carry out daily leisure activities in the neighborhood
	G13	Theme parks	Green spaces with specific content and recreational service facilities including zoos, botanical gardens, historic gardens, ruins, amusement parks, and other theme parks
	G14	Gardens	Green places with dedicated land use, small in scale and diverse in format, convenient for residents to enter, performing recreational functions

2.2 Methods

2.2.1 Data preprocessing method

Incomplete demographic big data, such as missing attribute fields, missing time fields, and data anomalies, affect the accuracy of the analysis results. At the data preprocessing stage, Baidu Map Huiyan's big data were cleaned (Fig. 1) by adding missing attribute values and names. For the passenger volume data, the missing fields of some data entries, such as "date" and "hour", were supplemented by taking references from the complete data entries. The same approach was applied to the missing fields in passenger mobility data, such as "transportation mode" and "age group". By polynomial interpolation, the missing values for a certain day at a certain time were interpolated, taking the values for other dates as reference. To eliminate outliers, the expectation $E(x)$ and standard deviation (σ) of hourly values over all days were first calculated as follows:

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - E(x)\right)^2}. \tag{1}$$

The values located within the range of $(E(x)-\sigma, E(x)+\sigma)$ are normal values, while the remainder are outliers. The data cleaning scheme is as follows:

2.2.2 Analysis method

In this study, we analyzed four indicators, namely, the demographics of the elderly population in the core area, the service capacity of the parks and green spaces, the risks in terms of pandemic prevention and control, and convenience, utilizing the following approaches:

(1) Service coverage of parks and green spaces

A 10-min-walk radius map was retrieved from the analysis and calculation using the GIS network. The area of parks and green spaces with entrances and exits within a 10 min walk is

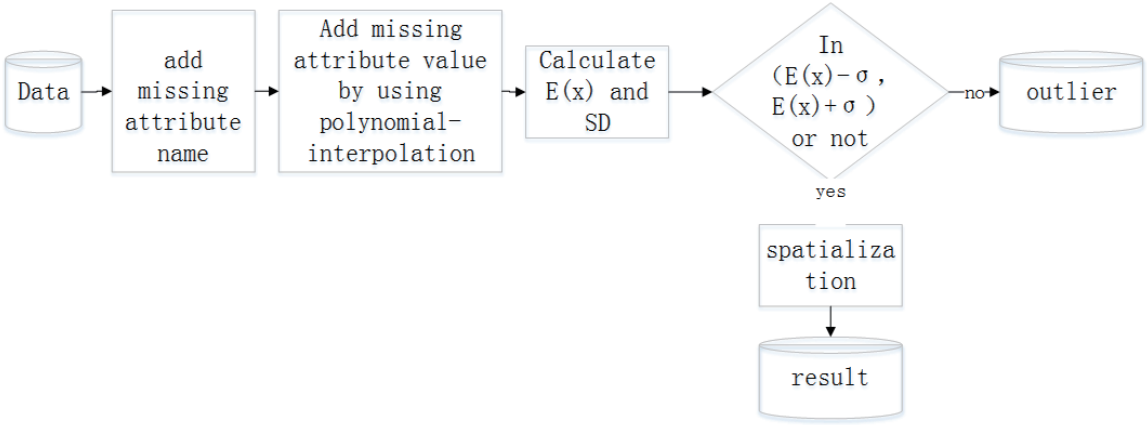

Fig. 1. Data cleaning scheme of Baidu Map Huiyan big data.

denoted as s_i in Eq. (2). The area of the street is denoted as S_{street}. Subsequently, the service coverage of the parks and green spaces P_{cover} is defined as

$$P_{cover} = \frac{\sum_i^n S_i}{S_{street}}. \tag{2}$$

(2) Intensity of population mobility in parks and green spaces

The intensity of population mobility refers to the ratio of the floating population to the number of residents in the region.[19–21] The intensity of population mobility in parks and green spaces is defined as the ratio of the difference between the peak and average numbers of visitors to the average number of visitors from 6:00 to 23:00, which is defined as flow_index. In this study, 17 × 24 h data were extracted for 64 scenic spots as follows:

$$\text{flow\_index} = \frac{Max\left(p_i(d,t)\right) - Mean\left(p_i(d,t)\right)}{Mean\left(p_i(d,t)\right)}, \tag{3}$$

where $Max(p_i(d,t))$ is the instantaneous number of visitors at peak time t on day d of the ith scenic spot, and $Mean(p_i(d,t))$ represents the average daily number of visitors.

(3) Per capita park area and peak visitor density

The per capita park area A_{glm} refers to the ratio of the area of the park and green space to the urban population:[16]

$$A_{glm} = \frac{A_{g1}}{N_p}, \tag{4}$$

where A_{g1} represents the area (m^2) of parks and green spaces and N_p represents the urban population.

(4) Average transportation distance to parks and green spaces

Through ArcGIS origin–destination (OD) cost matrix analysis, the distance from the geometric center of the street to the park was calculated, and the average commuting distance is

$$Average_{dist(i,j)} = \frac{\sum_{i=1,j=1}^{I,J} Dist(i,j)}{I}, \tag{5}$$

where i represents the ith park, j represents the jth block, $Dis(i,j)$ represents the OD cost distance of the park in block j, and I is the total number of parks, calculated as the sum divided by the total number of parks.

2.2.3 Traffic flow normalized model

GIS network analysis can be used to search for the shortest path, the nearest facilities in the neighborhood, the service area, and the OD. As data are added to the network, the peak and off-peak traffic on working days and weekends are increasingly accurately reflected.

In this study, the normalized traffic flow model was applied, and the speed values and curves showing the changing driving speed of all roads were analyzed 24 h a day on two weekends. Many roads were found to have regular periodic changes of speed on weekdays and weekends. Based on the mathematical algorithm we used to examine curve similarities, characteristic curves were extracted. The curves showing the changing driving speed on all roads on working days and weekends were characterized as several characteristic curves, which were normalized and configured in the network as traffic data. The workflow is shown in Fig. 2.

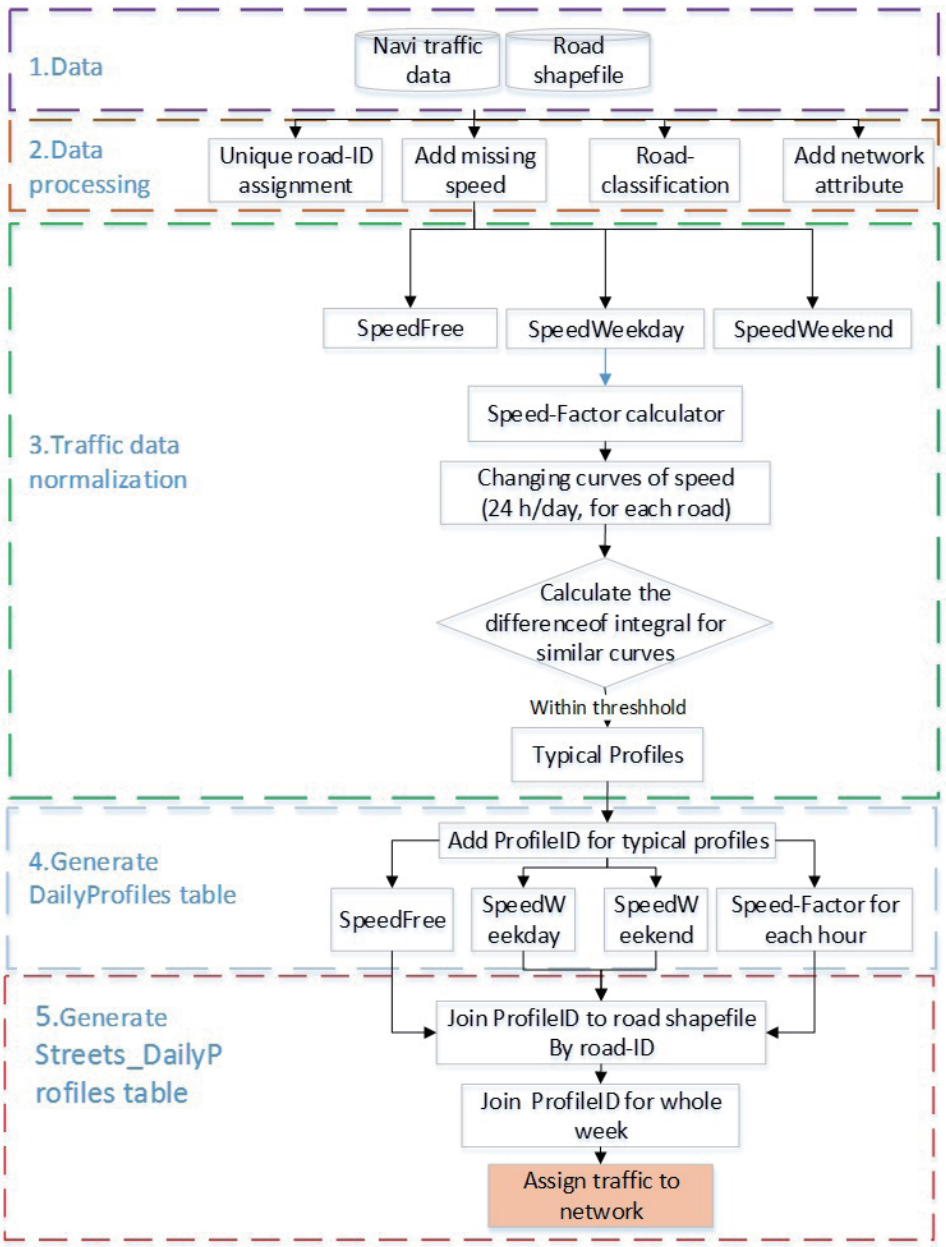

Fig. 2. (Color) Traffic data normalization method.

During the analysis of the driving speed on working days and weekends conducted 24 h a day, data on the smooth driving speed, average speed on working days, and average speed on weekends were extracted as normalized proportional denominators. The ratio of the speed at a specific time to the average speed was used as the scale factor, which was used in the generation of the curves showing the changing driving speed. The area under the curve was obtained by integration and a threshold was set of an integral threshold ratio of two curves of greater than 0.8 but less than 1.2. In this way, the difference of the integral was determined as an approximate curve within a certain threshold range to extract the characteristic curve and was connected to the network through the road ID. The driving speed and curves showing the changing driving speed were normalized.

3. Discussion

According to the Development Report of Beijing Municipal Undertakings for the Aged (2020) released by the Beijing Municipal Committee Office on Aging, the proportion of the population aged 60 and above was 26.5% in Dongcheng District and 25.9% in Xicheng District. According to the Baidu Map Huiyan statistics, the proportion of the population aged 65 and above was more than 25% in three of the 32 streets in the core area, namely, Andingmen Street, Jiaodaokou Street, and Xichang'an Street, among which the highest proportion was 38%. The lowest proportion, 3.8%, was found in Yongdingmenwai Street. The proportion of the population aged 65 and above is shown in Fig. 3.

According to the analysis of passenger mobility, among the senior residents aged 65 and above, 80% demonstrated medium and high consuming capacity; the highest proportion of senior residents with a high consuming capacity was in Jiaodaokou Street (76%). The traveling method was defined by the ownership of private cars: 70% did not own a car and 30% owned a

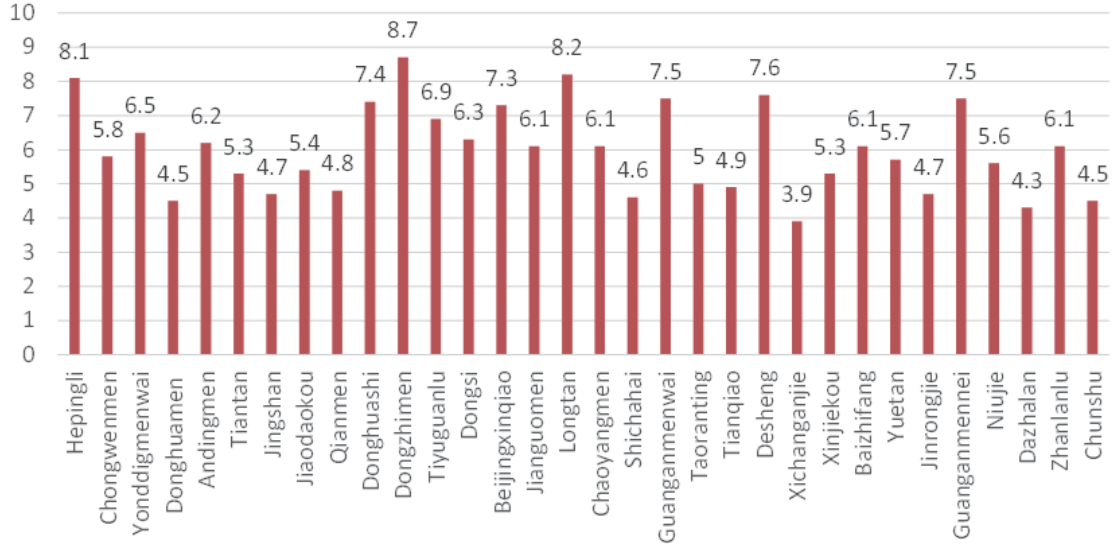

Fig. 3. (Color online) Proportion of population aged 65 and above.

car. Therefore, it is concluded that the consuming capacity of the elderly population in the core area tended to be of medium-to-high level. Comprehensive parks with further distance are accessible by private vehicles or public transport. The description of the elderly characteristics by street is shown in Fig. 4.

Based on the entrances and exits of 68 parks, 10-min-walk area coverage was calculated. People living in streets, where over 90% of the street area are covered within a 10 min walk from parks, including Andingmen Street, Qianmen Street, Tianqiao Street, Baizhifang Street, Guang'anmen Street, and Niujie Street, can conveniently walk to the park (Fig. 5).

The intensity of population mobility is closely related to the risk of infection in the context of ongoing pandemic prevention and control measures. In this study, 12 large parks characterized by the highest popularity were selected to calculate the intensity of population mobility. Zhongshan Park, Working People's Cultural Palace, and Yongdingmen Park exhibited the highest intensity of population mobility (Fig. 6).

The per capita park area was retrieved from the official release by the Beijing Municipal Bureau of Statistics. In May 2020, the latest data released by the Bureau of Statistics showed that the per capita park and green space area in Beijing has been increasing continuously in the past 10 years, and the per capita park and green space area reached 16.5 m^2 by 2020 (Fig. 7).[18]

Utilizing the ArcGIS network analysis and taking the geometric centers of the 32 streets as the starting points and the geometric centers of the municipal parks as the target points, the average traffic distance from the streets to the six municipal parks inside the core area was calculated (Fig. 8).

According to the results of OD spatial analysis, seven blocks had an average travel distance of more than 7 km. West Chang'an Street had the shortest average distance of about 3.9 km.

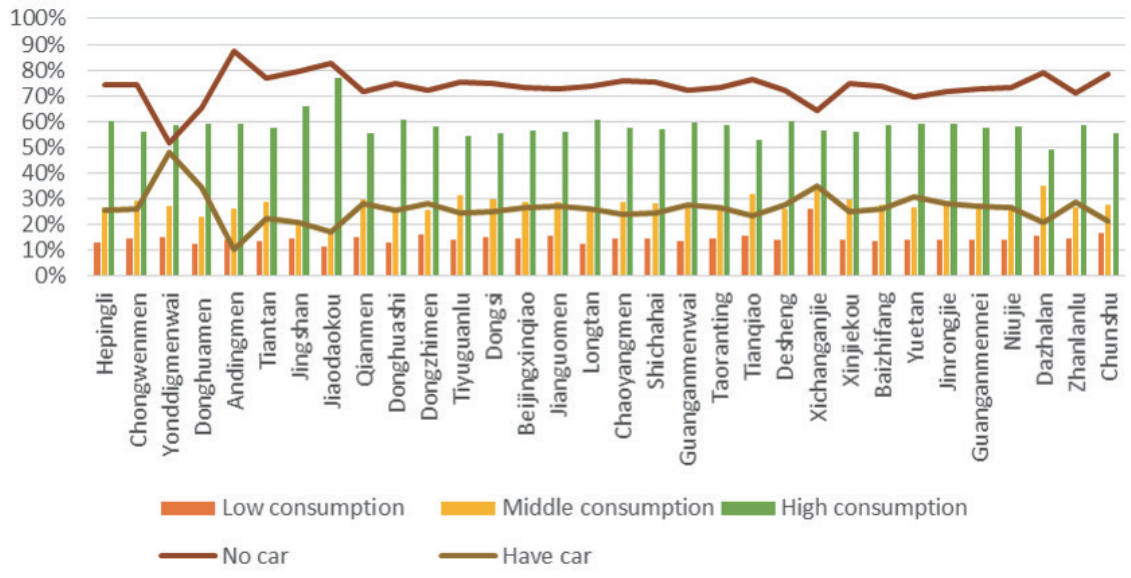

Fig. 4. (Color) Description of the elderly characteristics.

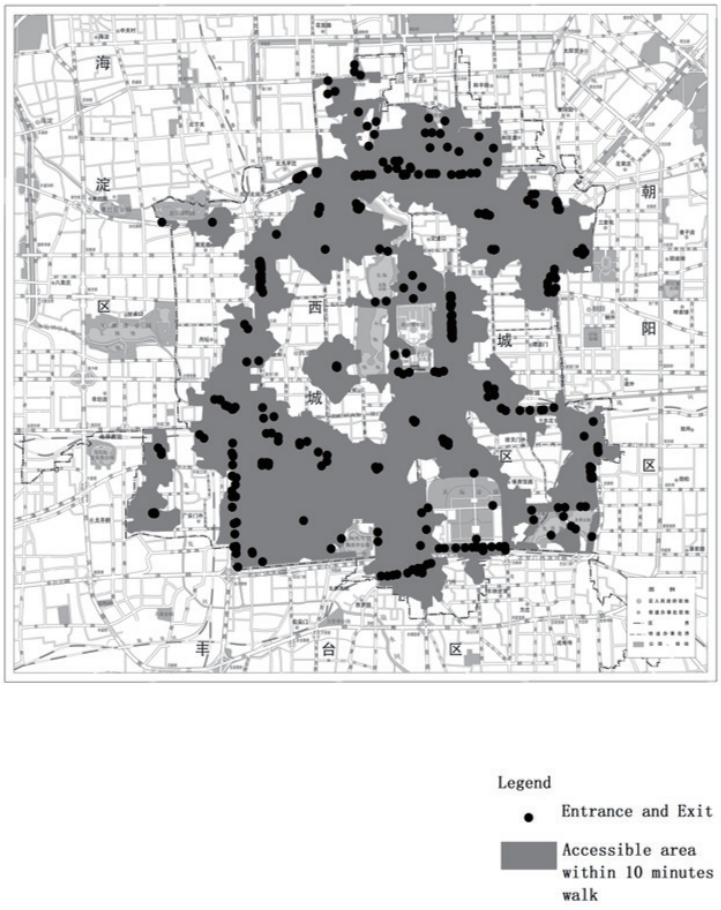

Fig. 5. Areas within 10 min walk from entrances and exits of parks.

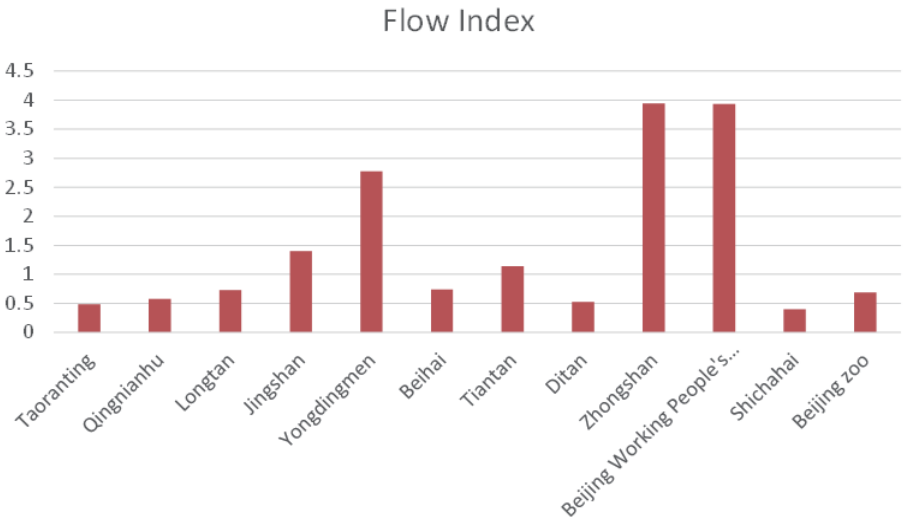

Fig. 6. (Color online) Intensity of population mobility.

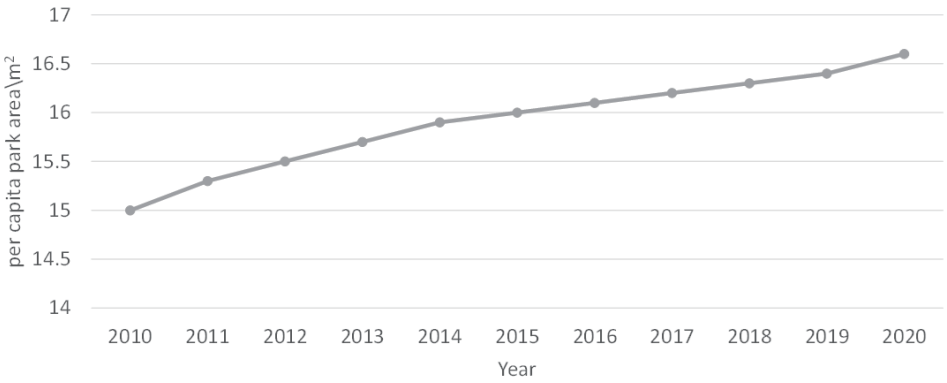

Fig. 7. Per capita park and green space in Beijing.

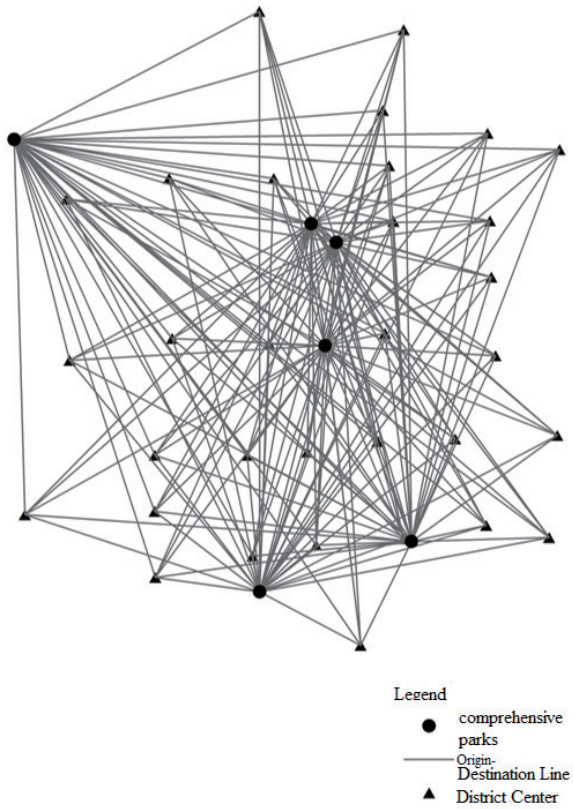

Fig. 8. OD cost distances from 32 streets to six comprehensive parks.

4. Conclusions

This study focused on the accessibility of parks and green spaces for the elderly population in Beijing. Big data spatial analysis, comprehensive evaluation of the coverage and intensity of population mobility, and the OD cost matrix were used to analyze various indexes. The conclusions are as follows:

(1) Variations were found in the proportion of the elderly population in the streets of the core area, with the proportion of the population aged 65 and above ranging from 3.8% to 38%. The consuming capacity of the elderly population in the core area tended to be at the medium-to-high level, indicating that the living conditions of the research population were beyond the subsistence level. Regarding vehicle ownership in the elderly population, traveling in private cars and public transportation were both common, while for long-distance travel, public transportation was prevalent.

(2) The per capita area of parks and green spaces has continued to grow and the urban environment is improving. The results of spatial analysis of parks within a 10 min walk indicated that many streets had a park coverage of more than 90%, close to the goal of "opening the door with a park in sight". However, the coverage rates of some streets, such as Zhanlanlu Street, Jinrongjie Street, and Chaoyangmen Street, were lower than the average. It is therefore recommended to improve the scope of park services in the neighborhood in combination with the urban renewal plan. In addition, some neighborhoods are far from municipal parks, with seven streets having a travel distance of more than 7 km, which is a long journey for elderly people. Improving the convenience and comfort of public transportation is suggested.

(3) From the perspective of pandemic prevention and control, parks with high population mobility, such as Zhongshan Park, the Working People's Cultural Palace, and Yongdingmen Park, need to pay more attention to and publicize pandemic prevention for people with relatively weak immunity, such as senior and young generations, and sick and vulnerable groups. The number of visitors to the park during peak hours should be controlled.

(4) Taking Jiaodaokou Street as an example of a neighborhood with a high proportion of elderly residents (over 20%), Baidu Map Huiyan big data showed that the park coverage was 40%, which was lower than the average level of the core area of the city. The average traveling distance to a large municipal park is 5.4 km. With reference to the goal of "opening the door with a park in sight", park coverage needs to be improved. In addition, further research on ensuring barrier-free facilities in the neighborhood should be conducted.

In the following research, more effort will be made to improve the normalized historical traffic algorithm, supplement the internal road data, and study the distributed deployment of big data cleaning algorithms, so that the research results can be further improved.

References

1 R. J. Zhao, X. Y. Ge, and X. Li: J. Beijing For. Univ. **40** (2018) 103. https://doi.org/10.13332/j.1000—1522.20180187
2 J. Q. Li and X. P. Qin: Chin. Landscape Archit. **15** (1999) 70. https://doi.org/10.1088/0256-307X/16/9/020
3 Y. X. Li, M. Y. Chen, and J. Chen: Chin. Landscape Archit. **12** (1996) 30. CNKI:SUN:ZGYL.0.1996-03-013
4 X.L. Tao. M.X. Chen and W.Z. Zhang: Geogr. Res. **32** (2013) 1965. CNKI:SUN:DLYJ.0.2013-10-019
5 T. T. Ding: Greening Life **40** (2018) 10. CNKI:SUN:LHYS.0.2018-11-006
6 Beijing Municipal Commission Office on Aging, Beijing Silver Industry Association, and Beijing Normal University China Philanthropy Research Institute: http://wjw.beijing.gov.cn/xwzx_20031/wnxw/202110/t20211014_2512063.html (2020).
7 Y. L. Yong: Sichuan Build. Mater. **46** (2020) 20. CNKI:SUN:SCJZ.0.2020-05-012
8 J. Barton and J. Pretty: Environ. Sci. Technol. **44** (2010) 3947.
9 P. Bolund and S. Hunhammar. Ecol. Econ. **29** (1999) 293.
10 Y. Zhao, F. Xu, and Y. L. Wan: Acta Ecologica Sinica **24** (2022) 1994. https://doi.org/10.12082/dqxxkx.2022.210765

11 Y. Y. Peng: Build. Smart City **8** (2021) 3. https://doi.org/10.13655/j.cnki.ibci.2021.08.072
12 D. A. Cohen, T. Marsh, S. Williamson, D. Golinelli, and N. Lurie: Preventive Med. Mater. **50** (2010) 27. https://doi.org/10.1016/j.ypmed.2009.08.020
13 M. Hillsdon, J. Panter, C. Foster, and A. Jones: Public Health 2006 Dec **120** (2006) 11. https://doi.org/10.1016/j.puhe.2006.10.007
14 C. Germann-Chiari and K. Seeland: For. Policy Ec. **6** (2004) 3. https://doi.org/10.1016/S1389-9341(02)00067-9
15 C. F. Liu, X. M. Li, and D. Han: Acta Ecologica Sinica **30** (2010) 5381. CNKI:SUN:STXB.0.2010-19-030
16 Y. F. Jin, Y. Du, Y. Zhou, B. Y. Wu, and J. Q. Wang: Urban Rural Plann. **1** (2019) 21. https://doi.org/10.12049/j.urp.201901003
17 Y. R. Wang, G. P. Zhu, and T. D. Liu. Nat. Sci. J. Hainan Univ. **39** (2021). https://doi.org/10.15886/j.cnki.hdxbzkb.2021.0051
18 Beijing Municipal Bureau of Landscaping and Afforestation: http://yllhj.beijing.gov.cn/ggfw/gyfjqyl/cs/ (accessed September 2022).
19 F. Z. Li and P. G. Zong: Landscape Archit. **28** (2021) 10. https://doi.org/10.14085/j.fjyl.2021.01.0010.07
20 A. Ayala, D. Diaz, and L. Zambrano: Landscape Urban Plann. **189** (2019) 27. https://doi.org/10.1016/j.landurbplan.2019.04.005
21 X. Jiang, S. Wang, and Y. Yang. Population Dev. **1** (2017) 11. https://doi.org/10.3969/j.issn.1674-1668.2017.01.002

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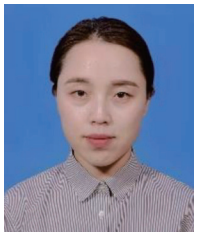

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