Research Paper

Research on Jogging Space Selection Factors Based on Spatial Accessibility

A case of Hangzhou, China

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Abstract

Walking is critical to the healthy development of cities and people's health. It is important that the factors which influence citizens' choice of walking or jogging spaces, as well as how to build a walkable city, should be thoroughly investigated. In this study, Hangzhou of China is selected as the research area. The data is collected about jogging trajectories, points of interest (POI), road networks, parks, water bodies, and population density. The POI data includes urban facilities, such as business housing, finance, life, transportation, culture, and so on. The accessibility of urban green space, water bodies, and various facilities are determined using network analysis based on the road network, and the factors influencing jogging space selection are investigated using linear regression and random forest regression. The result is found that (1) the accessibility of various facilities has varying effects on jogging space selection. (2) The area of water bodies shows a positive correlation with jogging space selection, while water bodies and green space accessibility show a negative correlation.

Keywords

Jogging Space, Spatial Accessibility, Hangzhou

1. Introduction

In 2021, China's State Council issued the "National Fitness Plan (2021-2025)" to promote jogging and other physical activities. But it is not clear what environment factors influence the jogging space selection.

In fact, jogging as physical activity is essential for people's health. In a study of physical activity on mental health, Schnohr *et al.* (2005) found that an increase in physical activity during leisure time reduced dissatisfaction with life. Haskell *et al.* (2007) proposed that unhealthy weight and chronic disease could be reduced by brisk walking for at least 30 minutes five days a week and jogging for at least 20 minutes three days a week. Alexandre Fett, Christiane Rezende Fett and Sérgio Marchini (2009) found the effects of jogging on glucose, waist-hip ratio, and blood pressure. Schnohr *et al.* (2013) found that jogging increased life expectancy by 3.8 years for men and 4.7 years for women after adjusting for confounders. Jogging 1-2.4 hours per week was associated with all-cause mortality, with light and moderate joggers having lower mortality rates than vigorous joggers and sedentary non-joggers (Schnohr *et al.*, 2015). Pedisic *et al.* (2020) discovered that even jogging just once a week may substantially improve population health and longevity.

Furthermore, during the COVID-19 outbreak, jogging effectively reduced people's stress as physical activity (Brailovskaia *et al.*, 2021; Uehara *et al.*, 2021).

The environment is important for jogging. Jogging as a recreational sport that can be done anywhere requires places and infrastructure that correspond to it (Qviström, 2017). Kavanagh *et al.* (2005) found that changing the local environment can promote physical activity. Dulin-Keita *et al.* (2015) discovered that changes in neighborhood walkability increased the odds of neighborhood walking/jogging. Arnberger and Eder (2007) used the long-term video and found that the peak use for jogging in forest park was on weekday evenings and weekend mornings. Karusisi *et al.* (2012) found that the parks or lakes increased the likelihood of jogging in the neighborhood. Sweden has invested in building lighted tracks, changing rooms, and parking spaces in forest parks to influence where and how running takes place (Qviström, 2016). Lupp *et al.* (2016) found jogging or Nordic walking to be an essential recreational activity near urban forests. Compared to urban forest parks, green spaces within cities also play an important role in jogging. Visitors considered urban green spaces suitable for running and jogging (Vujcic *et al.*, 2019). The most important urban park demand was sightseeing, followed by jogging (Sun, Li and Chen, 2019).

With the development of Information and Communication Technology, mobile phones are widely used in daily physical activities, including jogging (Wannenburg and Malekian, 2017). And the Global Positioning Systems (GPS) can measure jogging (Gray *et al.*, 2010). Sileryte, Nourian and van der Spek (2016) propose a workflow for collecting, constructing, and processing recreational travel data that can be used to monitor jogging in urban spaces. Liu *et al.* (2022) studied the effect of urban parks on jogging based on GPS data and found that walking loops and water features positively impacted jogging flow. There has been little research on using jogging spaces on a city scale. Previous research discuss the space and time of jogging based on urban green space, and the effect of urban facilities and spatial accessibility on jogging was not revealed.

This study uses urban facilities, urban green spaces and water bodies (rivers and lakes), population density, and jogging trajectory data to measure accessibility using network analysis and the two-step floating catchment area method (2SFCA) (Mengtong, Lingbin and Ye, 2016) to analyze the factors of jogging space selection using linear regression and random forest regression. The study has the following innovations: (1) Previous studies are usually limited to urban green areas or parks, but the accessibility of green places at the city level has not been discussed for the selection of jogging spaces. (2) The influence of urban facilities on the spatial selection of jogging will be studied.

2. Data and methods

2.1. Research area

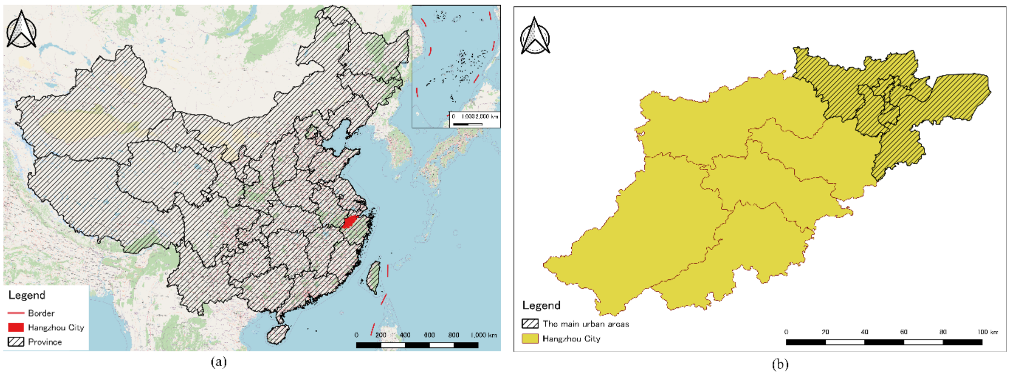

Figure 1. The Location and Main Urban Areas of Hangzhou.

The research area is the major urban area of Hangzhou City in Zhejiang Province, China, as shown in Figure 1. According to the administrative area division in 2019, the major urban area contains Shangcheng District, Xiacheng District, Jianggan District, Gongshu District, Xihu District, Binjiang District, Xiaoshan District, and Yuhang District. As of 2019, the total population of the major urban area is 7.09 million, and the area is 3349.305 km^2. The study area is divided into 500m*500m square areas using a fishing net for data analysis.

2.2. Data collection

Data on population density, point-of-interest (POI) of urban facilities, green spaces, water bodies, roads, and jogging trajectories were collected. The POI had urban facilities of 13 categories, including dining facilities, scenic spots, public facilities, shopping, transportation facilities, financial services, cultural facilities, business housing, living services, sports and leisure services, medical facilities, government and social groups, and accommodation services, as shown on Table 1. It was obtained from the API of AutoNavi map in 2020.

Table 1. **POI of urban facilities.**

No.	Category	Content	Number of points
1	Dining facilities	Chinese restaurants, fast food restaurants, etc.	40240
2	Scenic spots	Squares, parks, botanical gardens, etc.	3291
3	Public facilities	Public toilet	4994
4	Shopping	Shopping centers, shopping malls, supermarkets, etc.	3251
5	Transportation facilities	Subway station, bus station, parking lot, etc.	25754
6	Financial services	Bank	8261
7	Cultural facilities	Schools, Museums, Libraries, etc.	17710
8	Business housing	Residential quarters, office buildings, etc.	15633
9	Living services	Telecom service hall, beauty barber, post office, etc.	20804
10	Sports and leisure services	Fitness center, swimming pool, KTV, etc.	11116
11	Medical facilities	Hospitals, clinics, pharmacies.	10706
12	Government and social groups	Government agencies, charities, etc.	15428
13	Accommodation services	Hotels, guesthouses, youth hostels, etc.	7645

The population density of 1-km resolution was obtained from the 2015 monthly population distribution for China Harvard Dataverse. Data on roads and water bodies (river and lake) were obtained from the Open Street Map website. The green spaces data was obtained from the FROM-GLC 2017v1 dataset, combining cropland, forest, grassland, wetland, and shrubland. The Keep website, which provided publicly available and anonymous data, was used to collect 2021 jogging trajectories, as shown in Figure 2.

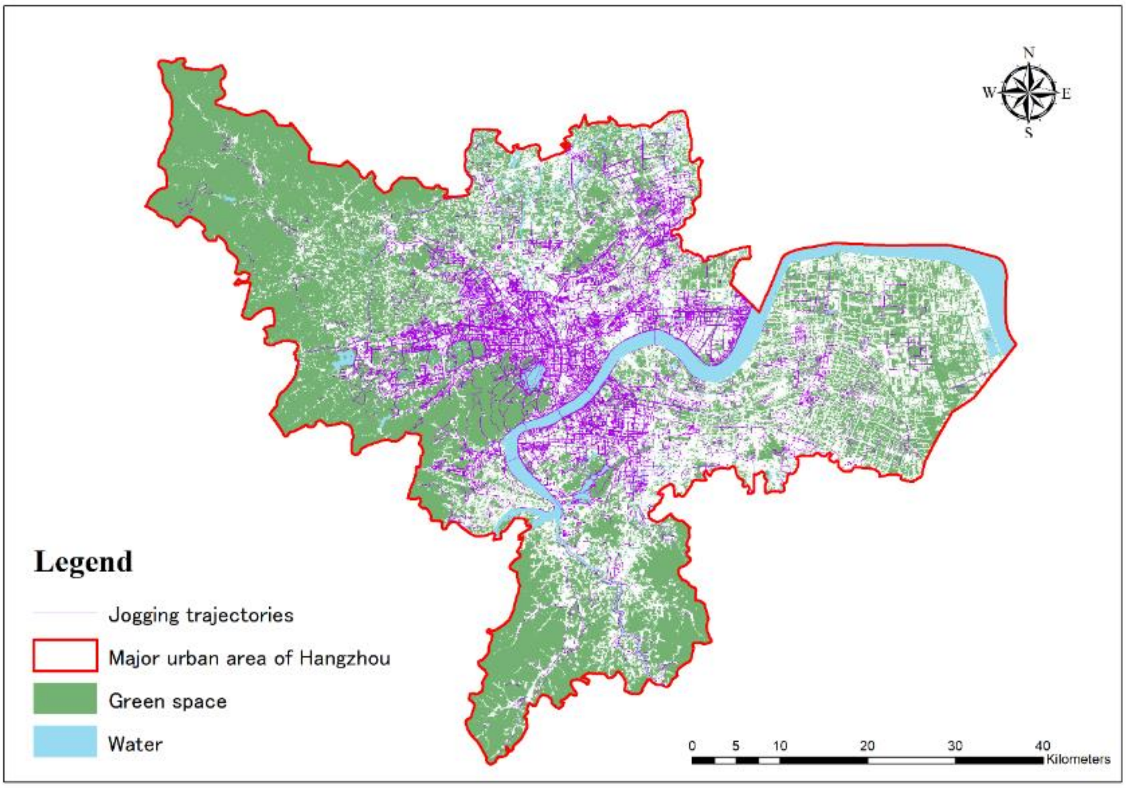

Figure 2. The Jogging Trajectories, Green Space and Water Bodies.

3. Methods

3.1. Network analysis

Because urban facilities are point data, network analysis can be performed to access their accessibility. The step speed was set to 80 m/s. According to the 15-minute living circle (Zhou and Li, 2018), the effective distance of urban facilities is 1200 m. In the range of 400 m, the influence of distance on walking is weak. The decay function of the accessibility score was constructed by fitting a Gaussian process, as shown in the formula (1).

$$S_{ij} = \begin{cases} 100 & , \quad d_{ij} \leq 400 \\ 100 \times e^{-\frac{(x-0.4)^2}{2\times 0.33^2}} & , \quad 400 < d_{ij} < 1200 \\ 0 & , \quad d_{ij} \geq 1200 \end{cases} \tag{1}$$

Here S_{ij} is the accessibility score of square center i (starting point) to urban facility j (end point).

Based on ArcGIS 10.8 and road data, the accessibility score of the facility in each square area was calculated by OD cost matrix and decay function, and superimposed by using the same facilities. Then, the final accessibility scores of 13 categories were obtained by normalizing each facility within all square areas.

3.2. Two-step floating catchment area method

The water body and green space area were counted using square areas. And the distance was calculated by network analysis.

In the first step, the ratio of supply and demand (RSD) of the water body area and green space area was performed using the weighting function (WF). In the second step, the accessibility of the people's demand (APD) to the destination was calculated by using SDR and WF. Finally, it was normalized to obtain the accessibility of green space and water bodies.

In this study, the effective distance for green space area and water body area is 1200 m. The accessibility, calculated by 2SFCA, means the available area of green space or water bodies per capita within a unit of the demand area. The Formula (2), (3), and (4) of 2SFCA are shown in Table 2.

Table 2. Formula and Parameter Explanation of 2SFCA.

Name	Formula		Parameter explanation
WF	$G(d_{kj}, d_0) = \begin{cases} \dfrac{e^{-\frac{1}{2}\times\left(\frac{d_{kj}}{d_0}\right)^2} - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} & , d_{kj} \leq d_0 \\ 0 & , d_{kj} > d_0 \end{cases}$	(2)	Here, d_{kj} represents the distance from the supply area j to the demand area k. And d_0 is the effective distance of supply place j. If d_{kj} exceeds the range of d_0, weight is 0. Otherwise, the Gaussian function is used to assign weights.
RSD	$R_j = \dfrac{S_j}{\sum_{k\in\{d_{kj}\leq d_0\}} G(d_{kj}, d_0) P_k}$	(3)	Here, R_j means the ratio of supply and demand in the supply area j. And P_k is the population density of demand area k. Furthermore, S_j is the area of green space or water bodies in the supply area j.
APD	$A_i = \sum_{l\in\{d_{il}\leq d_0\}} G(d_{il}, d_0) R_l$	(4)	Within the effective range d_0 of the demand place i, each supply area of ration of supply and demand R_l will be superimposed, and the WF is used. And A_i denotes accessibility of green space or water bodies.

3.3. Linear regression model and random forest regression model

Population density, accessibility of urban facilities, green spaces, and water bodies were used as independent variables. The line density of jogging trajectories, which was the frequency of jogging space usage, was used as the dependent variable. It is shown in Table 3.

Table 3. Formula and Parameter Explanation of 2SFCA.

Variables	Content
Independent variables	Population density
	Area of green spaces, and area of water bodies
	Accessibility of urban facilities, green spaces and water bodies
Dependent variable	The line density of jogging trajectories

Then, the multiple linear regression was performed to reveal the influence of factors, as shown in Equation (5).

$$y = a_1X_1 + a_2X_2 + \cdots + a_{17}X_{17} + a_{18}X_{18} + b \quad (5)$$

Here, X represents the 16 categories of Independent variables. Y is the dependent variable. And a is the coefficient of regression, and b is a constant.

In order to explore the nonlinear relationship and verify the influence of factors on the jogging space, Random Forest Regression was used to analyze the impact of factors on the jogging space.

4. Result

4.1. Accessibility of urban facilities

The accessibility of urban facilities was obtained based on network analysis, and the accessibility was classified into five categories using Jenks Natural Breaks Classification, as shown in Figure 3. Areas with no data mean no corresponding urban facilities within walking distance of 1200 m. It was found that the accessibility of facilities is very high around West Lake near Longxiangqiao and Fengqi Road.

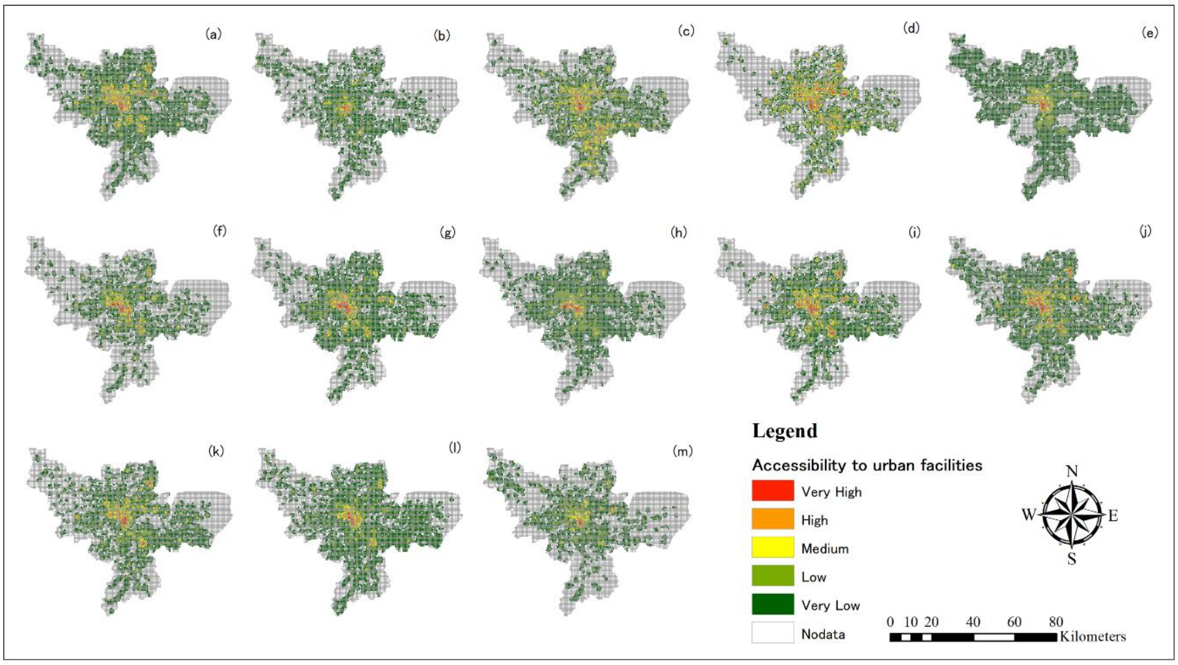

Figure 3. Accessibility of urban facilities: (a) dining facilities, (b) scenic spots, (c) public facilities, (d)shopping, (e) transportation facilities, (f) financial services, (g) cultural facilities, (h) business housing, (i) living services, (j) sports and leisure services, (k) medical facilities, (l) government and social groups, (m) accommodation services.

In addition, the number of no-data areas within 1200 m of the facilities is ranked from high to low. The facilities are financial services, accommodation services, shopping, scenic spots, living services, business housing, public facilities, medical facilities, cultural facilities, dining facilities, sports and leisure services, government and social groups, and transportation facilities.

4.2. Accessibility of green space and water bodies

The results of the 2SFCA analysis are shown in Figure 4. The no data area of green space is owing to the lack of road near the area. It was found that the accessibility of green space throughout the main urban area showed a trend of concentrated diffusion. The area was close to the boundary of the major urban area, which had higher accessibility. Because the boundary of the major urban area had less population and more green space. In addition, the accessibility of water bodies is mainly centered on the Qiantang River and its tributaries.

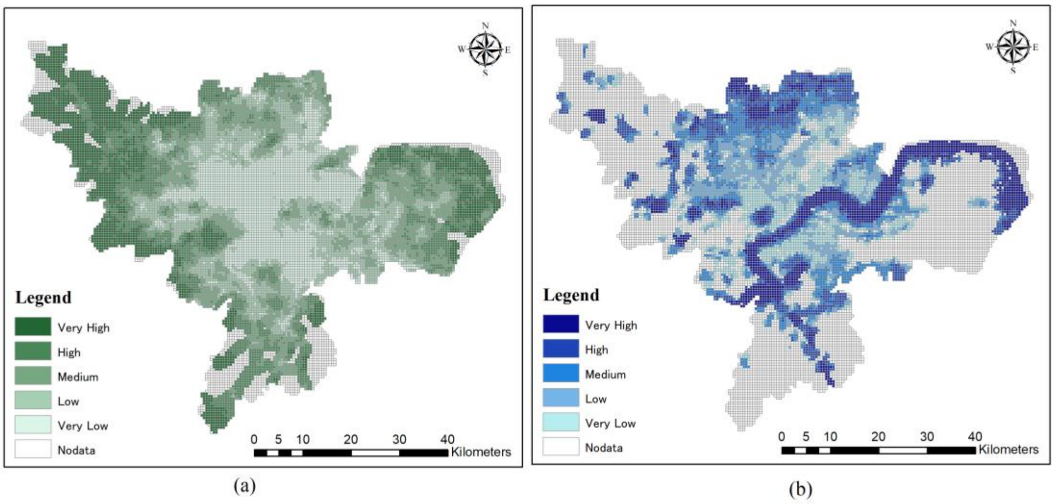

Figure 4. Accessibility of green space and water bodies: (a) green space, (b) water bodies.

The no data on the area of the water body is owing to the lack of road and river or lake. The availability of water bodies tended to decrease spatially from the north or south toward the Qiantang River, while it increased abruptly near the Qiantang River. The high population density near the Qiantang River has decreased the available water body area per capita.

4.3. The influence of factors on the choice of jogging space

A buffer of 100 meters was chosen to calculate the line density of jogging trajectories because of the errors in the positioning of the phone's Global Positioning System (GPS). The result of line density is shown in Figure 5.

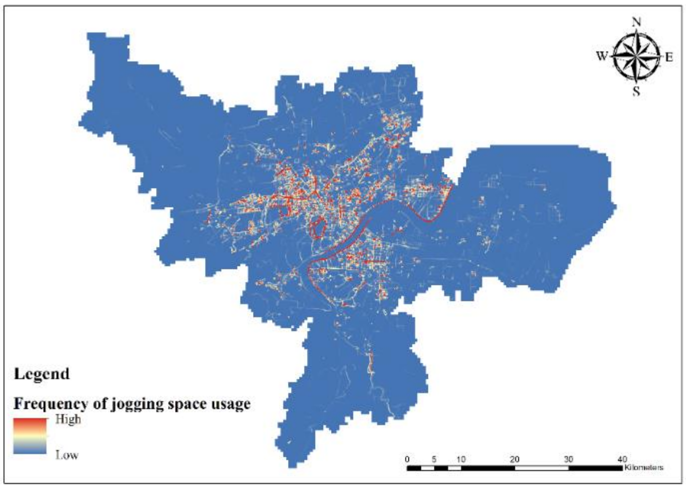

Figure 5. Frequency of jogging space usage.

The population density and spatial accessibility of urban facilities, green spaces and water bodies were taken as independent variables, and the frequency of jogging space usage was taken as the dependent variable. After normalizing all elements, the results were calculated by multiple linear regression using python 3.6, as shown in Table 4.

Table 4. The result of Multiple Linear Regression.

Variables	Coefficients	Variables	Coefficients
Cultural facilities	0.245***	Accessibility of green space	-0.021**
Scenic spots	0.239***	Dining facilities	-0.028
Population density	0.160***	Accessibility of water bodies	-0.036*
Sports and leisure services	0.144***	Public facilities	-0.040***
Area of water	0.035***	Transportation facilities	-0.046**
Area of green space	0.001	Living services	-0.060**
Shopping	-0.004	Accommodation services	-0.103***
Medical facilities	-0.007	Financial services	-0.106***
Business housing	-0.017	Government and social groups	-0.181***

Note: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

The adjusted R-squared of the multiple linear regression was 0.336. It was found that the population density and the accessibility of cultural facilities, scenic spots, and sports and leisure services promote the frequency of jogging space usage. The accessibility of government and social groups, financial services, accommodation services, living services, transportation facilities, and public facilities negatively affects the frequency of jogging space usage. Regarding water bodies and green areas, it was found that the area of water bodies has a positive effect on running. And the accessibility of water bodies and green spaces has a negative impact on the linear density of running trajectories.

Table 5. The result of Random Forest Regression.

Variables	Importance	Variables	Importance
Cultural facilities	0.156	Dining facilities	0.030
Accessibility of green space	0.128	Transportation facilities	0.027
Area of green space	0.120	Medical facilities	0.026
Area of water	0.119	Public facilities	0.026
Population density	0.085	Accommodation services	0.026
Scenic spots	0.050	Accessibility of water bodies	0.025
Business housing	0.045	Financial services	0.025
Government and social groups	0.039	Shopping	0.021
Sports and leisure services	0.036	Living services	0.016

Because linear regression is not flexible in identifying complex patterns, random forests were used to perform an in-depth analysis of jogging space selection. We selected 80% of the data as the training set and 20% of the data as the test set. The adjusted R-squared of the multiple linear regression was 0.382. It is higher than the R-squared of the linear equation. The result is shown in Table 5.

The most vital four factors in the jogging space selection were cultural facilities, accessibility of green space, and area of water bodies and green spaces. Compared to the results of the multiple linear regression, the results of the random forest differed significantly. It can be inferred that green space and water bodies have a more significant role in the jogging space selection, but not a simple linear relationship. Furthermore, the population density and accessibility of cultural facilities positively influence the jogging space selection.

5. Discussion

This study extends the research in urban jogging spaces. Firstly, the study confirmed the influence of green space and water bodies in jogging space selection. Secondly, the difference in the influence of urban facilities' accessibility on jogging space selection was revealed. And the critical influence of cultural facilities was confirmed.

The study findings are specified as follows. Firstly, there is a positive effect of population density on the jogging space in the multivariate linear model. Population density has an important influence on walkability studies, with high population density promoting walkability (Frank *et al.*, 2005, 2010). Jogging, as physical activity, is influenced by environmental walkability. Therefore, areas of high population density have environments that are good for jogging.

Secondly, there is a difference in the influence of urban facilities on the jogging space choice. Table 4 shows the important positive effects of cultural facilities, scenic spots, and sports and leisure services on jogging space. The negative influence of government and social groups, financial services, accommodation services, living services, transportation facilities, and public facilities. According to random forest regression, it was found that the influence of business housing is essential in Table 5. The business housing accessibility of all areas was classified into ten categories using quantile classification and the frequency of jogging space usage, as shown in Figure 6. There is a concentration of jogging in areas with 91-100% business housing accessibility and areas with 51-70%.

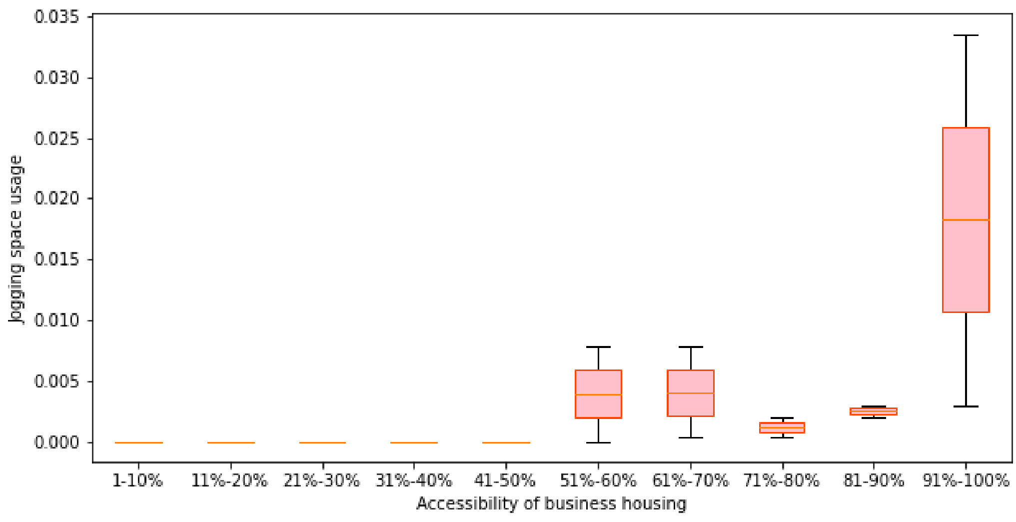

Figure 6. The Relationship between Frequency of Jogging Space Usage and Business Housing.

Thirdly, the influence of area and accessibility of green space and water bodies is important. According to the results of random forest regression, we can find that the effect of the area of green space and water bodies is stronger than their accessibility. However, in the results of the multiple linear regression, the area of water bodies shows a positive contribution to the running space selection. At the same time, there is no relationship for green space. Therefore, it is inferred that there may be a complex relationship between green space and running space selection. However, green space and water body accessibility present a negative effect. Compared to suburban areas, inner cities will have better jogging infrastructure, which may be one of the reasons. The high population density and the limited area of green space and water bodies within the city result in lower accessibility. And in suburban areas, although water bodies or green space accessibility is high, due to the lack of other configuration facilities, high-density jogging trajectories do not appear.

Although the accessibility of both green spaces and water bodies is negatively correlated with running space selection, the areas in which they are spatially concentrated differ significantly. The accessibility of green space and water bodies in all areas was classified into ten categories using quantile classification and combined with the frequency of jogging space usage, as shown in Figure 7. It is found that the relationship between green space and jogging space shows a distribution similar to a Gaussian function, and that the frequency of use is higher in the areas with the lowest 30% of green space accessibility. This may be related to the fact that despite the presence of forests around the city, jogging use is within the urban area. In contrast, water bodies are used most frequently in areas with 71-100% and 41-60% water body accessibility. And the frequency of jogging usage near areas with 71-100% water body accessibility is higher than in areas with 1-30% green space accessibility.

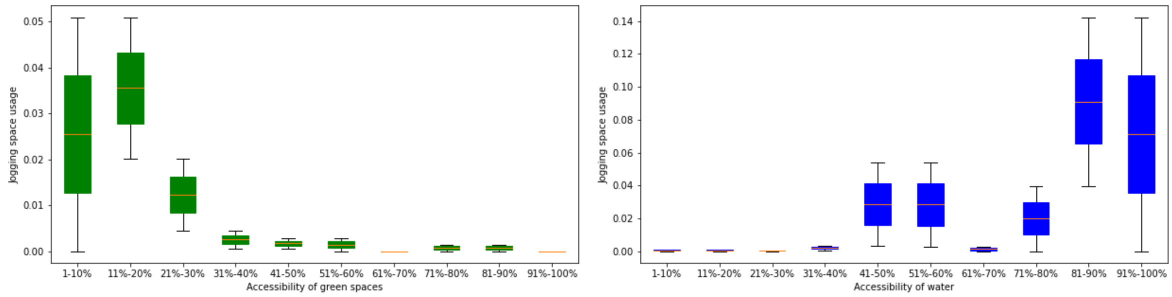

Figure 7. The Relationship between Frequency of Jogging Space Usage and Green Space or Water Bodies.

According to the above findings, there are differences in the influence of different urban facilities' accessibility on jogging space selection, with cultural facilities having the strongest impact. Green space and water bodies also play an essential role in the jogging space selection, of which the proximity to large water bodies makes it easy to form high-density jogging trajectories.

However, owing to data limitations, this study cannot analyze the differences in impacts across periods and between weekdays and rest days. Because the data were anonymous, this study could not examine the influence of socioeconomic characteristics on jogging space selection. In order to create livable and healthy cities, the government and urban planners should pay attention to the critical impact of urban water bodies and green spaces.

In the future, we will consider the influence of different green space attributes on the choice of running space, such as fields, urban parks, forest parks, etc. In order to create livable and healthy cities, governments and urban planners should pay attention to protecting large water bodies and increasing urban green spaces.

6. Acknowledgements

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