

Article

Distance Decay of Urban Park Visitation: Roles of Personal Characteristics and Visitation Patterns

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Abstract: Distance decay of urban park visitation (e.g., visitation number and visitation frequency) has been widely acknowledged and is increasingly integrated into urban park planning and management considering spatial accessibility and service equity. However, thorough understandings especially concerning the variations among visitors with different personal characteristics and visitation patterns are still scarce. Taking Changsha, China as an example, we collected data on visitation distance (i.e., the distance between urban parks and visitor's homes) and visitation frequency of 2535 urban park visitors, modeled the distance decay of visitation density and visitation frequency, and investigated their variations among visitors with different personal characteristics and visitation patterns. The results show that: (1) The median visitation distance was 1.3 km and the median visitation frequency was 24 times per season. (2) Both visitation density and visitation frequency showed clear spatial patterns of distance decay and can be effectively modeled using common distance decay functions (e.g., power function, exponential function, and logarithmic function). (3) Visitors' characteristics (e.g., gender and age) and visitation patterns (e.g., duration time, transportation modes, and visitation purposes) significantly impact visitation distance, visitation frequency, and the characteristics of distance decay (i.e., the rate of distance decay). These findings extend our understanding of the distance decay of urban park visitation which can help better urban park planning and management.

Keywords: distance decay; urban park; recreation service; spatial accessibility; urban greenspace



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1. Introduction

Urban parks, mainly covered by natural elements (e.g., trees, grass, water, etc.), are important components of the urban ecosystem. They have numerous benefits to both the natural ecosystem and the socioeconomic system in highly developed urban areas, for example mitigating the urban heat island effect [1,2], purifying air pollution [3], conserving biodiversity [4], and promoting citizens' physical and mental health [5]. Of these benefits, improving public health (including both physical health and mental health) has received increasing attention in the rapidly developed urban areas as cities usually have worse ecological environments and people suffer from more psychological stress [6,7]. It is not surprising that there are increasing demands for recreation services and decision-makers devote more attention to planning and managing urban parks to attract more citizens to participate in recreation activities.

Urban parks' benefits for public health are realized after people travel to the park from their homes and stay in the park for types of physical activities. The distance between the park and citizens is one of the key factors that impact whether people visit or not and determine how frequently people visit [8,9]. Urban park visitation (e.g., visitation number

and visitation frequency) usually nonlinearly decreases with the increase in distance to the park, known as the distance decay phenomenon [10,11]. Accurately characterizing the distance decay of urban park visitation, for example, how fast it decreases, is of significant importance for park accessibility modeling and effective urban park planning and management [10,11].

Different distance decay functions have been applied to characterize the distance decay of urban park visitation. Power function [10], exponential function [11,12], Gaussian function [13,14], and gravity model [15] for example were widely applied to model urban park accessibility with the decay rate usually theoretically set [10,16]. The distance decay of urban park visitation was recently modeled with empirical data. The power function was used to calibrate the distance decay of visitation number and the logarithmic function was applied to model the distance decay of visitation frequency in Wuhan, China [10]. Rossi et al. [17] fitted the exponential function to characterize the distance decay of visitation for a peri-urban national park in Brisbane, Australia. Ode and Fry [18] modeled a power function to predict urban pressure on woodland. Phillips et al. [19] fitted a symmetric sigmoid function to model the spatial accessibility of urban greenspace in the Brussels Capital Region, Belgium. The distance decay of urban park visitation varies from city to city and empirically modeling the distance decay function is a prerequisite for effective urban park planning and management.

Personal characteristics (e.g., gender, age, income, and occupation) and visitation patterns (e.g., visitation purpose, duration time, and transportation modes) are fundamental factors determining the spatial distribution of visitors and the distance decay [20,21]. For example, younger visitors tend to travel farther to visit parks but with lower frequency compared to older visitors [17,22]. Females visit the parks less than men [8], and less educated and unemployed people visit urban parks more frequently [23]. Some studies showed that the visitation distance and visitation frequency varied significantly among different visitation purposes [20]. However, few studies investigated the variation of distance decay (e.g., how fast it decays) considering different personal characteristics and visitation purposes.

Taking the subtropical city of Changsha, China as an example, the objective of this study is to quantitatively characterize the distance decay of urban park visitation in terms of visitation density and visitation frequency and to investigate their responses to personal characteristics and visitation patterns. Specifically, we tried to answer two scientific questions: (1) How far do visitors travel to urban parks and what are the differences among visitors with different personal characteristics and visitation purposes? and (2) How does urban park visitation decay with the increase in distance to urban parks and what are the differences among visitors with different personal characteristics and visitation purposes? We conducted field surveys by questionnaires in eight urban parks to collect information on visitors' characteristics (e.g., gender, age), visitation patterns (e.g., duration time, transportation mode, visitation purpose, and visitation frequency), quantified distance between visitors' homes and urban parks, and modeled distance decay of urban park visitation.

2. Methods

2.1. Study Area

Changsha (112.59 E, 28.12 N), the capital city of Hunan province is located in central south China (Figure 1). It has a subtropical monsoon climate with an annual temperature of 17.2 °C and annual precipitation of 1361.6 mm. Changsha has long and hot summers (more than 30 days with a temperature higher than 35 °C and an average maximum temperature of 28 °C), and cold winters (more than 10 days with a temperature less than 4 °C and an average maximum temperature of 10 °C). The vegetation is dominated by subtropical evergreen broad-leaved forests. Changsha is the most populous city in Hunan province, hosting 10.51 million populations with an urbanization rate of 83.59% in 2023.

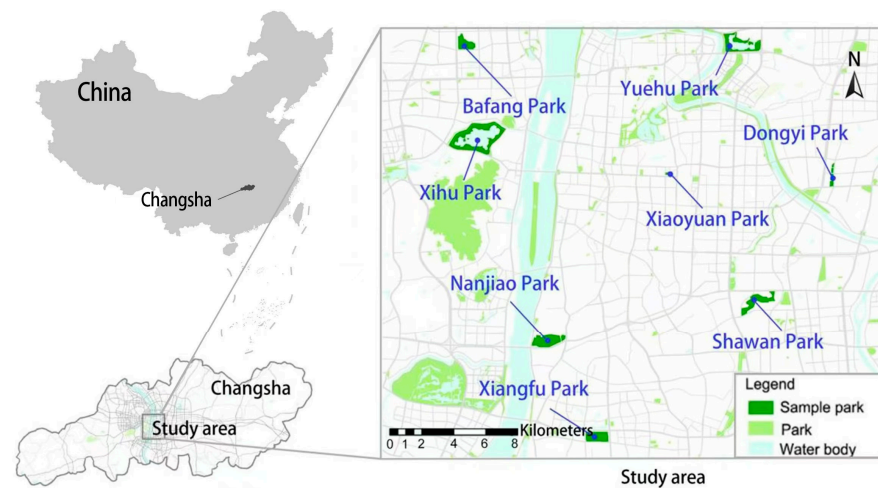


Figure 1. Location of the study area and spatial distribution of the selected eight urban parks.

There are 257 urban parks with a total coverage of 5369 ha in 2022. We selected eight typical urban parks considering factors such as size, function, popularity, spatial distribution, management status, and so on. Figure 1 shows the spatial distribution and Table 1 displays some basic information of the selected eight urban parks. The high spatial resolution remote sensing image of these urban parks can be found in the Supplementary File.

Table 1. Description of the selected eight urban parks.

Name	Open Year	Size (ha)	Parameters (m)	Shape Index	Vegetation Coverage (%)	Impervious Surface Coverage (%)	Water Coverage (%)
Dongyi Park	2019	6.36	1480.41	1.66	59.20	35.63	0.00
Xiaoyuan Park	1986	3.40	729.74	1.12	51.74	25.09	0.00
Yuehu Park	2006	54.74	3688.52	1.41	27.62	23.06	48.08
Shawan Park	2014	27.06	4442.86	2.41	85.37	14.23	0.40
Xiangfu Park	2017	26.62	2237.33	1.22	66.03	31.46	0.90
Nanjiao Park	1986	35.54	2798.62	1.32	94.60	3.68	0.94
Xihu Park	2015	127.58	4851.16	1.21	34.65	17.15	47.91
Bafang Park	2016	21.64	2219.64	1.35	84.95	12.07	0.00

2.2. Data Collection

We designed a questionnaire (See Supplementary File taking Yuehu Park as an example). The questionnaire aims to collect information on (1) personal characteristics (e.g., gender, age, income, and occupation) (2) visitation patterns (e.g., visitation purpose, duration time, transportation modes, and visitation frequency), and (3) location of the gate people enter the park and their home address (to estimate the visitation distance). The questionnaire was delivered in the eight selected urban parks on sunny days in the autumn of 2021. Each urban park was divided into several zones and one research assistant completed the questionnaire survey in each zone. Research assistants randomly invited visitors to fill in the questionnaire. A brief introduction of the research purpose and necessary explanation of the questions were also included to help the respondents better understand and complete the questionnaire.

2.3. Data Analysis

We calculated Euclidean distance and travel distance between the respondents' home and the nearest entrance of the visited urban park. The travel distances were estimated as the distance between the nearest entrance of the urban park and the home using the Gaode map (<https://ditu.amap.com> (accessed on 1 November 2021)). We conducted the Kruskal–Wallis H-test to check whether visitation distance and visitation frequency of different visitor groups with different personal characteristics and visitation patterns are

significantly different as these two variables are not normally distributed. The post hoc test was applied to further check how personal characteristics and visitation patterns impact visitation density and visitation frequency. We grouped the respondents into different classes based on their distance to urban parks for every 500 m and 1000 m interval, and calculated visitation density and mean visitation frequency. Visitation density was calculated as the number of visitors (or respondents) divided by the circle area of each distance interval. We used visitation density instead of visitation number to eliminate the impacts of the change in the circle area [17].

Following previous studies [10,11,17,19], we tested two distance decay functions (power (Equation (1)) and exponential (Equation (2))) to model the distance decay of visitation density and three distance decay functions (power (Equation (1)), exponential (Equation (2)), and logarithm (Equation (3))) to model the distance decay of visitation frequency for both Euclidean and travel distances for two distance intervals (500 m and 1000 m).

$$y = ax^{-b} \quad (1)$$

$$y = ae^{-b x} \quad (2)$$

$$y = a + \ln(-bx) \quad (3)$$

where y represents visitation density or visitation frequency, and x means the Euclidean distance or travel distance to an urban park. a and b are estimated parameters. a determines the maximum values of visitation density or visitation frequency. b determines how fast the two indicators decrease with the increase in distance to urban parks. These two parameters were estimated using the R package of *nls*.

To investigate the impacts of personal characteristics and visitation patterns on the distance decay of park visitation, we fitted the distance decay functions for different personal characteristics and visitation patterns, respectively.

3. Results

3.1. Visitors' Personal Characteristics and Visitation Patterns

2589 questionnaires were distributed and 2535 were returned with valid answers (Table 2). A total of 45.8% of the respondents are male and 54.2% are female. Slightly more females participated in the survey considering the sex ratio of about 1:1.03 in Changsha, China. A further 32.1% of the respondents were younger than 18 years, 27.9% were between 18 and 28 years, 22.3% were between 29 and 45 years, and about 9.1% were older than 60 years. About half of the visitors stayed in the park for around 1–2 h, followed by less than 1 h (20%), 2–3 h (17.5%), 3–4 h (7.1%), and more than 4 h (6.4%). More than half of people visit urban parks by foot, followed by cars (28.2%). In total, 70.4% of the respondents visited parks for exercise, followed by 23.8% for social communication, 3.1% for professional study, and 2.7 for other visiting purposes.

Table 2. Visitation distance and visitation frequency for respondents with different personal characteristics and visitation patterns.

Category		Number	Percentage	Visitation Distance (km)			Visitation Frequency (Times per Season)		
				Median	1st–3rd Quantile	ANOVA *	Median	1st–3rd Quantile	ANOVA *
Gender	Male	1161	45.8	1.3	0.625–2.5	b	24	12–60	a
	Female	1374	54.2	1.3	0.7–3.3	a	24	12–48	b
Age	Younger than 18	815	32.1	1.5	0.71–3.3	a	12	12–24	e
	18–28	707	27.9	1.5	0.8–3.95	a	24	12–36	d
	29–45	565	22.3	1.21	0.612–2.4	b	24	12–60	c
	46–60	218	8.6	1	0.625–1.8	c	42	24–72	b
	Older than 60	230	9.1	0.82	0.6–1.6	c	72	48–84	a

Table 2. Cont.

	Category	Number	Percentage	Visitation Distance (km)			Visitation Frequency (Times per Season)		
				Median	1st–3rd Quantile	ANOVA *	Median	1st–3rd Quantile	ANOVA *
Duration	Less than 1 h	506	20	0.92	0.582–1.7	d	36	12–60	a
	1–2 h	1242	49	1.1	0.611–2.2	c	24	12–60	b
	2–3 h	444	17.5	1.9	0.87–3.9	b	12	12–36	c
	3–4 h	180	7.1	2.6	1.3–5.725	a	12	12–24	d
	More than 4 h	163	6.4	4	1.3–8.55	a	12	3–24	f
Transportation	On foot	1397	55.1	0.82	0.543–1.3	e	36	24–60	a
	By bicycle	125	4.9	1.5	0.92–2.5	d	24	12–36	b
	By Car	716	28.2	2.85	1.3–5.4	c	12	12–24	c
	By Bus	156	6.2	3.25	1.975–5.7	b	12	12–36	c
	By subway	141	5.6	7.3	3.7–9.9	a	12	3–24	d
Purposes	Health	1785	70.4	1.2	0.612–2.3	b	24	12–60	a
	Culture and education	78	3.1	1.5	0.8–4.25	a	36	12–60	c
	Social communication	603	23.8	1.9	0.95–4.6	a	12	12–24	b
	Others	69	2.7	1.2	0.8–5	ab	12	12–36	b
All	All	2535	100	1.3	0.65–2.9	–	24	12–48	

* Kruskal–Wallis H tests are all significant ($p < 0.01$). Different letters indicate significant differences ($p < 0.05$).

3.2. Visitation Distance and Visitation Frequency

Urban park visitation distance and visitation frequency show left skewed distribution with more short-distance visitations and less frequent visitors. Table 2 displays the descriptive statistics of visitation distance and visitation frequency. As the variables based on Euclidean distance and travel distance were highly correlated with a Pearson correlation of 0.97 ($p < 0.01$), we only described the results based on travel distance. The median travel distance was 1.30 km with the first and third quartiles of 0.65 and 2.90 km, respectively. The median visitation frequency was 24 times per season with the first and third quartiles of 12 and 48, respectively.

The median travel distances for males and females were equal (1.3 km), but females statistically traveled longer distances than males (Table 2). Younger visitors traveled significantly longer distances than elders to visit the park. For example, the median travel distance was 1.50 km for those younger than 18 years, compared with the median of 0.82 km for those older than 60 years. The travel distances increased significantly with the increase in duration time in the park with a Spearman correlation of 0.30 ($p < 0.01$) between them. The median travel distance also varies among different visitation purposes, for example, 1.20 km, 1.50 km, and 1.90 km, respectively for exercise, professional study, and social communication.

Males visited urban parks more frequently than females even though they had equal median visitation frequency. Older people visited urban parks more frequently than younger people. For example, people older than 60 years had a median visitation frequency of 72 times per season, while the corresponding value of those younger than 18 years was 12. Visitors spent less time each visitation had significantly higher frequency. For example, the median visitation frequencies were 36 and 12 times per season for those staying less than one hour and those staying more than four hours for each visitation. Visitation frequency was the highest for those by foot, followed by those by bicycle, by car, by bus, and by subway. People motivated by culture and education visited urban parks 36 times per season, followed by those for health and social communication.

3.3. Distance Decay of Visitation Density and Visitation Frequency

Urban park visitation showed similar distance decay patterns for Euclidian distance and travel distance with both 500 m and 1000 m intervals. Here we reported the results based on travel distance with a 1000 m interval. Both the power function and the exponential function effectively characterized the spatial decay of visitation density with the R^2 close to 1. All three distance decay functions modeled the spatial distribution of visitation

frequency with R^2 around 0.9 (Figure 2). We reported the results of the power function for visitation density and the logarithmic function for visitation frequency in the later analysis.

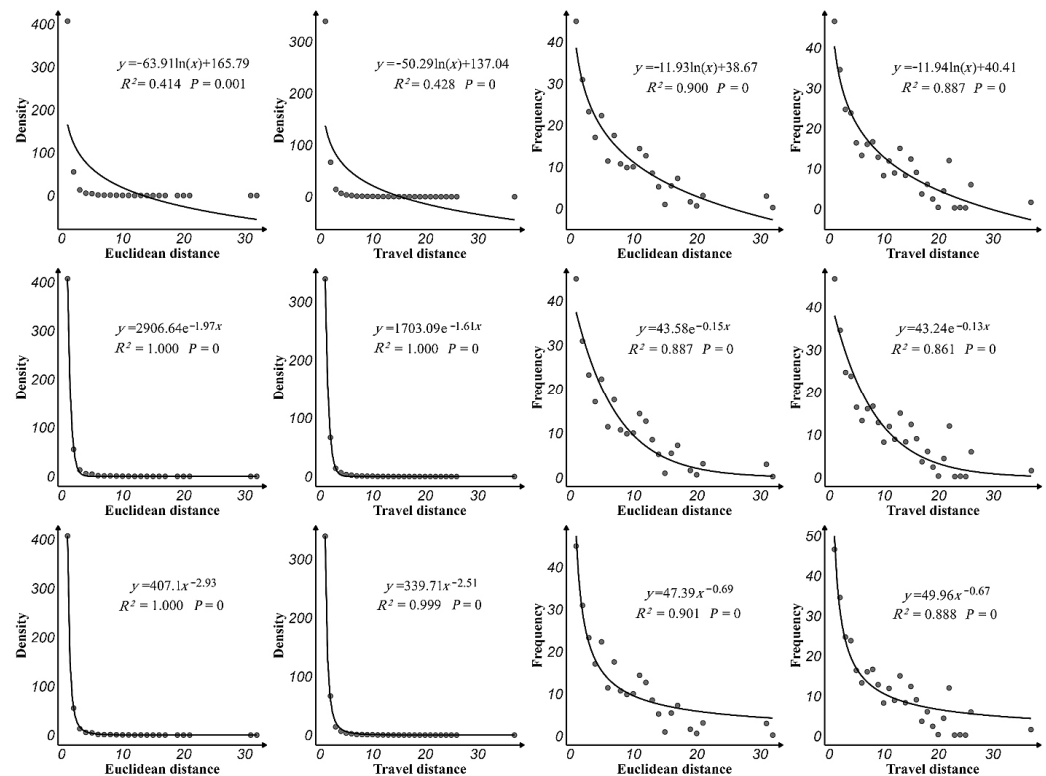


Figure 2. Distance decay of visitation density (person per km^2) (columns 1 and 2) and visitation frequency (times per season) (columns 3 and 4) with the increase in Euclidean distance (km) (columns 1 and 3) and travel distance (km) (columns 2 and 4) to urban parks based on logarithmic function (**first row**), exponential function (**second row**), and power function (**third row**).

The power function effectively depicted the distance decay of visitation density with R^2 close to 1 for respondents with any personal characteristics and visitation patterns (Table 3). The estimated b is higher for males (2.58) than for females (2.44). The estimated b is the lowest for those younger than 18 years old, then increases with the age increase, and reaches the highest (2.96) for those older than 60 years old (2.29). People with shorter duration time per each visitation have a larger value of b (e.g., 2.78 for those staying less than one hour) than those with longer duration (e.g., 1.79 for those staying more than 4 h). The estimated b varies for people with different transportation modes, ranging from 1.08 by subway to 2.91 by foot. The values of b are close for people with different visitation purposes (2.15–2.77).

The logarithmic function effectively modeled the distance decay of visitation frequency with an R^2 of 0.89 and a and b of 40.41 and 11.94, respectively (Table 3). The decay rate (i.e., the estimated parameter of b) increases with the increase in age for example with 11.03 for those younger than 18 years old and 24.99 for those older than 60 years old. The decay rates were estimated as 13.14, 13.07, 10.9, 8.89, and 12.33 for visitors who stay less than 1 h, 1–2 h, 2–3 h, 3–4 h, and more than 4 h, respectively. There are no clear patterns of the decay rate for different transportation modes (15.20 by foot, 7.45 by bicycle, 10.02 by car, 12.50 by bus, and 5.75 by subway).

Table 3. Summary of power function of visitation density and logarithmic function of visitation frequency.

Category		Visitation Density				Visitation Frequency			
		<i>a</i>	<i>b</i>	<i>R</i> ²	<i>p</i>	<i>a</i>	<i>b</i>	<i>R</i> ²	<i>p</i>
Gender	Male	165.502	2.583	0.999	0	45.124	13.36	0.894	0
	Female	174.211	2.441	0.999	0	36.954	10.898	0.827	0
Age	Younger than 18	94.497	2.288	0.999	0	31.325	8.704	0.697	0
	18–28	85.489	2.455	0.999	0	38.549	11.033	0.812	0
	29–45	80.394	2.551	0.998	0	43.76	14.098	0.8	0
	46–60	36.343	2.775	0.999	0	56.838	18.534	0.671	0
	Older than 60	43.022	2.958	0.999	0	77.278	24.987	0.812	0
	Less than 1 h	88.652	2.775	0.998	0	49.503	13.137	0.315	0.009
Duration time	1–2 h	189.072	2.655	0.999	0	43.121	13.067	0.87	0
	2–3 h	42.519	2.078	0.998	0	37.092	10.9	0.87	0
	3–4 h	10.62	1.705	0.995	0	30.514	8.888	0.74	0
	More than 4 h	9.021	1.785	0.987	0	38.226	12.33	0.613	0
Transportation mode	On foot	278.958	2.911	0.999	0	51.344	15.203	0.683	0
	By bicycle	12.587	1.874	0.984	0	34.456	7.448	0.246	0.066
	By Car	42.502	1.696	0.995	0	33.582	10.016	0.859	0
	By Bus	4.56	1.127	0.903	0	40.786	12.497	0.696	0
	By subway	1.974	1.078	0.953	0	25.306	5.753	0.289	0.004
Purposes	Health	264.377	2.598	0.999	0	44.677	13.97	0.898	0
	Culture and education	9.24	2.472	0.999	0	54.996	14.132	0.232	0.075
	Social communication	56.891	2.149	0.998	0	29.868	7.86	0.808	0
	Others	9.243	2.767	0.999	0	30.353	8.215	0.454	0.001
All	All	339.706	2.508	0.999	0	40.408	11.944	0.887	0

4. Discussion

4.1. Urban Park Visitation Distance and Visitation Frequency

We obtained a median visitation distance of 1.30 km and a 75th percentile visitation distance of 2.9 km, indicating that more than half of the visitors need to travel 1.3 km further and more than 25% of the visitors need to travel 2.9 km further to participate in recreation activities in urban parks. The median visitation distance is slightly higher than that in Brussels, Belgium (<1.1 km) [19], but lower than that reported in Xuchang, China (more than 1.5 km) [9], in Wuhan, China (1.90 km) [10], and in three European cities (1.4–1.9) [24]. The 75th percentile visitation distance is consistently lower than that reported in different studies mainly based on mobile phone data, for example, 5.3–7.81 km for the elderly and 8.74–10.17 km for typical visitors in Beijing, China depending on park size [25], 3.63 km, 3.82 km, and 4.13 km on weekdays, weekends, and holidays, respectively, in Xuchang, China [9], 6–10.5 km in Shanghai, China [26]. These variations are possibly caused by different spatial distributions of urban parks, variations in residents' socioeconomic status and demands for park recreation, and road infrastructures and walkability [24,27,28].

The median visitation frequency was estimated as 24 times per season (2 times per week), which is lower than that reported in Wuhan, China (175 times per year) [10]. This may indicate a relatively low urban park visitation frequency in Changsha, China and the reasons require further investigation. Visitation frequency generally showed a negative relationship with distance to urban parks, which indicates that people near urban parks visited the park more frequently. Similar findings were also reported in other studies [8,9,21,29]. This is understandable as distance to urban parks is a major factor determining whether to visit or not.

Personal characteristics significantly impact visitation distance and visitation frequency. We found that males have significantly higher visitation frequency than females. Similar findings have also been reported in previous studies and the possible reason lies that females have stronger household responsibilities and thus have less time for recreational activities [8,20]. The elders, for example, those older than 60 years visit urban parks more frequently than the younger. This is possible because retired old men have much more free time to participate in recreational activities in urban parks [21,30]. However, some studies reported the opposite result that older people visited urban parks less frequently

than young men for example in Addis Ababa, Ethiopia [8]. We showed that travel distance decreases with the increase in the visitor's age. This is not surprising as older people have limited mobility [31,32].

Visitation patterns significantly impact visitation distance and visitation frequency. Our study showed that visitors staying longer time in the parks travel longer distances but with lower visitation frequency. Xu et al. [9] also reported that the duration time in the parks changes with different directions to visitation frequency but with the same direction to visitation distance in Xuchang, China. Transportation also determined visitation distance and visitation frequency. For example, people with high-speed transportation usually visit further greenspace at a lower frequency. Visitation purposes usually affect the visitation distance and visitation frequency. A big data survey of U.S. national parks suggests that people travel a shorter distance to experience nature than to participate in cultural activity [33]. Distance is not usually treated as a major factor when parents choose a park to play with their children [34].

4.2. Spatial Decay of Urban Park Visitation

This study showed that urban park visitation density can be effectively modeled by power function and exponential function and urban park visitation density can be effectively modeled by power function, exponential function, and logarithmic function. This is consistent with previous empirical modeling of the distance decay of urban park visitation. For example, Liu et al. [10] modeled the decrease in visitation numbers with the increase in distance to urban parks using the power function and the decrease in visitation frequency with the increase in distance to urban parks by logarithmic function in Wuhan, China.

The distance decay rate varied among visitors with different personal characteristics and visitation patterns. The elders had a faster distance decay rate for both visitation density and visitation frequency than the younger. This is possible because old people are not willing to travel long distances for recreational activities because of their limited mobility. This suggests that urban park has smaller service areas for elders and urban park planning and management should pay special attention to the recreation demand for elders.

Visitation density and visitation frequency with shorter duration time in the park decreased faster when the duration was shorter than 4 h. However, these two distance decay rates increased again for visitors who stayed in urban parks for more than four hours. This is possible because long-duration visitors visit urban parks for special purposes and travel distance is not an important factor to determine visit or not. The distance decay rate of visitation density for those by foot is the highest compared to other transportation modes. This is understandable as transportation modes of slow speed usually result in short-distance trips.

4.3. Limitations and Future Research Recommendations

Firstly, we mainly considered comprehensive parks that have multiple functions but ignored a large number of community parks (or neighborhood parks). Though community parks have smaller sizes with shorter service radius, they provide considerable recreational services. The distance decay of visitation for community parks should be further investigated to fully understand the spatial distribution of urban park visitation [21]. Secondly, we empirically quantified the distance decay of urban park visitation and investigated the variations among visitors with different personal characteristics and visitation patterns. However, we did not relate the distance decay (for example service radius, and distance decay rate) to the planning indicators that are highly required for better urban park planning and management. We recommend explicatively investigating how urban park planning indicators (such as size, land cover, and management measures) impact the distance decay of urban park visitation [10,11]. Thirdly, we found that elders have quite different visitation distances, visitation frequencies, and related distance decay patterns. Considering the rapid population aging, further investigating the recreation demand, spatial accessibility, and service equity provided by urban parks to the elders are highly suggested [25,35].

5. Conclusions

This study evaluated the distance between urban parks and visitors' homes and modeled the distance decay of urban park visitation in terms of visitation density and visitation frequency in Changsha, China. We showed that urban park visitation was dominated by short distances with a median travel distance of 1.3 km and low frequent visitation with a visitation frequency of 24 times per season. Personal characteristics (e.g., gender and age) and visitation patterns (e.g., duration time, transportation modes, duration time, and purposes) significantly impact visitation density and visitation frequency, as well as their distance decay rates. These findings suggest the importance of a thorough understanding of visitation distance and visitation density and empirically modeling their distance decay for different groups of visitors with different personal characteristics and visitation patterns.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/f15091589/s1>, Text S1: Questionnaire for urban park visitation (A case of Yuehu Park); Table S1: High spatial resolution remote sensing image of the selected urban parks.

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Data Availability Statement: For relevant data, please contact the corresponding author.

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