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Research article

Urban park green space use analysis based on trajectory big data: Experience from a medium–sized city in China

Shuna Xu *, Shengyuan Yuan, Jingzhong Li, Xin Gao, Jinhua Hu

College of Urban and Environmental Sciences, Xuchang University, 88 Bayi Road, Xuchang, Henan Province, China

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ABSTRACT

Regular visits to park green space offer remarkable benefits for the physical and mental health of urban residents. Achieving a comprehensive understanding of the utilization across the entire city is a prerequisite for improving the overall utilization rate of park green spaces. Traditional social survey methods are limited by their sample size and time-consuming nature, while methods based on geographic location big data are gaining momentum. This study focuses on Xuchang, a medium-sized city in China, and systematically analyzes the current state and influencing factors of park green space utilization by mining GPS trajectory big data from April 3 to 12, 2022. Results indicate that residents' choices of park green spaces are highly diverse. Approximately 20% of visitors on holidays and weekends, and about 25% of visitors on weekdays, prefer the park green space closest to their homes. Notably, the distance threshold for park green space visits on weekdays, weekends, and holidays is 3633, 3824, and 4127 m, respectively. These distances are significantly higher than the several hundred meters specified in planning documents or commonly used in accessibility analyses. For individuals who frequently visit park green spaces, distance is the most critical influencing factor. Conversely, for those who occasionally visit, distance is not the primary consideration. For individuals who rarely or never visit park green spaces, personal attitudes play an essential role. In comparison to weekdays, the number of visitors on holidays and weekends is larger, the travel distance is longer, and they are more inclined to choose larger parks. Visits are concentrated in the afternoon and evening, and weather changes remarkably affect park green space utilization. Importantly, no compensatory effect is observed between the frequency and duration of park green space visits. These findings hold important implications for urban planning, management, and the promotion of park green space utilization.

1. Introduction

The world's urban population continues to grow[1], and the increasing size of cities, along with their highly concentrated populations, presents contemporary urban centers with a range of complex environmental and social challenges [2]. As a crucial ecological component of the urban built environment, urban park green spaces contribute to residents' well-being by enhancing the ecological environment, promoting physical health, and alleviating mental stress. The ecological and environmental advantages of urban park green spaces manifest in various aspects, including temperature regulation, humidity maintenance, carbon sequestration, oxygen

* Corresponding author.
E-mail address: xusn1027@aliyun.com (S. Xu).

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production, noise reduction, pollution mitigation, and biodiversity preservation [3]. Urban park green spaces primarily enhance physical and mental health by reducing environmental pollutants, providing spaces for physical activities, leisure, and social interactions, as well as offering aesthetic experiences. Individuals who regularly utilize these green spaces are less likely to be overweight or obese[4] and have a reduced risk of developing various chronic diseases (Sugiyama et al., 2018). Public green spaces in urban areas have a positive effect on reducing the prevalence of heart disease, chronic pneumonia, and hypertension (Wang and Lan, 2019), and residing in greener locales may lower overall mortality rates [5]. Furthermore, urban green spaces can alleviate loneliness[6], reduce the odds of depression and suicide [7]. Regular outdoor recreation in nearby natural settings positively influences the emotional well-being and mental resilience of urban residents (Buchecker and Degenhardt, 2015; [8]. The longer individuals spend in urban open green spaces, the less they are susceptible to the effects of stress[9]. Forestry Commission Scotland even launched a Woods In and Around Town (WIAT) programme aiming to lower levels of stress, and improve mental health and wellbeing of local residents[10–12]. Therefore, ensuring an appropriate number and equitable distribution of urban park green spaces, as well as encouraging their use, is a vital prerequisite for these spaces to benefit urban residents.

Several factors influence people's choices and usage of park green spaces, with distance/accessibility being one of the most crucial determinants [9,13–16] or, more precisely, perceived distance/accessibility [17,18]; Wan et al., 2020). The proximity to park green spaces is directly linked to the frequency of visits[14,19], and generally, a distance of 300–400 m [14,20–22] is considered the access threshold, beyond which usage sharply declines [19]. However, recent research has indicated that the threshold for park green space visitation extends much farther, sometimes reaching 1400–1900 m [23], 2000 m [24], or even greater distances [25,26]. Simultaneously, some studies have found no significant correlation between distance/accessibility and park green space access[27,28], suggesting that personal attitudes play a decisive role in this regard [29,30]. Therefore, in addition to optimizing the layout of green spaces within urban parks, publicity campaigns should also be carried out to change users' attitudes and positioning the use of urban green spaces as a social trend[31,32].

Research on the utilization of park green spaces encompasses various aspects, including visit distance, time, duration, and frequency. Generally, the use of green spaces in urban parks exhibits a phenomenon known as distance attenuation[4,15,20,23,24,33]. This phenomenon entails a decrease in the frequency of park green space visits as the distance between one's residence and the nearest park green space increases. In terms of seasonal patterns, people typically favor visiting parks and green spaces during weekends and holidays[34]. However [24], demonstrated that the number of visitors on weekends is lower than on weekdays. Regarding the daily variation in visitation times, the majority of visits are concentrated in the afternoon and evening[28,35], with a notably high average number of nighttime visitors in the Latin American region [36]. A compensation hypothesis regarding the relationship between visit frequency and duration exists. This hypothesis suggests that residents with fewer green spaces in proximity to their homes are more likely to visit more distant parks [37]. It also posits that residents spend less time visiting nearby urban green spaces frequently and more time occasionally visiting distant urban green spaces, resulting in an equal total time spent in urban green spaces[19]. However, the validity of this hypothesis is not universally confirmed. Some studies support it[38,39], while others refute it (e.g., Ref. [9]; Muniz et al., 2013; [40], and some studies arrive at inconclusive findings (Maat and Vries, 2006; [41–44].

The aforementioned studies primarily rely on traditional questionnaire surveys and on-site observations, which possess certain limitations, including small sample sizes, potential data validity and reliability issues, and being time-consuming and labor-intensive [28,34]. However, with the emergence of the era of big data, some researchers have started to leverage geolocation social media data and mobile phone data to investigate the utilization of urban parks and green spaces. Geographically tagged social media big data from platforms, such as Instagram [45,46], Flickr [46,47], Twitter [47], Weibo check-in data [48]; Lyu and Zhang, 2019; [49,50], Baidu Heatmap (Lyu and Zhang, 2019), Ctrip [50], and Dianping [50], as well as Tencent's Real-Time User Density per hour [28], are frequently employed to estimate the number or density of visitors to urban parks. When it comes to mobile phone location big data, there are two primary positioning principles. One relies on base station positioning, where the location of the mobile phone is determined by the base station it's connected to. Positioning accuracy depends on the base station interval, which is typically 100–300 m in the central city and around 1000–3000 m in suburban areas[51]. The other principle is based on GPS positioning, offering accuracy within tens of meters[52,53]. Mobile phone location big data is often used to analyze various aspects of urban parks, including their service area[24–26,51–54], the number of visitors [24,53], visitation rates [51], and visitation durations [51], among others. However, it's important to note that social media location data only records visitor check-ins or location information within the park, enabling analysis of visitor numbers or densities within the park itself. On the other hand, mobile phone data records visitor activity trajectories. Nonetheless, most studies rely on mobile phone data based on base stations, which is constrained by positioning accuracy. Consequently, these studies often focus on several large parks within a city, leaving a gap in comprehensive research on the utilization of park green spaces across the entire city.

This study utilizes high-precision mobile phone trajectory data to conduct a comprehensive analysis of park green space utilization across the entire central urban area of Xuchang, a medium-sized city in China. The primary objectives of this research are as follows: Analyze the accessibility distance threshold based on actual park green space visitors. Investigate the impact of various objective factors such as distance, park green area, holidays, weather, and others on the utilization of park green spaces. Evaluate the validity of the compensation hypothesis concerning park green space utilization.

2. Materials and methods

2.1. Data sources

The mobile phone location data used in this research was sourced from Guangzhou Mengxiang Network Technology Co., LTD. This company collaborates with mobile phone manufacturers to offer intelligent scene recognition services to mobile phone users. This service involves embedding a software development kit into the mobile phone system to obtain user location information. It's important to note that when users initiate the scene recognition service for the first time, it is only activated after the user consents to the license agreement. The data used in this study comprises half-hourly positioning trajectory data for the permanent population residing in the central urban area of Xuchang and its 2 km buffer zone. This data was provided by the company for the period from April 3 to April 12, 2022. This timeframe encompasses a 3-day Qingming Festival holiday, 5 working days, and 2 weekends, totaling 10 days of data collection. The positioning accuracy is approximately 10 m in open outdoor areas and, in locations with numerous obstacles, the maximum error does not exceed 20 m. It's important to highlight that all trajectory data used in this study lacks any personal attribute information. During data analysis, a total of 256,423 permanent residents were identified, with 186,970 individuals residing in the central city, representing 33.72% of the permanent population within the region (which stood at 554,465 people, as per the seventh national population census data from 2020). To validate the accuracy of the sample data, Pearson correlation analysis was conducted between the resident population identified through mobile big data and the resident population derived from the seventh population census data for each district [55]. The results yielded a correlation coefficient of 0.963 ($n = 15$, $p = 0.000$), indicating that the sample data effectively reflects the spatiotemporal distribution characteristics of the actual resident population. This demonstrates that the sample data accurately captures the spatiotemporal distribution characteristics of the real resident population.

The administrative division data utilized in this study were sourced from the Xuchang Municipal Bureau of Natural Resources and Planning. For other foundational data, including road networks, park green spaces, residential areas, and more, please refer to the research conducted by Ref. [56].

2.2. Methods

On the basis of the mobile phone location data and foundational data, first identify park visitors and their home addresses. Then count the number of visitors per day and summarize the visit frequency. Next, the network analysis method is used to calculate the shortest home-to-park distance and actual visit distance. Finally analyze the influence of distance, park green space area and other factors on park green space utilization. These processes are implemented by ArcGIS Pro 3.0.2 and SPSS 22.0 software.

(1) Visitor identification: Individuals who enter the park green area after 5:00 a.m. on any given day will be classified as visitors. Among these visitors, those who have spent more than 6 consecutive hours in the park on at least 5 out of 10 days will be categorized as the working population. This specific group will be excluded from the overall visitor count.
(2) Home–Park distance: Initially, the mobile phone location data is integrated with the spatial distribution information of residential neighborhoods. The residential quarter where a user's device registers the most frequent presence during the residential period (between 22:00 p.m. and 7:00 a.m.) over the last three months is designated as the device's residence. Subsequently, starting from the entrance of the residential quarter and concluding at the gate or entrance of the park green space (as per [56], a network analysis method is employed to determine the path distance from the residence to the park green space.
(3) Visit time: Consider the time when visitors initially enter a park green space as their time of arrival.
(4) Duration: The visit duration is approximated based on the frequency of visitor appearances in the park green space each day. Given that this dataset records locations once every half hour, the visit duration is calculated as $\approx$ the number of locations $\times$ 0.5. This approximation yields an error of less than 0.5 h. For instance, if a visitor is only recorded once in the park green space, their visit duration would fall within the range of 0–1 h. If a visitor appears twice in the park green space, their visit duration would span from 0.5 to 1.5 h, and so forth.
(5) Frequency: The visit frequency represents the number of times residents visited the park green space during April 3–12, 2022, computed on a daily basis. For each day, if a person visits the park green space, irrespective of the number and duration of visits, the value is set to 1. If an individual does not visit the park green space on a given day, the value is recorded as 0. The data for the 10 days are then aggregated, resulting in a visit frequency value range of [0, 10].
(6) Travel rate: The proportion of individuals visiting park green spaces in relation to the total population.

2.3. Study area

The study area encompasses Xuchang city center, covering an approximate area of 97 square kilometers. Situated in central China, Xuchang holds several prestigious titles, including being designated as a "national ecological garden city," a "National Forest City," a "National Health City," and a "National civilized city." Xuchang city is a microcosm of small and medium-sized cities in China [57]. As an ancient civilization with a long history, China emphasizes the harmonious coexistence of humans and nature, and pursues the unity of heaven and humanity. Most residents have a clear cognition of the ecosystem services provided by urban park green spaces, and are even willing to pay for the conservation of urban park green spaces[58]. And parks green spaces have a positive effect on house prices [59]. Compared with Western countries where urban park green spaces are generally used for walking, dog walking, sports activities and exercise [60], people in China use urban park green spaces generally for walking, having a trip with children, exercising, and enjoying the scenery [15]. As per the seventh population census of China in 2020, the permanent population of Xuchang city stands at 554,465, classifying it as a medium-sized city based on population size (State Council of China, 2014). The city's total GDP amounts to 44.842 billion yuan (Chen and Cui, 2022). The study area has a flat terrain with an elevation range of 65–95 m. The detailed information about the topographic and climatic characteristics can be found in the research conducted by Ref. [56]. Within this study area, there are 1300 residential quarters and 93 park green spaces, encompassing a combined area of roughly 774 ha. To mitigate boundary-related effects, a 2 km buffer was applied to the outer limits of Xuchang's central urban area. Consequently, 291 residential quarters and 24 park green spaces, accounting for approximately 363 ha, have been included in the statistical assessment of park green space usage within the buffer zone. figure A1illustrates the statistical relationship between the path distance from the residences of 256,423 permanent residents to the nearest park green space, as identified through mobile phone big data. Notably, over half of the population resides within a distance of less than 500 m from a park green space, nearly 80% of the population lives within a distance of less than 1000 m from a park green space, and only 3.04% of residents have a distance exceeding 2000 m to the nearest park green space.

The weather conditions observed from April 3 to April 12, 2022, during the research period, are detailed in table A1. At this time, the season is spring, marked by blossoming flowers and steadily rising temperatures. The prevailing weather consists of a mix of sunshine and clouds, occasionally transitioning to overcast conditions. It's worth highlighting that following several consecutive days of warming weather, a significant temperature drop of 16 °C occurred on April 12th. This abrupt change also resulted in a steep decline

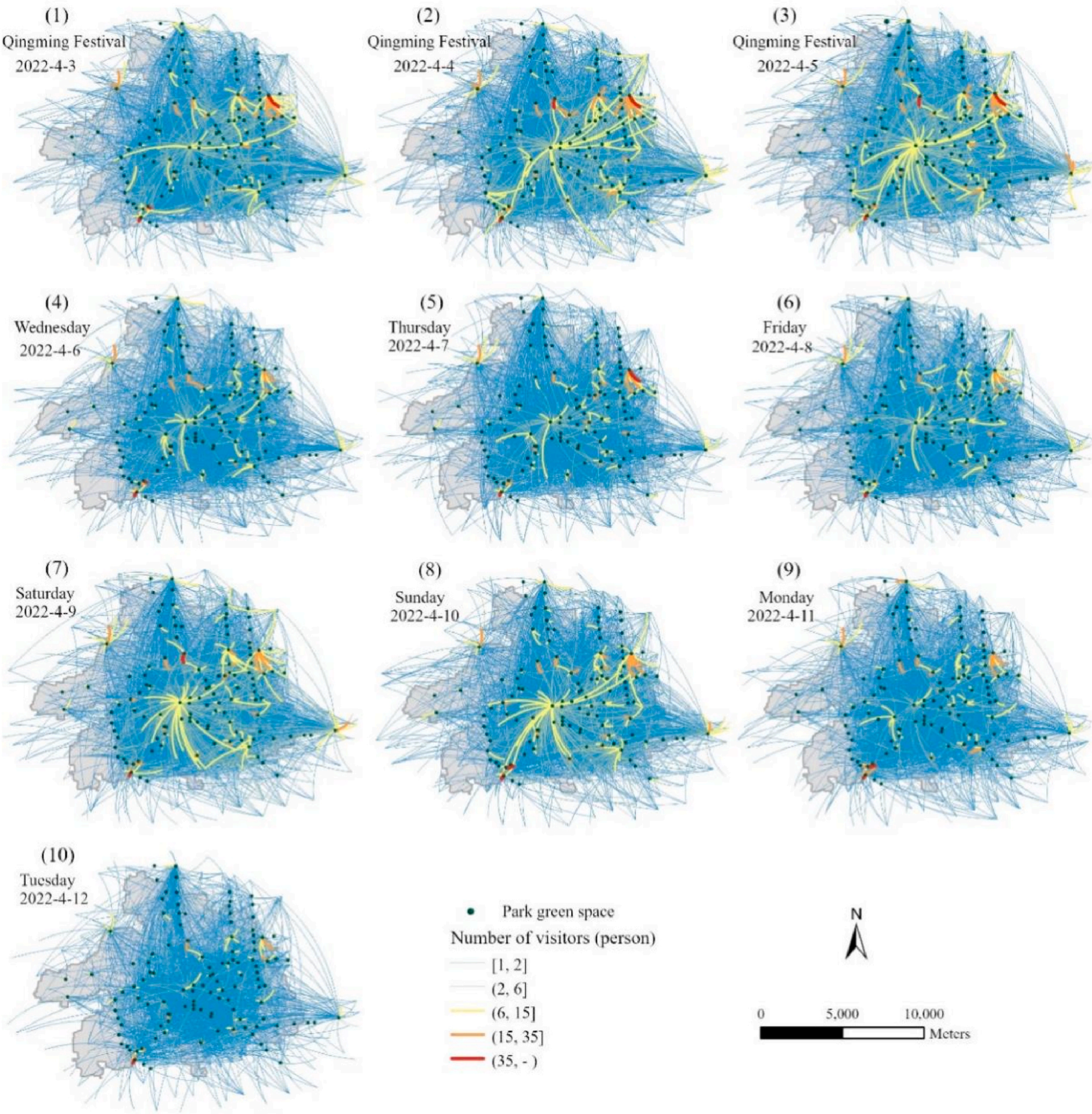

Fig. 1. Spatiotemporal distribution of residents visiting park green space from April 3 to April 12, 2022. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

in the number of visitors to the park green spaces on that particular day.

3. Results

3.1. Spatial and temporal distribution pattern of park green space use

Fig. 1 illustrates the spatial and temporal distribution of the number of residents visiting various park green spaces in each residential quarter. Regarding spatial distribution, residents in each residential quarter exhibit diverse preferences when choosing park green spaces. Even within the same residential quarter, different individuals may opt for different park green spaces. The number of park green spaces visited by residents in a given residential quarter varies widely, ranging from a few to over 30, primarily linked to the population size of the residential quarter. Larger populations tend to result in more varied choices of park green spaces. The number of people visiting specific park green spaces within each residential quarter follows a pyramid-shaped distribution, with a broad base primarily consisting of 1–2 visitors and a much smaller peak featuring more than 15 visitors. The distribution of visitors across park green spaces is not uniform, with the majority of visitors concentrated in a select few parks. Among the total number of visitors over the ten-day period, West Lake Park in the central study area attracts the most visitors, accounting for 9.92%. Following closely is Luming Lake Park in the northeast, making up 4.18% of the total. Dihao Plaza in the central region and Central Park (Chenzhuang Street to Yongchang Road section) in the northeast account for 3.11% and 2.97%, respectively. Additionally, there is a strong correlation between the daily number of visitors in each park, and this relationship remains relatively stable, displaying a significant positive correlation with the park's area (see table A2). Furthermore, the ranking of park popularity remains consistent, also demonstrating a significant positive correlation with their respective areas (see table A2). Regarding temporal variations, the number of park visitors is notably higher during the Qingming Festival (Fig. 1 (1)–(3)) and weekends (Fig. 1 (7)–(8)) in comparison to regular working days.

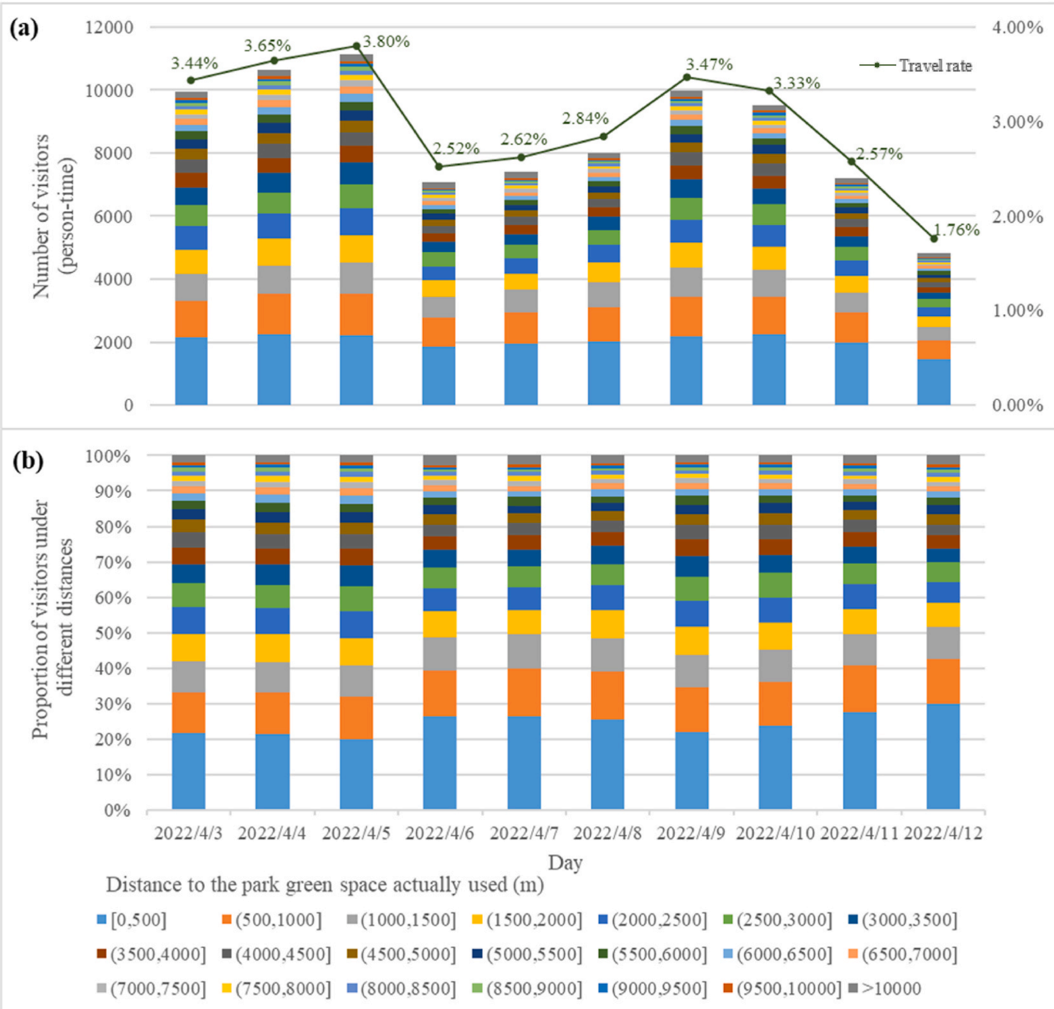

Fig. 2. The number (a) and proportion (b) of visitors under different dates and different distance thresholds.

Visitors also cover longer distances during these periods.

3.2. Travel distance analysis

Dates exert a significant influence on the number of park visitors (Fig. 2 (a)). The highest visitor count occurs on holidays, followed by weekends, both of which significantly surpass the numbers seen on working days. The visitation rate on holidays and weekends ranges from 3.33% to 3.80%, whereas on working days, it ranges from only 1.76%–2.84%. Additionally, weather conditions also have a noticeable impact on the visitation rate. For instance, compared to April 11, the maximum temperature on April 12 dropped by 16 °C, accompanied by a shift from cloudy to overcast weather (Table 1A). This change led to a sharp decline in the number of park visitors. In terms of travel distance, as the distance from one's residence increases, the corresponding number of visitors decreases. On holidays and weekends, the number of visitors in each distance segment is higher than on weekdays. Considering the proportion of visitors at different distance thresholds (Fig. 2 (b)), when the travel distance is less than 2000 m, the proportion at different distance thresholds on holidays and weekends is lower than that on working days. However, when the travel distance exceeds 2000 m, the proportion on holidays and weekends is higher than that on working days. For visitors at the 25th percentile, the home-park path distances were 440 m, 585 m, and 664 m on weekdays, weekends, and holidays, respectively. For those at the 50th percentile, the distances were 1528 m, 1840 m, and 2059 m on weekdays, weekends, and holidays, respectively. Lastly, for visitors at the 75th percentile, the distances were 3633 m, 3824 m, and 4127 m on weekdays, weekends, and holidays, respectively. Taking into consideration the proximity of the nearest park green space to one's residence, approximately 20 percent of visitors utilize the nearest park on holidays and weekends (fig. A2), compared to around 25 percent on weekdays.

3.3. Analysis of the use of park green spaces

3.3.1. Access time analysis

Overall, individuals tend to visit park green spaces predominantly in the afternoon (between 13:00 and 18:00) and in the evening (from 18:00 onwards), accounting for roughly two-thirds of the total number of visitors (Fig. 3). Following this, there's a preference for the morning (8:00 to 11:00), which represents approximately 18.74% of the total, as well as the early morning (5:00 to 8:00) and noon, constituting 6.09% and 8.89%, respectively. During holidays (April 3–4), the morning period sees the lowest number of visitors, at approximately 4%, while the afternoon experiences the highest number of visitors, at around 43%. In contrast, on weekdays and weekends (April 6–12), the number and proportion of visitors during the morning (about 7%) are notably higher than those on holidays. The evening remains the peak visiting time (around 34%), closely followed by the afternoon (about 30%), with the morning accounting for approximately 20%. The noon and morning periods have the fewest number of visitors during this time frame.

3.3.2. Duration analysis

As depicted in Fig. 4, over half of the visitors spend approximately half an hour (0–1 h) in the park green space, while more than 20% of visitors stay for around 1 h (0.5–1.5 h). Fewer than 30% of visitors extend their visits beyond 1.5 h (1–2 h). This proportion exhibits slight variations on different dates. On holidays and weekends, people tend to spend more time in the park green space. The only exception is that the proportion of tourists who visit for about 0.5 h (0–1 h) is lower than that on working days, while the proportion of visitors who stay for other durations is higher than that on working days.

3.3.3. Frequency analysis

Throughout the study period, over 85% of the residents did not visit the park green space within the span of 10 days (Table 1). In contrast, less than 15% of the residents made at least one visit. Approximately 7.36% of the residents visited the park green space once, around 3.11% visited twice, and roughly 1.55% visited three times. A mere 2.13% of residents visited the park green space more than three times, with only 0.34% making more than seven visits, and a mere 0.11% of residents visited the park green space every day.

Table 1
Statistics on the frequency of residents using park green spaces.

Frequency	Number of visitors	Proportion
0	220141	85.85%
1	18871	7.36%
2	7975	3.11%
3	3979	1.55%
4	2149	0.84%
5	1248	0.49%
6	740	0.29%
7	450	0.18%
8	342	0.13%
9	242	0.09%
10	286	0.11%

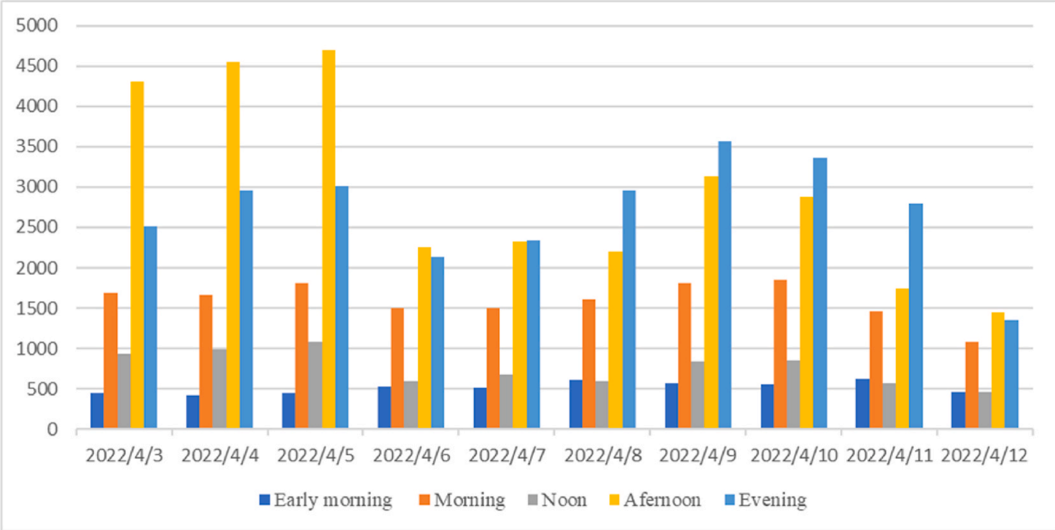

Fig. 3. Statistics on the number of visitors to park green spaces on different days and time periods. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

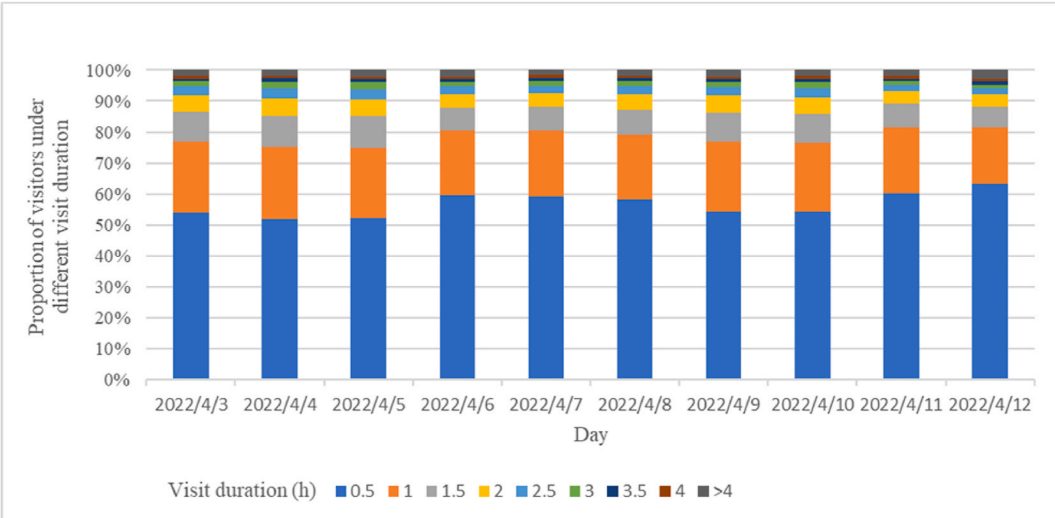

Fig. 4. Duration statistics of visitors' use of park green space on different days. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

3.3.4. Analysis of the relationship between visit duration and frequency

The relationship between visit duration and frequency is presented in Fig. 5. In general, the median visit duration shows an upward trend as visit frequency increases. For visitors who only visit the green space once, the median duration is 0.5 h, and it increases gradually with higher visit frequencies. When the visit frequency reaches 7 times, the visit duration exceeds 1 h, and from there, it increases rapidly with further increases in visit frequency. When the visit frequency reaches 10 times, meaning visitors went to the park green space every day, the median duration for these visitors in the park green space surpasses 2 h. In essence, the more frequently individuals visit the park green space, the longer their average duration during each visit. Conversely, lower visit frequencies are associated with shorter average visit durations. Consequently, this study contradicts the compensation hypothesis for park green space usage.

3.4. Factors affecting the use of park green spaces

Many factors affect the use of park green space, including personal factors, distance, park area, etc. Studies have shown that the frequency and duration of visits to park green space are influenced by personal factors such as gender, age, education level, occupation,

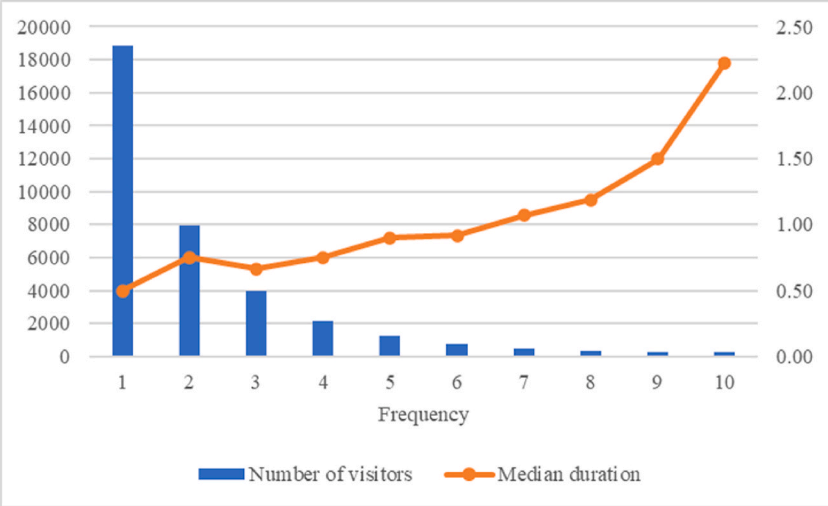

Fig. 5. Relationship between the duration and frequency of visitors using park green spaces from April 3 to 12. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

and income[13,16,20]. Since the trajectory data used in this study does not contain any personal attribute information, only objective factors such as distance and park area are analyzed here.

3.4.1. The relationship between visit frequency and distance

The shortest home-to-park distance has a significant impact on the frequency of park use (Fig. 6). As the shortest home-to-park distance shortens, the frequency of park use notably increases. Visitors who visited the park green space only once had a median shortest home-to-park distance of 475 m, whereas those who visited the park green space daily had a much shorter median distance of only 136 m. However, since only approximately 20–25% of visitors choose the park green space closest to their homes (fig. A2), the actual distance they cover is much greater than the shortest distance. For visitors who visited the park green space only once, the median actual visit distance is nearly 2.5 km. In contrast, for daily visitors to the park green space, the median actual visit distance is only 383 m, and this actual visit distance decreases rapidly with increasing visit frequency. This observation suggests that for those who occasionally visit park green spaces, distance is not the primary constraint. However, for those who frequently visit park green spaces, distance plays a crucial role as a constraint.

3.4.2. Relationship between the visit frequency and the area of park green space

There is also a significant relationship between the area of park green space and visit frequency (Fig. 7). As visit frequency increases, the area of the park green space that is actually visited becomes closer to that of the nearest park green space. This observation

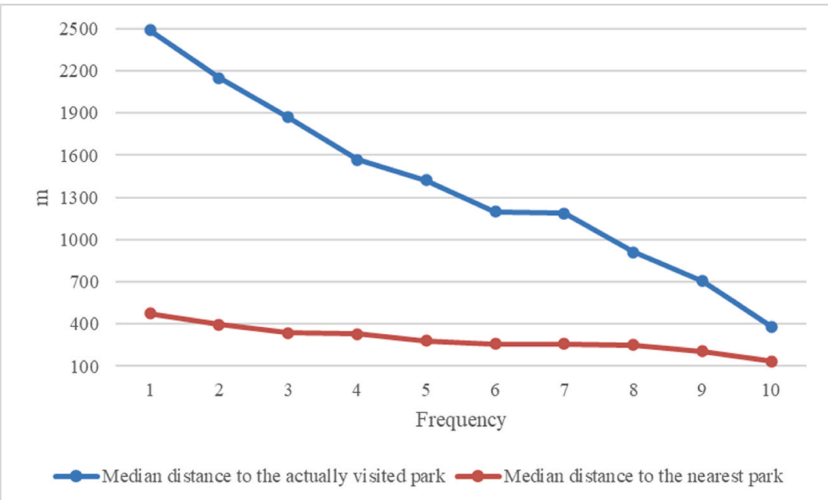

Fig. 6. The relationship between the visit frequency of and the shortest home–park distance.

raises two key points. First, visitors who frequently visit park green spaces tend to have a relatively large park located closest to their homes. Conversely, visitors who infrequently visit park green spaces typically have a relatively small park near their homes. Second, visitors who frequently visit park green spaces tend to visit relatively small park green spaces, whereas those who occasionally visit park green spaces often choose larger, more distant park green spaces. This suggests that occasional users are more inclined to select larger, more distant park green spaces, while frequent users often opt for park green spaces that are close to their homes. It's important to note that visitors who visit park green spaces every day have the smallest area of park closest to their home, suggesting that distance may be a more significant factor in their choice of park green spaces.

4. Discussion

4.1. Accessibility distance threshold of park green space

Choosing an appropriate distance threshold is crucial when assessing the accessibility of park green spaces, as it determines whether these spaces are considered reachable (Dai, 2011). However, as [56] have outlined, the current research displays a wide range of distance thresholds, including 300 m, 400 m, 500 m, 600 m, 800 m, 1000 m, 1200 m, 1600 m, or time-based thresholds like 10–20 min and 15 min of walking distance. The selection of these thresholds is primarily based on three criteria: firstly, national or city regulations and recommendations (e.g. Refs. [14,21,51,61], secondly, data from social surveys (e.g. Refs. [17,23], and thirdly, references to practices adopted in other studies (e.g., Refs. [22,62–64]. Among these thresholds, the range of 300–400 m has gained widespread acceptance. However, recent analysis of actual park green space visitors based on big data indicates that the distance threshold is often significantly larger. For instance Ref. [25], examined the distance thresholds (corresponding to the 75th percentile visitor) for elderly and typical visitors in Beijing when visiting green parks of various sizes using mobile phone signaling data. They found these thresholds to be 5.3021–7.807 km for the elderly and 8.7419–10.1677 km for typical visitors, significantly greater than the traditional 300–400 m threshold [26]. utilized mobile phone signaling data to distinguish visitors in various park types and their respective homes. They assessed the service areas of these parks in Beijing using one-standard deviation ellipses (encompassing about 68% of visitors) and found that the average service radius for each park ranged from 5.63 to 9.00 km on weekdays and from 5.52 to 9.22 km on weekends. In another study [24], investigated the distance threshold for residents' access to different park green spaces in Fuzhou based on mobile phone signaling data, and they consistently found this threshold to be 2 km (corresponding to 75–84% of visitors). Similarly [54], assessed the service range of parks in Shanghai using mobile phone signaling data and discovered that the home–park Euclidean distance for the 70th percentile of visitors in various parks within the inner ring road ranged from 6.0 to 10.5 km. Moreover, Guan et al. analyzed the service areas of parks in central Tokyo using the density threshold method based on mobile phone signaling data. They found that the average service area for six small parks was 3.17 km (2020), while for six medium-sized parks, it ranged from 2.81 to 17.97 km (2021). In our study's results (Fig. 3), the home-park path distance corresponding to the 75th percentile of visitors was 3633 m, 3824 m, and 4127 m on weekdays, weekends, and holidays, respectively. The reasons for the long travel distance to the park green spaces in our research area may be as follows: (1) The area is flat with an elevation between 65 and 95 m, which is conducive to walking. (2) There is a public bicycle network covering the whole area. Public bicycle stations are set up in bus stations, park greenspaces, supermarkets, schools, large residential quarters and other places with large traffic flow. On average, there is a station every 450 m, with a total of 359 public bicycle stations, about 8200 public bicycles and a total length of more than 200 km of public bicycle dedicated greenway. One can ride for free for 1 h at a time, with no limit on the number of rides per day, greatly

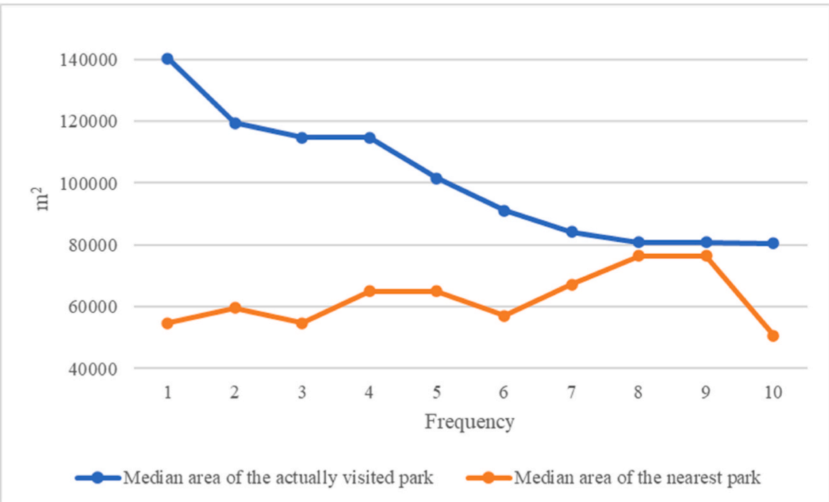

Fig. 7. The relationship between the visit frequency and the area of nearest and avtually visited park green space. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

facilitating green travel for citizens[65]. (3) The park green space is mainly distributed in the urban fringe, with wide and smooth roads and convenient parking, making driving very efficient.

This study diverges from the aforementioned studies in several key aspects. First, it examines medium-sized cities, whereas the earlier studies primarily focused on megacities and super-large cities (State Council, 2014). This distinction encompasses both scale and population size, with medium-sized cities being considerably smaller in both regards. The second distinction pertains to the varying positioning accuracy of data sources. With the exception of [52,53]; who used mobile phone big data with a positioning accuracy of 15–30 m, other studies relied on data sources with positioning accuracies ranging from several hundred meters in urban areas to several kilometers in rural areas [51]. In contrast, the maximum positioning error for the data source in this study does not exceed 20 m. Thirdly, this study employs a different distance metric. While [25] used path distance, several other studies employed Euclidean distance. In contrast, this study uses real path distance. Despite these distinctions, a shared characteristic of the distance thresholds derived from real-world trajectory data is that they are considerably larger than the few hundred meters typically specified in planning documents or widely used in accessibility analyses. This observation holds true across cities of various sizes, and it warrants attention from researchers in this field. For example, for the park green spaces with high number of visitors in this study area, those located in the downtown area can further improve the cycling and bus routes passing through the area, providing convenience for residents to walk, ride bicycles, or take public transportation. Those located on urban fringe can build sufficient parking lots to facilitate residents' driving trips.

4.2. Influence of distance and park green space area on the frequency of visits

The distance between one's home and the nearest park green space significantly affects the frequency of park green space visits (Fig. 6). Those who visit the park green space more frequently tend to have shorter distances to the nearest park green space, and their actual visit distances closely match the nearest distance. Conversely, individuals who visit the park green space less frequently have longer distances to the nearest park green space, and their actual visit distances are farther from the nearest distance. These findings align with the research results of [4,15] and confirm the distance decay phenomenon commonly observed in the use of urban park green space [15,33]. The influence of park green space area on visit frequency is primarily as follows (Fig. 7): Individuals who frequently visit park green spaces tend to visit relatively small park green spaces, whereas those who occasionally visit park green spaces prefer larger park green spaces. These findings are consistent with the research results of [15]. In summary, distance emerges as the most significant influencing factor for frequent park green space visitors, while distance is not the primary consideration for occasional park green space visitors, who are more attracted to larger park green spaces.

It's noteworthy that the overall visitation rate in the study area is relatively low (Fig. 2), with a substantial 85.85% of individuals not visiting the park green space within the ten-day period (Table 1). The distribution of distances to the nearest park green space among this group of non-visitors aligns with that of the entire population in the study area (fig. A3), indicating that, for this demographic, distance is not the primary factor influencing park green space usage. An ongoing social survey on park green space utilization in the study area (not shown) reveals that among individuals who visit park green space less than once a week (442 valid responses thus far), the main influencing factors (multiple choices allowed) for their infrequent or non-visitation to park green space are "busy with work and study, lack of time (67.87%)," followed by "not inclined to go out (36.65%)." Only 15.38% of respondents selected "distant from park green space," and a mere 4.52% opted for "limited nearby park green space area." Therefore, for those who rarely visit park green space, personal attitude plays a decisive role in their park green space utilization[29,31]. To encourage park green space utilization among this demographic, it is essential to not only enhance the park green space environment and accessibility but also bolster awareness campaigns [66] to firmly establish the concept that "utilizing park green spaces is beneficial for physical and mental health" in people's minds.

4.3. Influence of holidays, time and weather conditions on park green spaces use

The impact of holidays on the utilization of urban park green spaces manifests primarily in three aspects: Firstly, there is a notable increase in the number of park visitors during holidays and weekends compared to working days. The travel rate on holidays and weekends ranges from 3.33% to 3.80%, whereas it's only 1.76%–2.84% on working days. Secondly, during holidays and weekends, individuals tend to choose larger parks, and there is a stronger correlation between the number of park visitors and the park's area (table A2). Thirdly, people tend to travel greater distances and spend longer durations in parks on holidays and weekends as compared to weekdays. Approximately 20% of tourists use the park green space closest to their home on holidays and weekends, while on weekdays, this proportion is approximately 25%. These findings align with previous research summarized by Ref. [34]; which suggests that people globally prefer visiting parks and green spaces on weekends and holidays. However, it's worth noting that [24] reported lower visitor numbers in park green spaces on weekends compared to weekdays. This discrepancy may arise from differences between cities and the possibility that Lin et al. counted visitors only between 6:00 and 18:00 during the week. In this study, park visitors on weekdays and weekends are primarily concentrated in the evening after 18:00. Overall, residents' visits to park green spaces are concentrated in the afternoon and evening, consistent with the findings of [28,35]. During holidays, the highest number of people visit park green spaces in the afternoon, while on weekdays and weekends, the evenings see the highest footfall [36]. conducted a survey on green space utilization in parks in Santa Cruz, Latin America, and found that the average number of visitors was highest during the night. Weather conditions also exert a significant influence on travel rates. For instance, the sharp drop in maximum temperature on April 12 by 16 °C led to a substantial 31.42% decrease in the number of park visitors compared to the previous day. Nevertheless, the impact of weather conditions on park green space utilization remains less pronounced.

Considering the seasonal and daily variations in park green space visitors in the study area, specific measures can be devised to enhance the utilization of park green spaces and provide a better travel experience for visitors. Here are some recommendations: Enhance Existing Park Quality: Given the low travel rate in the study area, simply building more park green spaces to reduce distances may not be the most effective strategy. Instead, focus on improving the quality of existing park green spaces. Consider adding leisure and entertainment facilities, as well as fitness equipment, to attract more users. Create an environment that encourages people to visit and spend time in these parks. Holiday and Weekend Programs: Since holidays and weekends experience a higher number of visitors, organize special programs and promotional activities during these periods to encourage more citizens to use park green spaces. These initiatives can include cultural events, sports activities, or family-friendly programs that cater to diverse interests. Nighttime Facilities and Lighting: Recognizing the popularity of park visits during the evening and night, invest in the construction and enhancement of park green spaces specifically designed for nighttime use. Improve lighting facilities in and around parks to enhance safety and create a welcoming atmosphere for nighttime visitors.

4.4. The compensation hypothesis of park green space use

According to the compensation hypothesis of park green space use, residents with less green space around their residence are more likely to visit distant parks [37]. Alternatively, residents will spend less time frequently visiting nearby urban green spaces and more time occasionally visiting distant urban green spaces. This compensates for the total time spent in urban green spaces[19]. However, the results of this study indicate a different pattern: the more frequently people visit park green spaces, the longer the average duration of each visit. Conversely, the lower the frequency of visits, the shorter the average duration of each visit, directly challenging the compensation hypothesis. Several factors may contribute to these findings, including personal habits, beliefs, and available leisure time. Similar conclusions have been reached in related studies. For instance Ref. [9], study demonstrated that people typically do not compensate for the lack of green environment in their residential areas by visiting more public parks. The research results of [67] also strongly oppose the compensation hypothesis, as does the study conducted by Ref. [40]. These findings collectively challenge the traditional compensation hypothesis regarding park green space use.

4.5. Merits and limitations

Using trajectory data with high positioning accuracy and large sample sizes, this study conducted a comprehensive analysis of park green space usage during holidays, weekends, and working days in Xuchang City. This approach offers distinct advantages over traditional social survey methods. It boasts a substantial effective sample size, representing approximately one-third of the permanent population, and is based on actual population activity trajectories. Furthermore, in contrast to social media big data that merely records visitors' check-ins or location information within the park, the data source employed in this study documents complete population activity trajectories. This allows for a more effective analysis of how distance impacts green space utilization in the park. Additionally, compared to mobile signaling big data that relies on base station positioning, this method provides superior positioning accuracy and can better identify park green space visitors and their residential addresses.

This study has a few limitations worth noting. Firstly, due to privacy protection measures, the trajectory data used in this study do not contain any personal attribute information, such as gender, age, occupation, and economic status. Consequently, the study cannot analyze the influence of these factors on park green space usage. Further analysis would require the integration of social survey data. Secondly, the study exclusively focuses on public park green spaces and does not account for green spaces within residential quarters. Some individuals may frequently use green spaces within residential areas, but this study does not capture such cases. Lastly, the accessibility distance considered in this study pertains to the distance from home to park green spaces. Some individuals may visit park green spaces from their workplaces or other locations, which could result in a small number of people frequently visiting park green spaces located far from their homes. This aspect may warrant more in-depth exploration in future research endeavors.

5. Conclusions

Based on high-precision and large-sample trajectory big data collected from April 3 to 12, 2022, this study serves as the primary data source. Through data mining, the study identified the actual visitors to park green spaces and their places of residence. Subsequently, the study conducted a systematic analysis of the usage patterns and influencing factors of park green spaces in the central urban area of Xuchang, a medium-sized city in China. The key findings are summarized as follows.

(1) Residents exhibit diverse preferences in selecting park green spaces. During holidays and weekends, approximately 20% of visitors opt for the park green space nearest to their residences, while on weekdays, this proportion increases slightly to about 25%. It's important to note that distance represents just one of the various factors influencing residents' choices regarding park green spaces.

(2) The distance threshold for accessing park green spaces based on real trajectory data is 3633 m on weekdays, 3824 m on weekends, and 4127 m on holidays. It is noteworthy that a consistent feature of these distance thresholds derived from people's actual trajectory data is that they are significantly greater than the several hundred meters typically specified in urban planning documents or commonly used in accessibility analyses, irrespective of the city's size or level.

(3) Distance emerges as the paramount factor for individuals who frequently visit parks. Conversely, for those who make occasional park visits, distance is not their primary concern, and they are more inclined to be drawn to larger parks. For individuals who seldom or never visit parks, their personal attitudes and preferences exert the most significant influence on park usage.
(4) Holidays significantly impact the utilization of urban park green spaces in several ways: there's a higher number of visitors on holidays and weekends compared to working days, with these visitors traveling greater distances and opting for larger park green spaces. Residents predominantly visit park green spaces in the afternoon and evening, and weather fluctuations also wield a substantial influence on park green space utilization.
(5) There is no compensation effect observed between the frequency and duration of park green space use. In contrast, individuals who visit park green spaces more frequently tend to have longer average visit durations, while those who visit less frequently have shorter average visit durations.

Our findings offer empirical evidence to establish service scope and accessibility distance thresholds for park green spaces in medium-sized cities. They also shed light on the impact of factors such as home-park distance, park green space area, holidays, time periods, and weather on park green space utilization. These insights are highly valuable for urban park green space planning, management, and the promotion of park green space usage.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Shuna Xu: Writing – review & editing, Writing – original draft, Visualization, Methodology, Funding acquisition, Conceptualization. **Shengyuan Yuan:** Writing – original draft, Formal analysis, Data curation. **Jingzhong Li:** Methodology, Investigation, Formal analysis. **Xin Gao:** Software, Formal analysis. **Jinhua Hu:** Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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References

[1] C. Knudsen, E. Moreno, B. Arimah, R.O. Otieno, O. Ogunsanya, World Cities Report 2020: the Value of Sustainable Urbanization, United Nations, United Nations Human Settlements Programme, 2020.
[2] R.T.T. Forman, in: W. Jianguo, L. Zhifeng, H. Ganlin, H. Lu, H. Qingxu, L. Yinghui, S. Weijun, Y. Jian, Z. Yuanyuan, Z. Weiqi, Z. Weixing (Eds.), Urban Ecology: Science of Cities, Higher Education Press, Beijing, 2017 [in Chinese].
[3] Y. Su, G. Huang, C. Xiuzhi, C. Shuisen, Z. Li, Research progress in the eco-environmental effects of urban green spaces, Acta Ecol. Sin. 31 (23) (2011) 7287–7300 [in Chinese].
[4] E. Coombes, A.P. Jones, M. Hillsdon, The relationship of physical activity and overweight to objectively measured green space accessibility and use, Soc. Sci. Med. 70 (2010) 816–822, https://doi.org/10.1016/j.socscimed.2009.11.020.
[5] C. Li, Z. Du, S. Fan, M.H.E.M. Browning, L.D. Knibbs, M.S. Bloom, T. Zhao, B. Jalaludin, J. Heinrich, X. Liu, J. Li, Y. Zhang, L. Hu, M. Xiang, G. Chen, Q. Wang, C. Han, S. Li, Y. Guo, P. Dadvand, G. Dong, Z. Zhang, B. Yang, Association between long-term green space exposure and mortality in China: a difference-in-differences analysis of national data in 2000, 2010 and 2019, Sci. Total Environ. 887 (2023) 164023, https://doi.org/10.1016/j.scitotenv.2023.164023.
[6] T. Astell-Burt, T. Hartig, I.G.N.E. Putra, R. Walsan, T. Dendup, X. Feng, Green space and loneliness: a systematic review with theoretical and methodological guidance for future research, Sci. Total Environ. 847 (2022) 157521, https://doi.org/10.1016/j.scitotenv.2022.157521.
[7] K. Min, H. Kim, H. Kim, J. Min, Parks and green areas and the risk for depression and suicidal indicators, Int. J. Publ. Health 62 (2017) 647–656, https://doi.org/10.1007/s00038-017-0958-5.
[8] L. Wood, P. Hooper, S. Foster, F. Bull, Public green spaces and positive mental health – investigating the relationship between access, quantity and types of parks and mental wellbeing, Health Place 48 (2017) 63–71, https://doi.org/10.1016/j.healthplace.2017.09.002.
[9] P. Grahn, U.A. Stigsdotter, Landscape planning and stress, Urban For. Urban Green. 2 (2003) 1–18, https://doi.org/10.1078/1618-8667-00019.
[10] E. Silveirinha de Oliveira, P. Aspinall, A. Briggs, et al., How effective is the Forestry Commission Scotland's woodland improvement programme —'Woods In and Around Towns' (WIAT)—at improving psychological well-being in deprived urban communities? A quasi-experimental study, BMJ Open 3 (2013) e003648, https://doi.org/10.1136/bmjopen-2013-003648.
[11] C. Ward Thompson, E. Silveirinha De Oliveira, S. Tilley, A. Elizalde, W. Botha, A. Briggs, S. Cummins, A.H. Leyland, J.J. Roe, P. Aspinall, K. Brookfield, R. Mitchell, Health impacts of environmental and social interventions designed to increase deprived communities' access to urban woodlands: a mixed-methods study, Publ. Health Res. 7 (2019) 1–172, https://doi.org/10.3310/phr07020.

[12] C.W. Thompson, A. Elizalde, S. Cummins, A.H. Leyland, W. Botha, A. Briggs, S. Tilley, E.S. de Oliveira, J. Roe, P. Aspinall, R. Mitchell, Enhancing health through access to nature: how effective are interventions in woodlands in deprived urban communities? A quasi-experimental study in Scotland, UK, Sustainability 11 (2019) 3317, https://doi.org/10.3390/su11123317.

[13] S. Schetke, S. Qureshi, S. Lautenbach, N. Kabisch, What determines the use of urban green spaces in highly urbanized areas? – Examples from two fast growing Asian cities, Urban For. Urban Green. 16 (2016) 150–159, https://doi.org/10.1016/j.ufug.2016.02.009.

[14] M. Mears, P. Brindley, R. Maheswaran, A. Jorgensen, Understanding the socioeconomic equity of publicly accessible greenspace distribution: the example of Sheffield, UK, Geoforum 103 (2019) 126–137, https://doi.org/10.1016/j.geoforum.2019.04.016.

[15] X. Tu, G. Huang, J. Wu, X. Guo, How do travel distance and park size influence urban park visits? Urban For. Urban Green. 52 (2020) 126689 https://doi.org/10.1016/j.ufug.2020.126689.

[16] L. Pinto, C.S.S. Ferreira, P. Pereira, Environmental and socioeconomic factors influencing the use of urban green spaces in Coimbra (Portugal), Sci. Total Environ. 792 (2021) 148293, https://doi.org/10.1016/j.scitotenv.2021.148293.

[17] V. Žlender, C.W. Thompson, Accessibility and use of peri-urban green space for inner-city dwellers: a comparative study, Landsc. Urban Plann. 165 (2017) 193–205, https://doi.org/10.1016/j.landurbplan.2016.06.011.

[18] J. Zhang, P.Y. Tan, Demand for parks and perceived accessibility as key determinants of urban park use behavior, Urban For. Urban Green. 44 (2019) 126420, https://doi.org/10.1016/j.ufug.2019.126420.

[19] J. Schipperijn, O. Ekholm, U.K. Stigsdotter, M. Toftager, P. Bentsen, F. Kamper-Jørgensen, T.B. Randrup, Factors influencing the use of green space: results from a Danish national representative survey, Landsc. Urban Plann. 95 (2010) 130–137, https://doi.org/10.1016/j.landurbplan.2009.12.010.

[20] J. Schipperijn, U.K. Stigsdotter, T.B. Randrup, J. Troelsen, Influences on the use of urban green space – a case study in Odense, Denmark, Urban For. Urban Green. 9 (2010) 25–32, https://doi.org/10.1016/j.ufug.2009.09.002.

[21] P.Y. Tan, R. Samsudin, Effects of spatial scale on assessment of spatial equity of urban park provision, Landsc. Urban Plann. 158 (2017) 139–154, https://doi.org/10.1016/j.landurbplan.2016.11.001.

[22] F. Wei, Greener urbanization? Changing accessibility to parks in China, Landsc. Urban Plann. 157 (2017) 542–552, https://doi.org/10.1016/j.landurbplan.2016.09.004.

[23] M. Schindler, M. Le Texier, G. Caruso, How far do people travel to use urban green space? A comparison of three European cities, Appl. Geogr. 141 (2022) 102673, https://doi.org/10.1016/j.apgeog.2022.102673.

[24] Y. Lin, Y. Zhou, M. Lin, S. Wu, B. Li, Exploring the disparities in park accessibility through mobile phone data: evidence from Fuzhou of China, J. Environ. Manag. 281 (2021) 111849, https://doi.org/10.1016/j.jenvman.2020.111849.

[25] S. Guo, C. Song, T. Pei, Y. Liu, T. Ma, Y. Du, J. Chen, Z. Fan, X. Tang, Y. Peng, Y. Wang, Accessibility to urban parks for elderly residents: perspectives from mobile phone data, Landsc. Urban Plann. 191 (2019) 103642, https://doi.org/10.1016/j.landurbplan.2019.103642.

[26] S. Guo, G. Yang, T. Pei, T. Ma, C. Song, H. Shu, Y. Du, C. Zhou, Analysis of factors affecting urban park service area in Beijing: Perspectives from multi-source geographic data, Landsc. Urban Plann. 181 (2019) 103–117, https://doi.org/10.1016/j.landurbplan.2018.09.016.

[27] M. Hillsdon, J. Panter, C. Foster, A. Jones, The relationship between access and quality of urban green space with population physical activity, Publ. Health 120 (2006) 1127–1132, https://doi.org/10.1016/j.puhe.2006.10.007.

[28] Y. Chen, X. Liu, W. Gao, R.Y. Wang, Y. Li, W. Tu, Emerging social media data on measuring urban park use, Urban For. Urban Green. 31 (2018) 130–141, https://doi.org/10.1016/j.ufug.2018.02.005.

[29] H. Liu, F. Li, L. Xu, B. Han, The impact of socio-demographic, environmental, and individual factors on urban park visitation in Beijing, China, J. Clean. Prod. 163 (2015) S181–S188, https://doi.org/10.1016/j.jclepro.2015.09.012.

[30] M. Schindler, M. Le Texier, G. Caruso, Spatial sorting, attitudes and the use of green space in Brussels, Urban For. Urban Green. 31 (2018) 169–184, https://doi.org/10.1016/j.ufug.2018.02.009.

[31] C. Wan, G.Q. Shen, Encouraging the use of urban green space: the mediating role of attitude, perceived usefulness and perceived behavioural control, Habitat Int. 50 (2015) 130–139, https://doi.org/10.1016/j.habitatint.2015.08.010.

[32] R.F. Hunter, C. Cleland, A. Cleary, M. Droomers, B.W. Wheeler, D. Sinnett, M.J. Nieuwenhuijsen, M. Braubach, Environmental, health, wellbeing, social and equity effects of urban green space interventions: a meta-narrative evidence synthesis, Environ. Int. 130 (2019) 104923, https://doi.org/10.1016/j.envint.2019.104923.

[33] W. Liu, W. Chen, C. Dong, Spatial decay of recreational services of urban parks: characteristics and influencing factors, Urban For. Urban Green. 25 (2017) 130–138, https://doi.org/10.1016/j.ufug.2017.05.004.

[34] G. Zabelskyte, N. Kabisch, Z. Stasiskiene, Patterns of urban green space use applying social media data: a systematic literature review, Land 11 (2022) 238, https://doi.org/10.3390/land11020238.

[35] V. Heikinheimo, H. Tenkanen, C. Bergroth, O. Järv, T. Hiippala, T. Toivonen, Understanding the use of urban green spaces from user-generated geographic information, Landsc. Urban Plann. 201 (2020) 103845, https://doi.org/10.1016/j.landurbplan.2020.103845.

[36] H.E. Wright Wendel, R.K. Zarger, J.R. Mihelcic, Accessibility and usability: green space preferences, perceptions, and barriers in a rapidly urbanizing city in Latin America, Landsc. Urban Plann. 107 (2012) 272–282, https://doi.org/10.1016/j.landurbplan.2012.06.003.

[37] K. Maat, P. de Vries, The influence of the residential environment on green-space travel: testing the compensation hypothesis, Environ. Plann. 38 (2006) 2111–2127, https://doi.org/10.1068/a37448.

[38] C. Holz-Rau, J. Scheiner, K. Sicks, Travel distances in daily travel and long-distance travel: what role is played by urban form? Environ. Plann.: Econ. Space 46 (2014) 488–507, https://doi.org/10.1068/a46.

[39] A. Strandell, C.M. Hall, Impact of the residential environment on second home use in Finland – testing the compensation hypothesis, Landsc. Urban Plann. 133 (2015) 12–23, https://doi.org/10.1016/j.landurbplan.2014.09.011.

[40] L. Lategan, J. Cilliers, Considering urban green space and informal backyard rentals in South Africa: disproving the compensation hypothesis, Town and Regional Planning 69 (2016).

[41] P. Næss, Are short daily trips compensated by higher leisure mobility? Environ. Plann. Plann. Des. 33 (2006) 197–220, https://doi.org/10.1068/b31151.

[42] M. Czepkiewicz, J. Heinonen, J. Ottelin, Why do urbanites travel more than do others? A review of associations between urban form and long-distance leisure travel, Environ. Res. Lett. 13 (2018) 73001, https://doi.org/10.1088/1748-9326/aac9d2.

[43] M. Czepkiewicz, V. Klaas, J. Heinonen, Compensation or cosmopolitan attitudes: explaining leisure travel of Nordic urbanites, Travel, behaviour & society 21 (2020) 167–187, https://doi.org/10.1016/j.tbs.2020.06.002.

[44] J. Raudsepp, Á. Árnadóttir, M. Czepkiewicz, J. Heinonen, Long-distance travel and the urban environment: results from a qualitative study in reykjavik, Urban planning 6 (2021) 257–270, https://doi.org/10.17645/up.v6i2.3989.

[45] V. Heikinheimo, E.D. Minin, H. Tenkanen, A. Hausmann, J. Erkkonen, T. Toivonen, User-Generated geographic information for visitor monitoring in a national park: a comparison of social media data and visitor survey, ISPRS Int. J. Geo-Inf. 6 (2017) 85, https://doi.org/10.3390/ijgi6030085.

[46] X.P. Song, D.R. Richards, P. He, P.Y. Tan, Does geo-located social media reflect the visit frequency of urban parks? A city-wide analysis using the count and content of photographs, Landsc. Urban Plann. 203 (2020) 103908, https://doi.org/10.1016/j.landurbplan.2020.103908.

[47] Z.A. Hamstead, D. Fisher, R.T. Ilieva, S.A. Wood, T. McPhearson, P. Kremer, Geolocated social media as a rapid indicator of park visitation and equitable park access, Comput. Environ. Urban Syst. 72 (2018) 38–50, https://doi.org/10.1016/j.compenvurbsys.2018.01.007.

[48] S. Zhang, W. Zhou, Recreational visits to urban parks and factors affecting park visits: evidence from geotagged social media data, Landsc. Urban Plann. 180 (2018) 27–35, https://doi.org/10.1016/j.landurbplan.2018.08.004.

[49] H. Ullah, W. Wan, S.A. Haidery, N.U. Khan, Z. Ebrahimpour, A.A.M. Muzahid, Spatiotemporal patterns of visitors in urban green parks by mining social media big data based upon WHO reports, IEEE Access 8 (2020) 39197–39211, https://doi.org/10.1109/ACCESS.2020.2973177.

[50] H. Liang, Q. Zhang, Temporal and spatial assessment of urban park visits from multiple social media data sets: a case study of Shanghai, China, J. Clean. Prod. 297 (2021) 126682, https://doi.org/10.1016/j.jclepro.2021.126682.

[51] Y. Xiao, D. Wang, J. Fang, Exploring the disparities in park access through mobile phone data: evidence from Shanghai, China, Landsc. Urban Plann. 181 (2019) 80–91, https://doi.org/10.1016/j.landurbplan.2018.09.013.
[52] C. Guan, J. Song, M. Keith, Y. Akiyama, R. Shibasaki, T. Sato, Delineating urban park catchment areas using mobile phone data: a case study of Tokyo, Comput. Environ. Urban Syst. 81 (2020) 101422–101474, https://doi.org/10.1016/j.compenvurbsys.2020.101474.
[53] C. Guan, J. Song, M. Keith, B. Zhang, Y. Akiyama, L. Da, R. Shibasaki, T. Sato, Seasonal variations of park visitor volume and park service area in Tokyo: A mixed-method approach combining big data and field observations, Urban For. Urban Green. 58 (2021) 126973, https://doi.org/10.1016/j.ufug.2020.126973.
[54] Y. Zhai, H. Wu, H. Fan, D. Wang, Using mobile signaling data to exam urban park service radius in Shanghai: methods and limitations, Comput. Environ. Urban Syst. 71 (2018) 27–40, https://doi.org/10.1016/j.compenvurbsys.2018.03.011.
[55] O.O.T.L. Census, TABULATION ON 2020 CHINA POPULATION CENSUS BY COUNTY, China Statistics Press, Beijing, 2022.
[56] S. Xu, Y. Wang, Influence of spatial scale on the study of access fairness of urban park green space, Front. Environ. Sci. 10 (2023), https://doi.org/10.3389/fenvs.2022.1030796.
[57] S.C. China, Notice on Adjusting the Standards for Urban Scale Division, 2014 [2014] No. 51.
[58] Y. Tian, H. Wu, G. Zhang, L. Wang, D. Zheng, S. Li, Perceptions of ecosystem services, disservices and willingness-to-pay for urban green space conservation, J. Environ. Manag. 260 (2020) 110140, https://doi.org/10.1016/j.jenvman.2020.110140.
[59] R.R. Camargo, The Effects of Urban Green Spaces on Houseprices, Technische Universität Berlin, 2016.
[60] H. ÖzgüNER, Cultural differences in attitudes towards urban parks and green spaces, Landsc. Res. 36 (2011) 599–620, https://doi.org/10.1080/01426397.2011.560474.
[61] L. Nesbitt, M.J. Meitner, C. Girling, S.R.J. Sheppard, Y. Lu, Who has access to urban vegetation? A spatial analysis of distributional green equity in 10 US cities, Landsc. Urban Plann. 181 (2019) 51–79, https://doi.org/10.1016/j.landurbplan.2018.08.007.
[62] H. You, Characterizing the inequalities in urban public green space provision in Shenzhen, China, Habitat Int. 56 (2016) 176–180, https://doi.org/10.1016/j.habitatint.2016.05.006.
[63] Y. Shen, F. Sun, Y. Che, Public green spaces and human wellbeing: mapping the spatial inequity and mismatching status of public green space in the Central City of Shanghai, Urban For. Urban Green. 27 (2017) 59–68, https://doi.org/10.1016/j.ufug.2017.06.018.
[64] H. Wüstemann, D. Kalisch, J. Kolbe, Access to urban green space and environmental inequalities in Germany, Landsc. Urban Plann. 164 (2017) 124–131, https://doi.org/10.1016/j.landurbplan.2017.04.002.
[65] Urban Management Bureau of Xuchang City. 2021. Xuchang's 8,200 "Little Green" Cars are both popular and successful. – Accessed January 5, 2024. http://cgj.xuchang.gov.cn/csgl/001004/20230109/80b65479-004a-4997-8cda-cc04bf933ed0.html.
[66] R.F. Hunter, H. Christian, J. Veitch, T. Astell-Burt, J.A. Hipp, J. Schipperijn, The impact of interventions to promote physical activity in urban green space: a systematic review and recommendations for future research, Soc. Sci. Med. 124 (2015) 246–256, https://doi.org/10.1016/j.socscimed.2014.11.051.
[67] I. Muñiz, D. Calatayud, R. Dobaño, The compensation hypothesis in Barcelona measured through the ecological footprint of mobility and housing, Landsc. Urban Plann. 113 (2013) 113–119, https://doi.org/10.1016/j.landurbplan.2013.02.004.