Characterization of Recreational Activities and Assessment of Service Range for Urban Comprehensive Parks: A Case Study from the Perspective of Mobile Signaling Data

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Abstract. In the current trend of shifting from qualitative to quantitative research on the benefits of park green spaces, employing spatiotemporal big data analysis techniques such as mobile signaling data to investigate the interaction patterns between visitors and parks holds significant importance for gaining insights into the actual usage of parks, enhancing park service capabilities, and optimizing the allocation of park green spaces. This study investigates the variations in recreational services offered by the comprehensive parks in the city centre of Hefei from two distinct vantage points: the time at which residents arrive at the park and the length of time they spend engaging in recreational activities within the park. These dimensions are analysed in the study using mobile phone signalling data collected on both workdays and leisure days. The spatial distribution characteristics of the accessibility of the comprehensive park are then determined based on the recreational characteristics of inhabitants, and the park's zone of sphere of influence is delimited to demonstrate the rationality of the comprehensive park's spatial architecture. The research findings can be summarised as follows: (1)The temporal span of recreational activities in comprehensive parks within the central metropolitan area exhibits a pattern characterised by higher durations in the western region and lower durations in the eastern region. During days when individuals are not engaged in work-related activities, the duration of recreational activities tends to be greater compared to days when individuals are occupied with work. However, it is worth noting that Xishan Park exhibits a unique pattern, since it experiences higher popularity on weekdays rather than on non-working days. (2)Urban comprehensive parks see a greater utilisation rate during non-working days, with a notable concentration of recreational activity occurring after 12 PM, particularly between 3 PM and 6 PM. During weekdays, there is a significant variation in recreational intensity, with the highest level observed between 6 PM and 9 PM. (3)The equitable distribution of comprehensive parks' accessibility in Hefei's central urban area is seen across various time thresholds and modes of transportation. Nevertheless, the level of walking accessibilityis very limited. Expanding the search radius has the potential to enhance the level of accessibility to parks. (4)The spatial extent of the impact of compre-

G. Zhao et al. (eds.), *Proceedings of the 2023 5th International Conference on Civil Architecture and Urban Engineering (ICCAUE 2023)*, Atlantis Highlights in Engineering 25,
https://doi.org/10.2991/978-94-6463-372-6_15

hensive parks within the central urban area is dispersed over the periphery, without distinct enclaves. Certain locations have a more pronounced dearth of complete parks on weekdays. The comprehensive assessment method proposed in this study, based on mobile signaling data, for evaluating park recreational activities and service coverage, contributes to the optimization and enhancement of effective measures and recommendations for urban park green space management systems. Furthermore, future research will integrate behavioral survey data of park visitors to further investigate the quality of park recreational services and explore the differences in recreational characteristics among different age groups.

Keywords: Green spaces; Comprehensive parks; Service range; Accessibility; Mobile phone signalling data

1 Introduction

Urban parks have a significant impact on enhancing the overall health status [1] and enhancing the quality of life of individuals residing in urban areas [2]. The equitable and efficient provision of park services to urban people is contingent upon the reasonable allocation of green spaces within urban parks [3]. In contrast to other parks, comprehensive parks exhibit bigger spatial extents and boast a more extensive array of recreational and service amenities. The provision of diverse recreational and leisure opportunities can effectively address the recreational and leisure requirements of inhabitants, hence playing a crucial role in enhancing the overall well-being of individuals [4].

In the past few decades, there has been a significant advancement in China's economy and society, resulting in notable enhancements in urban transportation and the overall quality of urban public spaces. Consequently, these developments have had a profound impact on the modes of travel and recreational activities of urban dwellers. The relationship between individuals residing in metropolitan areas and the presence of parks within these environments has experienced notable transformations [5]. Assessing park services within the context of conventional green space planning, utilising metrics such as per capita green space area, green space ratio, and greening rate, presents challenges in accurately capturing the true quality of park services and the soundness of their arrangement [6]. Hence, the examination of the temporal and spatial dynamics between inhabitants and urban parks, as well as the assessment of the true operational capability of urban parks, assume a significant role in informing the design and arrangement of park green spaces.

The existing research pertaining to the recreational behaviour of park residents and the characteristics of park services can be classified into two distinct categories. The first category employs the principle of accessibility. The analysis of park accessibility and the examination of fairness characteristics in park service distribution are conducted using several methods, including statistical indicators [7], the gravity model [8, 9], and cost-weighted distance [10]. These methods utilise data on park acreage and urban population distribution to quantitatively assess park accessibility and show patterns of fairness in the distribution of park services [11], but they neglect to account for the genuine recreational requirements of residents and the appeal ofhigh-quality parks.

Consequently, they are unable to accurately depict the true extent of services provided and the logical arrangement of green spaces inside parks.

The second category pertains to the utilisation of conventional questionnaire surveys for the purpose of examining the capacity and scope of park services, with a focus on residents' recreational behaviour [12-14]. These methodologies are mainly dependent on survey data acquired through interviews conducted with individuals visiting the park. The acquisition of a substantial quantity of data is hindered by the complexities associated with data collecting, hence posing a challenge. Furthermore, ensuring the accuracy of such data proves to be a formidable task, thereby impeding the ability to accurately depict the true nature of the interaction between inhabitants and parks [15]. The advent of big data has the potential to address the constraints associated with conventional data and offers several benefits, including a substantial sample size, extensive coverage, and robust objectivity [16]. The use of big data has been extensively observed in many domains, such as urban residential and employment dynamics [17], commuting patterns [18], urban spatial configuration [19], and accessibility of public amenities [20]. Simultaneously, it also presents novel prospects for examining the correlation between the recreational behaviour of inhabitants and the amenities offered by parks.

Conventional research on park service provision, which relies on analysing the spatial distribution of residential populations and park green spaces, and employs terms such as accessibility, can provide a partial assessment of the rationality of park green space. Nevertheless, these studies fail to take into account the aesthetic appeal of parks, resulting in a situation where there is a high level of accessibility theoretically but a relatively low number of actual visitors in some park areas in reality. This is due to the omission of the park's intrinsic quality in the assessment.

This study utilised mobile signalling data to examine comprehensive parks located in the central urban area of Hefei. This study examines the recreational service characteristics of comprehensive parks through an analysis of inhabitants' real recreational travel behaviour, including visitor time and duration. Following an analysis of the recreational service attributes of the parks, and employing the principles of accessibility and catchment area, we have determined the extent of service coverage provided by comprehensive parks. The findings acquired have the potential to offer valuable insights for the future enhancement of park green space arrangement in the central urban area.

2 Data and methods

2.1 Research area

Hefei is situated in the eastern part of China and serves as a sub-center city within the metropolitan agglomeration of the Yangtze River Delta. Additionally, it holds the status of being a comprehensive national scientific centre. According to the National Bureau of Statistics of China (2020), the region under consideration encompasses a land area measuring 11,445 square kilometres and is inhabited by a population of around 9.36 million individuals. The primary emphasis of this study is the centre urban region, as delineated by the "Master Plan for Hefei City (2011-2020)". The central urban area of

the region spans from the northern administrative boundary of Changfeng County to the southern shores of Chaohu Lake. It extends from the western administrative boundary of Feixi County and Nangang Town to the eastern administrative boundaries of Dawei Town, Feihe Town, and Daxing Town. The geographical extent of the region is around 486 square kilometres and comprises four distinct administrative districts, namely Shushan District, Yaohai District, Luyang District, and Baohe District (Figure 1).

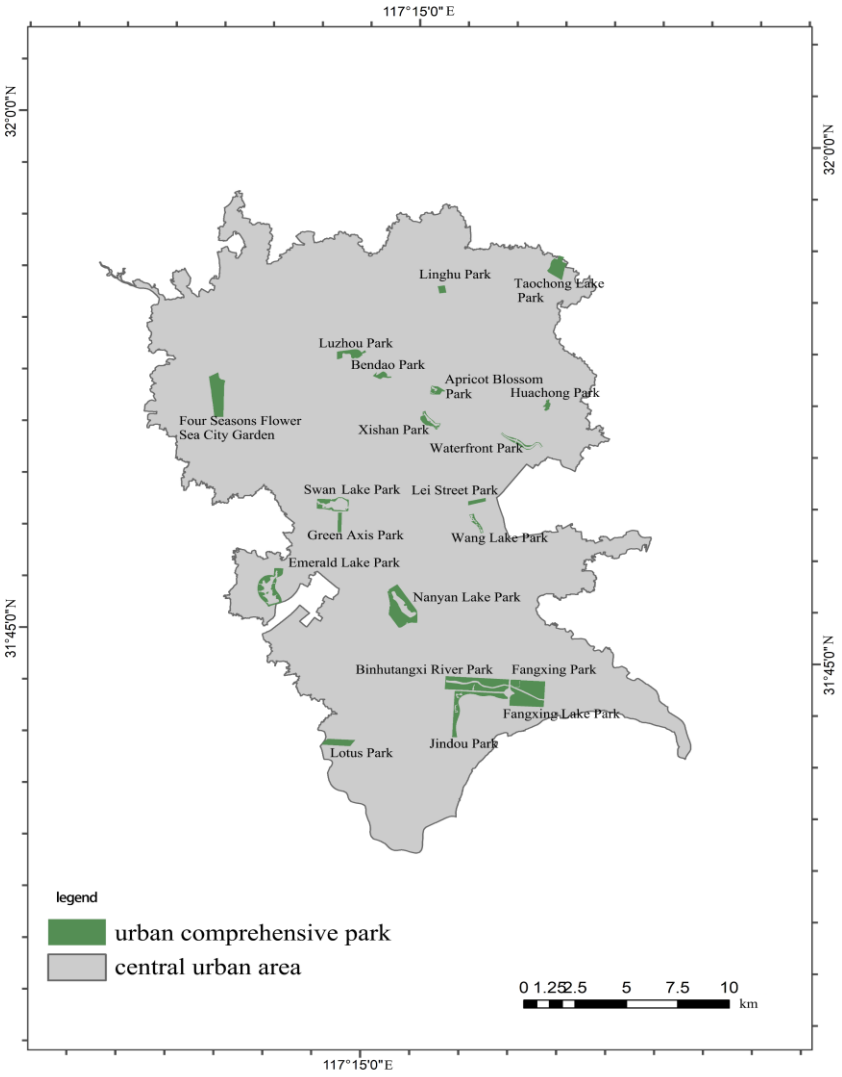

Fig. 1. The scope of Hefei's central urban area and the location of urban comprehensive parks.

2.2 Data Sources and Preprocessing

2.2.1. Data on Park Green Spaces.

The park and green space statistics were collected from Amap, with reference to authoritative sources such as the "Hefei Green Space System Planning (2007-2020)" and the "Master Plan for Hefei City (2013-2020)". The verification process of the spatial placements, areas, and quantities of significant parks and green spaces involved the utilisation of both maps and field surveys. Excluded from consideration were parks and green spaces that were inaccessible, either due to ongoing construction, or as a result of demolition or removal. A comprehensive inventory revealed the presence of 50 distinct parks inside the central urban area, each exhibiting unique characteristics and attributes. The application of the definition supplied in the "Classification Criteria for Urban Green Spaces" (CJJ/T85-2017) was utilised in order to make additional selections for urban comprehensive parks. The selection process involved choosing parks that were situated within urban construction areas and had an area exceeding 10 hectares. However, parks having specific designations such as botanical gardens, heritage parks, and historic gardens were excluded from consideration. In this study, a total of 20 comprehensive parks were chosen as the primary subjects of investigation (Figure 1).

2.2.2. Data on population and park recreation behaviour.

In recent years, there has been a growing trend in utilising big data, namely mobile signalling data, for population information identification. This is primarily attributed to the notable advantages it offers in terms of timeliness and accuracy, as supported by previous studies [21] [22]. The present study utilised anonymized mobile signalling data from China Unicom consumers residing in Hefei city throughout the month of May 2021. The data was obtained from Unicom's Smartsteps DaaS platform. When mobile phone users establish a connection with Unicom base stations, the base stations perform user localization and log their interaction details. These details encompass the area identifier, duration of interaction, base station identification number, and the type of event (such as call answering, text message reception or transmission, or location updates). Within the centre urban region of Hefei, there exists an estimated total of 13,000 base stations, which are predominantly distributed at an average interval of around 250 metres. A subset of base stations situated in the periphery of the centre urban region exhibit a spacing of either 500 metres or 1000 metres. In general, the utilisation of base stations for user positioning yields significantly higher levels of data accuracy compared to street-level or district-level statistics data.

This study exclusively examines the park recreation behaviour of China Unicom mobile users, with a primary emphasis on data accuracy. The park recreation behaviour of users in the central urban region, referred to as "users" henceforth, was identified based on the acquired mobile signalling data. The sequential procedures are outlined as follows:

(1) The individuals classified as permanent residents of Hefei city are those who have remained inside the same base station site in Hefei city for a duration exceeding 10 days throughout the month of May 2021. The calculation involves determining the

length of time individuals spend at each base station site from 21:00 to 8:00 the following day. The user's residence location in Hefei city is determined by identifying the base station site with the longest duration. Individuals residing in the centre urban area of Hefei are identified as central urban area users.

(2) The calculation involves determining the duration of users' stays at each base station site within the central urban region, specifically between the hours of 8:00 and 21:00. The designation of the user's employment location is assigned to the geographical point with the greatest temporal extent, omitting the home location.

(3) The comprehensive park grids refer to the base station units situated in major metropolitan area parks, which are utilised for identifying users' recreation information. The dataset comprises information pertaining to individuals who occupied the base station units for a minimum duration of 30 minutes. This information includes their time of arrival, time of departure, and the total duration of their stay. The exclusion of records pertaining to residential or employment stays leads to the recreation information of users in the centre urban region.

2.2.3. Data on traffic distance.

The GaoDe API is employed to access the routing 2.0 interface, which facilitates the retrieval of travel routes connecting residential areas and comprehensive parks. This methodology has the capability to generate the most efficient travel routes by taking into account current traffic circumstances. The primary purpose of the coordinate conversion interface is to facilitate the conversion of GPS coordinates pertaining to residential sites and comprehensive parks into GaoDe coordinates. Subsequently, the routing interface is employed to initiate routing requests for electric vehicles and motor vehicles, utilising the coordinates of the origin and destination places as input parameters. Python is utilised for the purpose of retrieving distance data pertaining to various kinds of transportation. This data specifically indicates the factual distance between individual residential locations and extensive parks.

2.3 Methods

2.3.1. Cumulative opportunity approach.

Prior studies have demonstrated that a regular hexagon exhibits equidistant properties between its vertices and the centroid in six distinct orientations. The inclusion of this feature mitigates the potential bias in the sample produced by the boundary effects of grid shapes, hence enhancing its suitability for spatial analysis [25, 26]. Consequently, for the purposes of this study, regular hexagonal grids with a side length of 500m were selected. The grids were constructed using ArcGIS 10.2 software in order to conduct an analysis on the level of accessibility of comprehensive parks inside the core metropolitan region. A cumulative sum of 827 grid units was acquired.

The cumulative opportunity approach is employed to ascertain the quantity of public service facilities that are located within a specified distance or time threshold from a given demand point. The primary benefit of this approach is in its consideration of the

variations in the service radius of public service facilities [23]. This study used the cumulative opportunity technique to assess the accessibility of comprehensive parks inside the core metropolitan region. Given the varying effects that different modes of transportation have on accessibility outcomes, the service radius of comprehensive parks has been established to encompass journey durations of 15 minutes and 30 minutes for walking, electric vehicles and motor vehicles. This facilitates a comparative examination of the extent to which parks are accessible within various service radii.

The equation used to compute cumulative opportunity accessibility is as follows:

$$A_i = \sum_j O_j f(C_{ij}) \tag{1}$$

The variable A_i denotes the aggregate measure of opportunity accessibility for a given grid unit i in the equation. The variable O_j represents the amount of comprehensive parks j. Meanwhile, the function $f(C_{ij})$ is a binary variable that is equal to 1 if the time cost C_{ij} from grid unit i to comprehensive park j is less than or equal to the predetermined threshold value, and 0 otherwise.

2.3.2. Identification of sphere of influence.

In order to delineate the service areas of several parks inside the core city, it is necessary to consider the residential locations of the population. Consequently, there may be instances where the service areas of many parks overlap. The present study investigates the service radiation features of several parks by employing the notion of catchment area [19]. The catchment area of a comprehensive park might be defined as the geographic region where the park's appeal and influence are most prominent [24]. The quantification of park visitors inside individual residential spatial units allows for the identification of the park that attracts the highest number of recreational visits, so establishing it as the catchment region for that specific residential space. This methodology facilitates the segmentation of the residential zones inside the core city into distinct catchment areas encompassing a total of 20 comprehensive parks. The methodology for determining the catchment regions of each comprehensive parks involves the following precise steps:

(1) Divide the central city into a hexagonal grid. It has been demonstrated in prior research that a regular hexagon possesses equidistant properties between its vertices and its centroid along six distinct directions. The inclusion of this feature mitigates the potential sample bias that may arise from the boundary effects of grid shapes, hence enhancing its suitability for spatial analysis [25, 26]. Hence, for the purpose of this study, regular hexagonal grids with a side length of 500m were selected. The grids were constructed using ArcGIS 10.2 software in order to encompass the centre city region. The residential base station units located within a regular hexagon were consolidated to the centroid of the grid, establishing a correlation between the numbers assigned to the residential base stations and the numbers assigned to the hexagonal grid.

(2)In order to quantify the number of recreational trips made by residential users within each hexagonal grid unit across many comprehensive parks, it is necessary to conduct a comprehensive analysis. The selection of the designated park for each user journey was determined by utilising the grid numbers associated with the park base

stations. The occurrences of each target park within each hexagonal grid were counted by establishing a correspondence between the target park for each trip and the hexagonal grid. This correspondence was based on the relationship between the user's residential base station number and the hexagonal grid number.

(3)The park that has the greatest number of visits to the target park inside each hexagonal grid unit is designated as the predominant park for that specific hexagonal grid. The sphere of influence for each comprehensive park is determined by aggregating the hexagonal grid units according to their dominant parks. This process yields the appropriate hexagonal grid units for each park.

3 Results

3.1 Characteristics of park recreation services

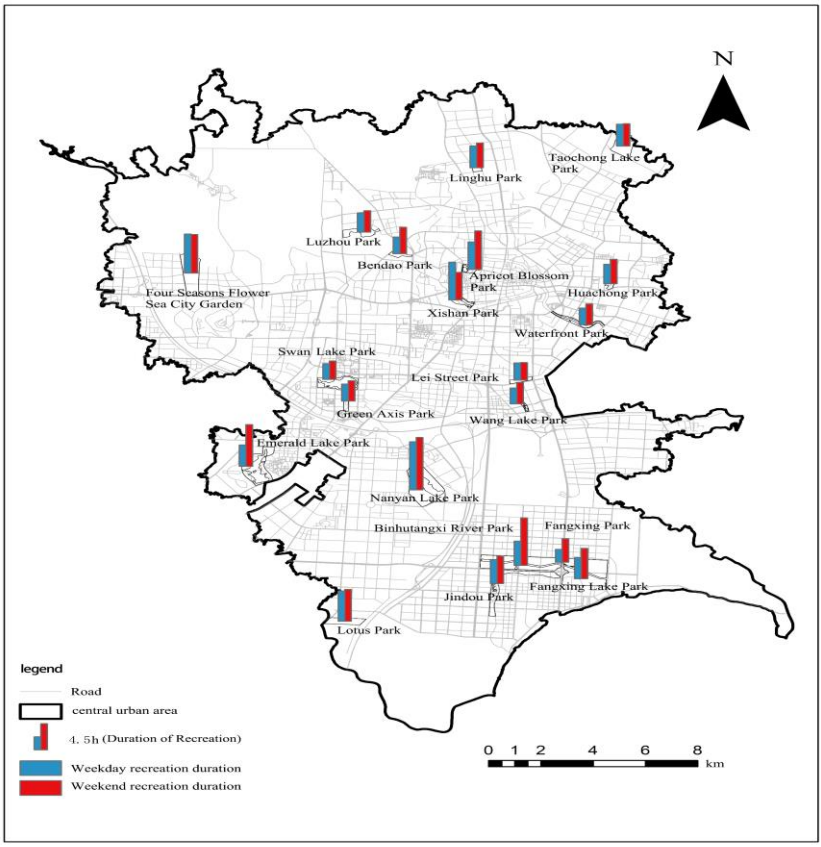

Fig. 2. Distribution of average recreational service hours in parks.

3.1.1. Characteristics of Park Recreation Service Duration.

Figure 2 illustrates that the mean duration of park recreation services in the central urban area constantly exceeds 2 hours. This pattern reveals a spatial distribution characterised by greater values in the western region and lower values in the eastern region. The regions exhibiting elevated mean durations of recreational services are predominantly clustered in the western periphery, encompassing Binhutangxi River Park, Emerald Lake Park, Nanyan Lake Park, and Four Seasons Flower Sea City Garden. On non-working days, the average duration of enjoyment in these parks might extend to 6 hours or more. In contrast, it can be observed that the regions exhibiting lower mean durations are predominantly clustered in the eastern periphery. These locations encompass Taochong Lake Park, Huachong Park, Waterfront Park, Lei Street Park, and Wang Lake Park. The recreational durations of these parks range from 2 to 4.5 hours, regardless of whether it is a working day or a non-working day.

Upon comparing the attributes pertaining to the duration of recreation services in comprehensive parks, a notable observation emerges: a substantial majority (95%) of these parks exhibit considerably longer recreation service durations on non-working days as opposed to working days. Certain parks, like as Binhutangxi River Park and Emerald Lake Park, demonstrate notable disparities in visitor patterns between weekdays and weekends. This phenomenon can be ascribed to various variables, including the limited presence of residential zones in close proximity to these parks and the expansive size of the park areas. It is noteworthy that Xishan Park has a larger mean duration of recreational activities on weekdays in comparison to weekends. Xishan Park, situated in the historical district of Hefei, enjoys the advantages of a denser residential population, a more compact park space, and easily accessible transportation options. As a result, the park is often preferred by people on weekdays when their leisure time is constrained.

3.1.2. Characteristics of Time Granularity in Park Recreation Services.

The arrival times of park residents are categorised into seven distinct time intervals: 0:00-6:00, 6:00-9:00, 9:00-12:00, 12:00-15:00, 15:00-18:00, 18:00-21:00, and 21:00-24:00. There is a notable increase in the frequency of inhabitants' leisure activities during non-working days, as seen across various time intervals, in contrast to working days. This finding suggests that urban comprehensive parks see greater levels of usage during days that are not designated as working days. Furthermore, it is seen that both weekdays and weekends exhibit a distinct "M-shaped" pattern characterised by two troughs and two peaks. Recreational activities exhibit a consistent pattern of diminished engagement across the time intervals of 0-6 and 21-24, with notable variations in the occurrence of high peaks across different time periods (Figure 3 and 4) .

During weekdays, there is a notable variation in the level of park recreational activity at different time intervals. The time interval between 18:00 and 21:00 exhibits the most pronounced surge in park recreational activities, constituting 21.05% of the overall daily recreational visits. This proportion is notably more than that observed during other time intervals. The subsequent biggest peaks are recorded during the time intervals of 15-18, accounting for 19.92% of the total visits, and 6-9, accounting for 16.07% of the

total visits. The time intervals between 0-6 and 21-24 exhibit the least amount of recreational visits, comprising merely 4.54% and 9.38% of the overall daily visits, respectively. This observation suggests a notable disparity when compared to the hours of highest visitation.

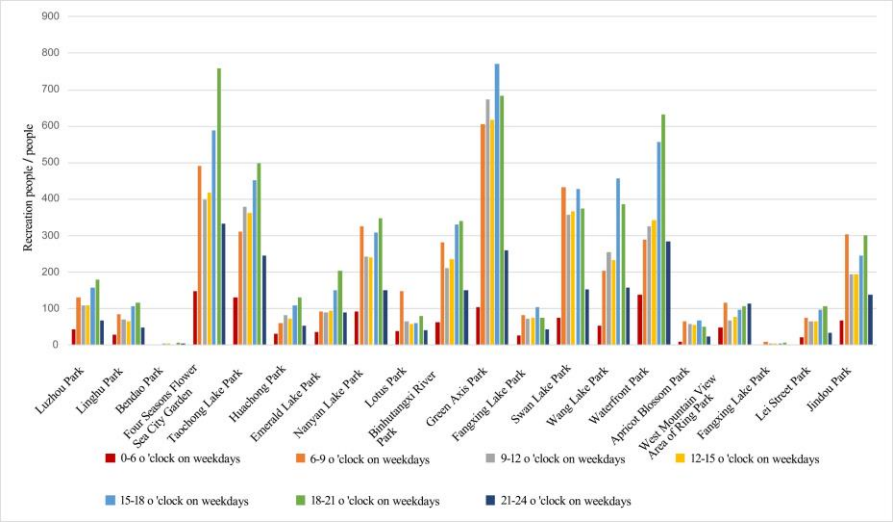

Fig. 3. Park recreation intensity at different time granularities on weekdays.

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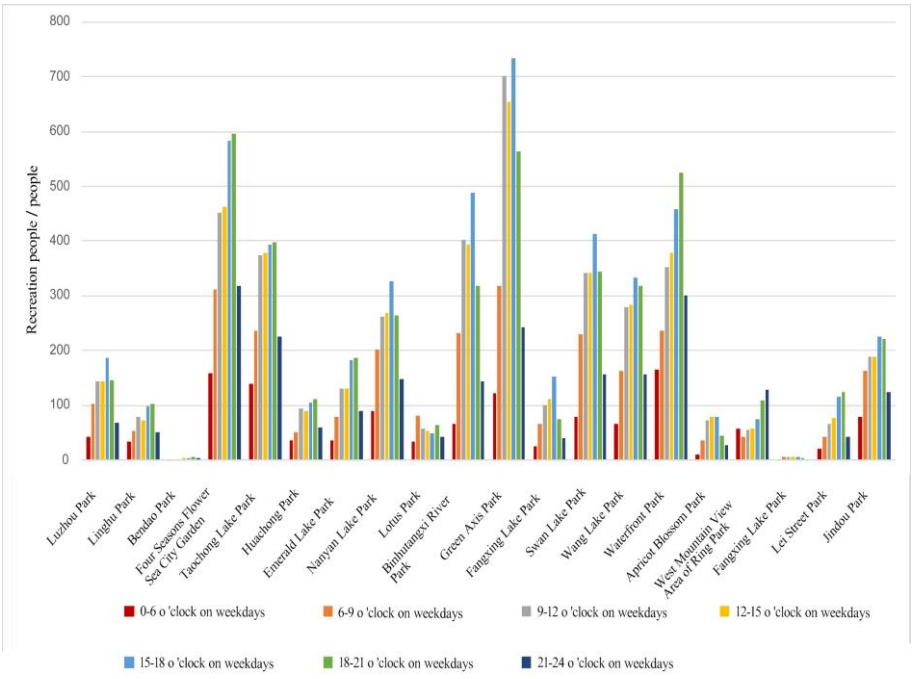

Fig. 4. Park recreation intensity at different time granularities on non-working days.

3.2 Characteristics of Park Service Coverage

3.2.1. Characteristics of Accessibility in Comprehensive Parks.

Figure 5 depicts the levels of accessibility to parks based on varying time thresholds and modes of transportation, respectively. In general, the spatial arrangement of urban comprehensive parks with good accessibility in the core region of Hefei city exhibits a rather consistent pattern when taking into account time thresholds and transportation modes of 15 minutes and 30 minutes for bothbicycling and driving. This suggests that in such circumstances, urban comprehensive parks have the capacity to equitably offer recreational amenities to the neighbouring population. Nevertheless, when considering the walking criterion of 15 minutes and 30 minutes, it is observed that the proportion of places exhibiting great accessibility to urban comprehensive parks is rather small. Specifically, these regions account for about 0.24% and 4.84% of the overall grid count, respectively. The aforementioned areas are predominantly situated in the northern section of the central urban area and the southern central region. Typically, these geographical areas have a greater concentration of parks and a comparatively reduced population, hence yielding elevated levels of accessibility. On the other hand, it can be observed that the ancient city area inside the centre urban region of Hefei exhibits comparatively lower levels of accessibility. This may be attributed to the limited presence of parks, resulting in a deficiency of recreational amenities for the local inhabitants in this particular vicinity.

When examining the accessibility of comprehensive parks over various time thresholds, it becomes evident that as the search distance expands, the percentage of locations with high accessibility rises significantly, ranging from 0.24% to 49.46%. There is a notable rise in the quantity of regions with high accessibility, suggesting a positive correlation between the distance residents travel and the level of accessibility offered by comprehensive parks. Hence, it is worth considering the enhancement of accessibility for comprehensive parks in regions with limited park availability. This can be achieved by extending residents' travel distances through the implementation of measures such as direct park buses or shared electric vehicle services. These initiatives aim to elevate the accessibility level of parks in these specific areas.

Fig. 5. Spatial distribution of accessibility of comprehensive parks.

3.2.2. Characteristics of Sphere of Influence.

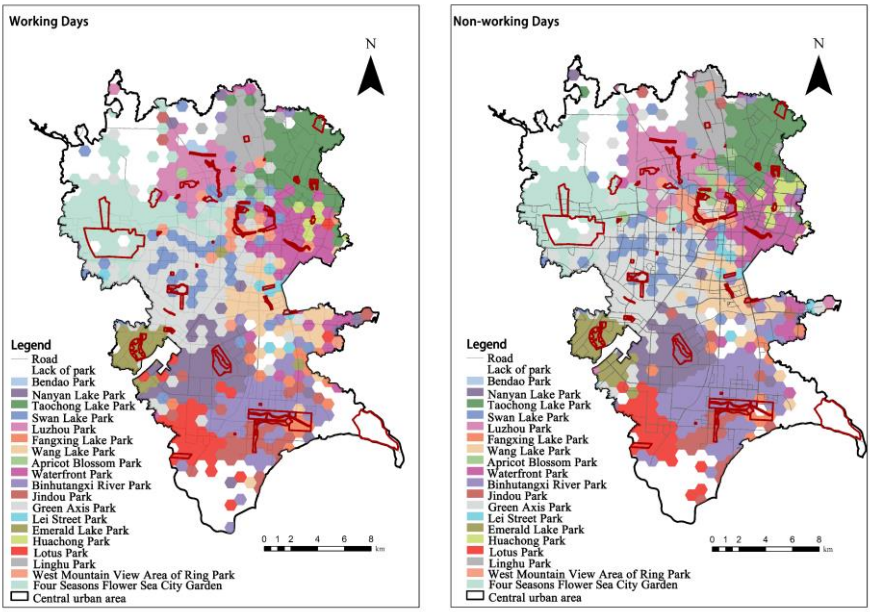

Fig. 6. The sphere of influence of the comprehensive park.

Figure 6 depicts the catchment regions of diverse comprehensive parks inside the core urban area during weekdays and weekends. Several observations can be discerned from the given information.

Irrespective of weekdays or weekends, the comprehensive parks' catchment areas are primarily located near the periphery, exhibiting no notable enclave phenomenon within the neighbouring regions. Enclaves are more prevalent in places that lack complete parks, with a higher frequency observed on working days in comparison to non-working days.

In Shushan District, the catchment areas of Four Seasons Flower Sea City Garden, Green Axis Park, Nanyan Lake Park, and Emerald Lake Park encompass most localities, both on working days and non-working days, without any observable enclave phenomena. Swan Lake Park, Xishan Park, and Bendao Park have relatively limited catchment areas. Swan Lake Park demonstrates a clear instance of an enclave phenomenon, which draws in residents from comparatively distant locations. Within the Luyang District, a significant portion of its geographical regions are encompassed by the catchment areas of Luzhou Park and Linghu Park. Notably, there is a lack of observable enclave phenomena in these locations. Within the Yaohai District, a significant portion of its territory falls within the catchment areas of Waterfront Park and Taochong Lake Park. However, Huachong Park exhibits a comparatively smaller catchment area, constituting merely 0.60% and 1.21% of working days and non-working days, respectively. This disparity can potentially be attributed to the park's limited size and its relatively diminished attractiveness to the surrounding regions. The northern region of Baohe District

falls within the geographical boundaries of Wang Lake Park, and the southern region is encompassed by the catchment regions of Binhutangxi River Park, Jindou Park, and Fangxing Park. In the central region, there is a complex and overlapping distribution of parks due to the lack of comprehensive parks.

The examination of catchment areas indicates that the demarcations surrounding each comprehensive park exhibit a notable level of clarity. However, in regions lacking comprehensive park systems, the catchment areas exhibit a heterogeneous composition. The implementation of new comprehensive parks in these regions constitutes a viable strategy for mitigating the challenges associated with diverse catchment areas and enhancing the urban park system.

4 Conclusion and discussion

4.1 Discussion

The primary focus of the research discussed in this article is the precise assessment of the service capacity of urban parks, taking into consideration their appeal and the recreational interests of individuals. This study focuses primarily on the analysis of comprehensive parks located inside the central urban area of Hefei city. The researchers investigate the characteristics of recreation services in parks by analysing mobile signalling data, which allows them to identify park visitors and examine parameters such as their arrival time and duration of stay. The utilisation of accessibility and catchment area concepts is also employed to unveil the characteristics of service space and distribution patterns of these parks, offering a fresh viewpoint for the study of spatial layout in comprehensive parks.

The study's findings indicate that the accessibility range of urban comprehensive parks, as determined by accessibility measures, extends outward from the park as the central point. When considering catchment regions, it is observed that certain parks, like Swan Lake Park, demonstrate notable instances of enclave phenomenon. Hence, in the development of ancillary amenities such as parking facilities and dining establishments for these parks, it is imperative to take into account the recreational requirements of both local inhabitants in the vicinity and visitors from far locales.

Through a comparative analysis of research findings on service range and catchment area, it becomes evident that locations characterised by inadequate park layouts can be readily identified. The accessibility around Hua Chong Park exhibits favourable characteristics, while its catchment area is limited in scope. This implies that despite the availability of a greater number of park resources for those residing in the surrounding area, their frequency of park visitation is reduced as a result of the park's substandard quality. Therefore, it is vital to implement enhancements or establish novel parks in order to adequately address the recreational requirements of the local populace.

This study examines the attributes of park recreation services and service space through the utilisation of mobile signalling data, which presents several advantages in comparison to conventional survey data: (1) The utilisation of mobile signalling data allows for the discernment of intricate activity patterns exhibited by individuals visiting parks, hence offering a higher degree of precision in comparison to traditional survey

data. (2) The researchers utilise fine-grained population activity data derived from mobile signalling data to assess the accessibility of comprehensive parks. This assessment is conducted by employing various time thresholds and transportation modes. (3) The incorporation of the catchment area concept, taking into account the observed visiting patterns, facilitates a more profound comprehension of the service areas and catchment areas pertaining to the comprehensive parks situated in the core metropolitan region of Hefei.

Nevertheless, it is important to acknowledge the limitations of this study. The comprehensiveness of mobile signalling data is limited, and its ability to accurately identify population activities is subject to certain limits. For example, populations such as the elderly and children have lower smartphone usage frequencies. When analyzing the activity patterns of park visitors, the analysis of such population's activity characteristics is limited due to the low sample size of mobile signaling data. In fact, due to this limitation, this paper only explores the activity characteristics of certain age groups using mobile signaling data. Therefore, in future studies, it would be beneficial to combine mobile signaling data with traditional survey data. This combination would involve incorporating survey results from a significant number of respondents to reflect the usage patterns of a diverse range of park visitors, thus compensating for the lack of specific age group data solely obtained from mobile signaling data.

4.2 Conclusion

This study examines the service coverage of urban comprehensive parks in the central area of Hefei city by utilising mobile signalling data to identify patterns of recreational behaviours. The findings are presented as follows:

(1) The average duration of recreational services offered in the comprehensive parks located inside the central metropolitan area regularly exceeds 2 hours. This observation reveals a discernible spatial trend, with higher average durations observed in the western region and lower average durations observed in the eastern region. The locations located along the western margin have higher average durations, whereas the regions situated along the eastern edge display lower average durations. In addition, it is observed that a majority of the comprehensive parks, specifically 95%, exhibit notably longer durations of recreational services on non-working days in comparison to working days. However, it is worth noting that Xishan Park stands as an exception, as it demonstrates a larger average duration of recreational activities on working days as opposed to non-working days.

(2) The data reveals a notable disparity in the frequency of recreational trips made by inhabitants to urban comprehensive parks on non-working days compared to working days, suggesting a higher level of utilisation on non-working days. The temporal distribution of recreational activities on non-working days exhibits a higher concentration during the post-meridian period, particularly between 3 PM and 6 PM. On the other hand, there is greater variability in recreational intensity during working days, with the most pronounced surge observed between 6 PM and 9 PM.

(3) In the centre area of Hefei city, the geographical distribution of high accessibility zones for urban comprehensive parks remains reasonably similar when considering

time thresholds and transportation modes of 15 minutes for bicycling and driving, as well as 30 minutes forbicycling and driving. Nevertheless, when considering walking thresholds of 15 minutes and 30 minutes, it is observed that the proportion of locations with significant accessibility to urban comprehensive parks is rather small, constituting about 0.24% and 4.84% of the overall grid count, respectively. The aforementioned areas are predominantly situated in the northern section of the central urban area and the southern central region.

(4) Irrespective of weekdays or weekends, the impact radius of each comprehensive park predominantly extends to the adjacent regions, without any discernible enclave phenomenon within these locations. The presence of enclaves is more pronounced in regions that lack comprehensive park facilities, and there is a higher frequency of enclaves on weekdays as opposed to weekends or non-working days.

Acknowledgments

This work was financially supported by the Natural Science Research Project of Anhui Educational Committee (Grant No.2023AH051009 and No. 2023AH051027) and Anhui Province Housing and Urban-Rural Development Scientific and Technological Plan Project(Grant No.2023-YF042 and No. 2023-RK024)

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