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# Understanding the Spatial Distribution and Behavior of Elderly Residents in Age-Friendly Communities: An Analysis of Outdoor Space Features in Hangzhou, China

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**Abstract:** In the context of an aging population and the rise of age-friendly communities, the creation of outdoor spaces that cater to the daily needs of elderly residents, promote their physical and mental well-being, and strengthen their sense of community is a pressing matter requiring immediate attention and solutions. This study focuses on boosting the outdoor space of communities that are age-friendly. The research sample consists of four age-friendly communities in the representative city of Hangzhou. Aerial and ground surveys were carried out to examine the spatial distribution and behavioral tendencies of elderly citizens in outdoor community gathering locations. A GoPro MAX panoramic camera and a weather meter were utilized to evaluate the outside space's landscape components, spatial attributes, and microclimate. Using Pearson correlation and multiple linear regression analyses, we discovered the key parameters impacting the spatial gathering and behaviors of elderly residents in age-friendly communities' outdoor spaces. When constructing outdoor gathering spaces for the elderly, our findings indicate that weatherproof amenities, a greater variety of pavers, and greenery should be prioritized. Community fitness facilities should be considered throughout the development and refurbishment phases for activity areas. Consideration should also be given to the construction of weatherproof facilities with less walls and increased hard surface areas for chess spaces.

**Keywords:** age-friendly community; outdoor space; spatial trajectory; optimization strategy; multiple regression model



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## 1. Introduction

The World Health Organization projects that by 2050, the worldwide population aged 60 and older will account for 22 percent of the overall population, or around 2 billion people ([1]) China, the world's most populated developing nation, is likewise dealing with an aging population. The National Health and Wellbeing Commission of the People's Republic of China projects that by 2035, China's elderly population will exceed 400 million. The Chinese city of Hangzhou aspires to attain complete coverage of aging-friendly communities in both urban and rural areas. The elderly population of Hangzhou is distinguished by its early beginning, high degree of aging, and quick rate of aging. Moreover, the family structure of elderly individuals is diminishing, and aging is occurring unevenly. Although the government has introduced policies and welfare services and increased the corresponding support facilities, there are still significant issues and deficiencies in the living environment of age-friendly communities, especially in the primary urban communities where aging in place is a pressing issue.

The creation of age-friendly communities must be tightly integrated with the demands of the elderly, and it is essential to have an in-depth understanding of the number of elderly and their behaviors in outdoor gathering spaces, which will also aid in the development of age-friendly communities. Outdoor space environment indicators concentrate on the visual evaluation of the landscape environment [2] and on microclimate evaluation [3], which include three aspects: landscape features, spatial characteristics, and microclimate environment. With the use and development of mobile communication technologies, various location technologies (GPS, GSM, RFID, etc.), and storage technologies, the trajectory data of a large number of mobile objects are simultaneously collected and stored. Considering the elderly's low cell phone penetration rate and other holiday travel needs, this is unlikely. This study chose the use of a UAV to investigate the spatial trajectories of elderly-friendly community residents between 7:00 a.m. and 5:00 p.m. on weekdays, as well as the needs of outdoor spaces of elderly people of different genders in elderly-friendly communities, such as whether they need to bring children with them, and their needs for sports facilities, weather facilities, etc. To better promote active aging, the World Health Organization refers to age-friendly communities in many policy documents, defining it as "a community that enhances the quality of life of older persons and encourages age-friendly development through the provision of health care, social participation and safe services" and identifies eight key areas for age-friendly community construction: outdoor space and construction, transportation, housing, social participation, respect and social inclusion, civic engagement and employment, communication and information, community support and health services [4]. This study proposes a design strategy for outdoor space renovation based on the analysis results. The United Nations General Assembly (https://www.who.int/zh/news-room/fact-sheets/detail/ageing-and-health, 2 May 2023) declared 2021–2030 the United Nations Decade of Action on Healthy Ageing and asked the World Health Organization to take the lead in implementation. Relevant studies have shown that the social participation patterns of the elderly can be divided into high participation, low participation, and family care, which is consistent with the characteristics of China's emphasis on family culture. China has a rich culture focused on the elderly; because the parents of children have to work, Chinese elderly with children is the norm. The research results show that it is necessary to improve the elderly service system; establish an age-friendly environment; and improve the internal and external ability of the elderly to participate in society, especially paying attention to the needs of the vulnerable elderly group to participate in society, to truly build a society shared by all, so as to promote and achieve healthy aging and active aging [5]. A trajectory is a spatial function that records changes in the position of moving objects over a certain time interval, whereas a semantic trajectory is a sequence of dwell points and movement points. A dwell point is an important semantic component of a trajectory [6], and a dwell point typically indicates that a user has stayed in a geographic area for a certain amount of time and may have engaged in an activity, and it can be assumed that they are very interested in the area, indicating that the user's behavior in the area is more significant than the user's behavior in other areas. A dwell analysis of geographical trajectory data can describe the behavioral features of inhabitants residing in age-friendly communities. By examining information such as the length of the resident's stay, the location of the stay, and the characteristics of the stay area, for instance, it is possible to identify if the resident is in an active stay state or if they have certain stay habits, etc.

This study investigates the effect of outdoor space elements in aging-friendly communities on the spatial movements of the elderly in Hangzhou as the research site. The purpose of the study is to identify the concerns with outdoor spaces in aging-friendly communities and to give a scientific foundation for the careful renewal and redesign of such communities. The specific research objectives are as follows: (1) examining gender-based differences and activity patterns of elderly residents at outdoor community gathering points; (2) analyzing the effects of landscape elements, spatial characteristics, and the microclimate environment of outdoor spaces on gathering frequency and activity behavior of elderly residents; and (3) evaluating how the gathering frequency of elderly residents of different genders is affected by outdoor space features.

## 2. Literature Review

### 2.1. Outdoor Space

Previous research has proposed design strategies for promoting health-oriented residential open space planning for elderly people by taking into account outdoor environment components of age-friendly communities, the healing environment perspective of outdoor spaces, and elderly age groups in age-friendly communities [7–9]. Nevertheless, not enough empirical field investigations based on quantitative correlations have been undertaken for these studies. For instance, studies on outdoor space activities have been conducted in large-scale urban greenway trajectories and in the internal spatial environments of buildings [10,11], but fewer studies have focused on outdoor space use trajectories in communities, especially in "elderly-friendly communities". Thus, there is a dearth of study on outdoor places ideal for elderly populations. The trajectory of outdoor space utilization in communities and the outdoor spaces in "elderly-friendly communities" require additional research. Previous studies have measured outdoor spaces in terms of their attributes, accessibility, neighborhood environment, and subjective perception of the environment. Outdoor space attributes encompass indicators such as site size, greenness, and landscape amenities. For instance, Ref. [12] found that park size, green coverage, and landscape pattern affect park use efficiency based on the three elements of density, diversity, and design proposed by Cervero and Kock Elman. Empirical studies measure accessibility through different methods such as commuting costs, while surveys of urban residents' perceptions of outdoor space safety and amenities can measure subjective perceptions of outdoor spaces. Research has shown gender differences in green space exposure, with significant gender differences in residents' travel green space exposure and a slight predominance of men in overall green space exposure, as shown by [13]. However, this study did not take into account gender differences in outdoor space for the elderly population.

### 2.2. Spatial Trajectory

The method of acquiring spatial trajectory data using positioning technologies has advantages over the traditional logbook survey data collection method in terms of time efficiency and flexibility, and the collected trajectory data are characterized by a high volume of data, high accuracy rate, and significant spatial features [14]. Ref. [15] used cell phone data to target the tourist population by analyzing the cell phone trajectories of international travelers to three different cities in Korea, introducing nine mobility indicators that provided a comprehensive description of the mobility patterns of individual tourists. These indicators captured travelers' travel behavior from a spatial, temporal, or spatiotemporal perspective, revealing that visitors explored the cities in different ways. Ref. [16] analyzed the spatial patterns and influencing factors of jogging activities in urban parks based on GPS track data recorded by a mobile app, finding that jogging flow in urban parks exhibited obvious spatial clustering characteristics. Although the findings of the regression analysis suggested that park characteristics were more influential than neighborhood surroundings and accessibility, there were some limitations to the study. The jogging track data gathered by the sports app were acquired voluntarily and primarily from sports enthusiasts, which may have resulted in a sampling bias toward the middle-aged and younger age groups and excluded the elderly population [17]. Tian, Z., et al. used a large quantity of multi-occurrence aspect trajectory data to describe outdoor jogging activity patterns and proposed the MAT-LDA model to reveal hidden preference patterns based on six aspects: time of day, days of the week, space, duration, weather, and temperature. Unfortunately, the MAT-LDA model cannot capture themes that fluctuate over time. To comprehend changes in individual behavior, it would be good to examine the evolution of themes over time. Ref. [18] investigated the daily mobility patterns of elderly persons in California using human mobility themes and discovered significant variation in the daily travel patterns of elderly living in urban cores, urban areas, and communities. These distinctions were linked to the geographical and functional similarities in these regions. It was determined that the diverse patterns of daily activity among elderly people indicate a considerable demand for social interaction among this population.

Prior research has employed various approaches, including field observations [19–21], field surveys [22], questionnaires [23,24], and remote sensing [25,26], to assess park attributes and community environments. Nevertheless, these conventional methods are costly and time-consuming, restricting their application to small-scale studies of a limited number of urban parks. Furthermore, no research has been conducted on outdoor spaces in age-friendly communities. Although remote sensing techniques can provide an overview of the environment, the dense building's shadow effect can introduce bias in the actual environmental exposure perceived by urban residents [27], and the data collection might not cater to the elderly population. Recently, some scholars have relied on social media platforms' ratings and comments to gauge users' views of park environments [28]. With newly available open-source data (e.g., social media data and online maps), current studies can overcome the constraints of traditional labor-intensive and time-consuming methods [29,30].

Previous research has overlooked the interconnectedness between the spatial trajectories of the elderly in age-friendly communities and their use of outdoor spaces, particularly the number and behavior of elderly people at gathering points. This gap in knowledge hinders a comprehensive understanding of elderly people's outdoor behavior and spatial trajectories compared with younger adults. However, given that the elderly tend to use cell phones less frequently and with slower iterations, unmanned aerial vehicles (UAVs) can be used to obtain data on all the aggregation points in a neighborhood simultaneously and to quickly gather information within the neighborhood's aggregation points. Therefore, this study has opted to combine UAVs and field research to examine the spatial trajectories of residents in age-friendly communities.

In conclusion, the establishment of communities that are age-friendly is an urgent issue in urban regeneration and restoration. Technological advancements allow for the investigation of the impact of outdoor environments on the geographical trajectories of inhabitants in age-friendly communities. In order to offer a scientific foundation for the optimization and transformation of outdoor spaces in age-friendly communities, it is important to analyze the relationship between outdoor spaces and inhabitants' spatial trajectories utilizing a variety of equipment. The ultimate objective is to provide people with a comfortable and healthy living environment.

## 3. Data and Methodology

### *3.1. Study Area*

The National Health Commission and the National Office on Aging released the list of national exemplary age-friendly communities in 2022, and nine communities in Hangzhou received this award. In this study, 10 gathering points of the four national exemplary age-friendly communities were selected for outdoor spatial real-scene measurement based on spatial trajectories, all of which belong to age-friendly communities (Figure 1), covering communities of different time ages; the first three belong to the renewed community, and the last belongs to the age-friendly community that is relatively new and can be temporarily adapted. According to the completion time, field surveys were carried out successively, and representative age-friendly communities were selected as research samples. The construction age and construction background of these communities were different, and there were also great differences in the quality of the landscape environment, which could provide better research materials for this study (Table 1).

**Table 1.** Basic data of age-friendly communities in Hangzhou.

| Community Name | Build Time | Volume Fraction (%) | Elderly Population (Count) | Percentage of Elderly Population (%) |
|---|---|---|---|---|
| Laofangdi Community | 1989 | 2.8 | 1017 | 17 |
| Xiyuan Community | 1996 | 2.5 | 1244 | 21.6 |
| Fuyuan Community | 2000 | 1.5 | 1041 | 18 |
| Jiahe Community | 2007 | 3 | 1104 | 24 |

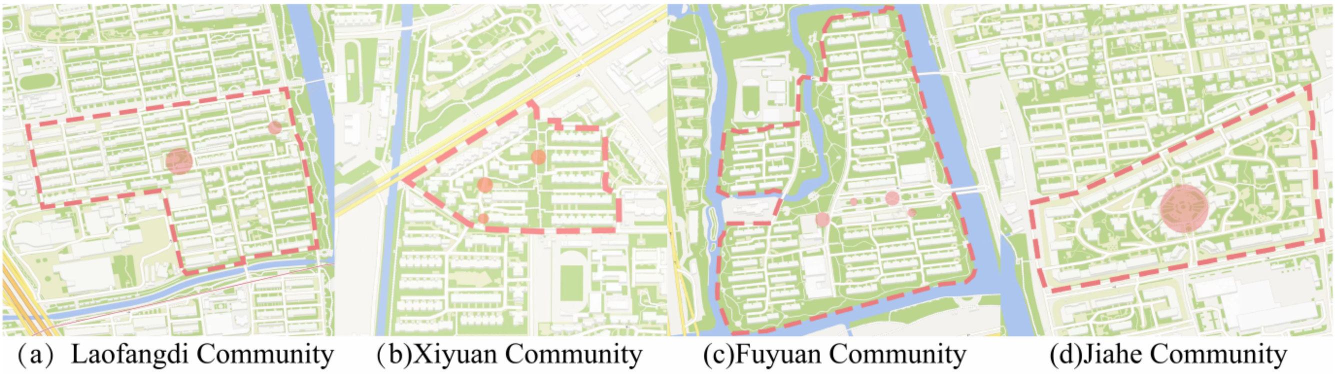



**Figure 1.** Gathering points in aging-friendly community.

*3.2. Data Collection*

Due to Hangzhou's subtropical monsoon environment, with a rainy season from April to June and hot weather from July to September, which has a substantial impact on physiological data collecting, it was decided to conduct the experiment in autumn, when the weather is clear. In the experimental site, outside spatial indicators were measured using a GoPro MAX panoramic camera and a portable weather meter. A UAV and a GoPro MAX were used to observe the quantity and behavior of elderly people of various sexes in the plot at each aggregation point for three days.

Monitoring of Outdoor Spatial Trajectories of Elderly Residents

This study investigated 10 gathering points in four age-friendly communities in Hangzhou and conducted surveys every two hours from 7 a.m. to 5 p.m. on autumn weekdays, and each gathering point was investigated for three days to ensure a sufficient sample size. In the early stages of the experiment, drones were used to obtain the spatial distribution of gathering points for the elderly in the same time period, and then, field research was carried out on the identified gathering points; the activity type and sex ratio of outdoor space gathering points were recorded; and the needs of the elderly in terms of wind and rain facilities, sports facilities, and barrier-free facilities were investigated. Panoramic images were obtained using a GoPro MAX camera and semantically segmented to obtain the influence factor of landscape elements (Figure 2). A correlation analysis and a multiple regression analysis of age-friendly community aggregation points were carried out through these impact factors.

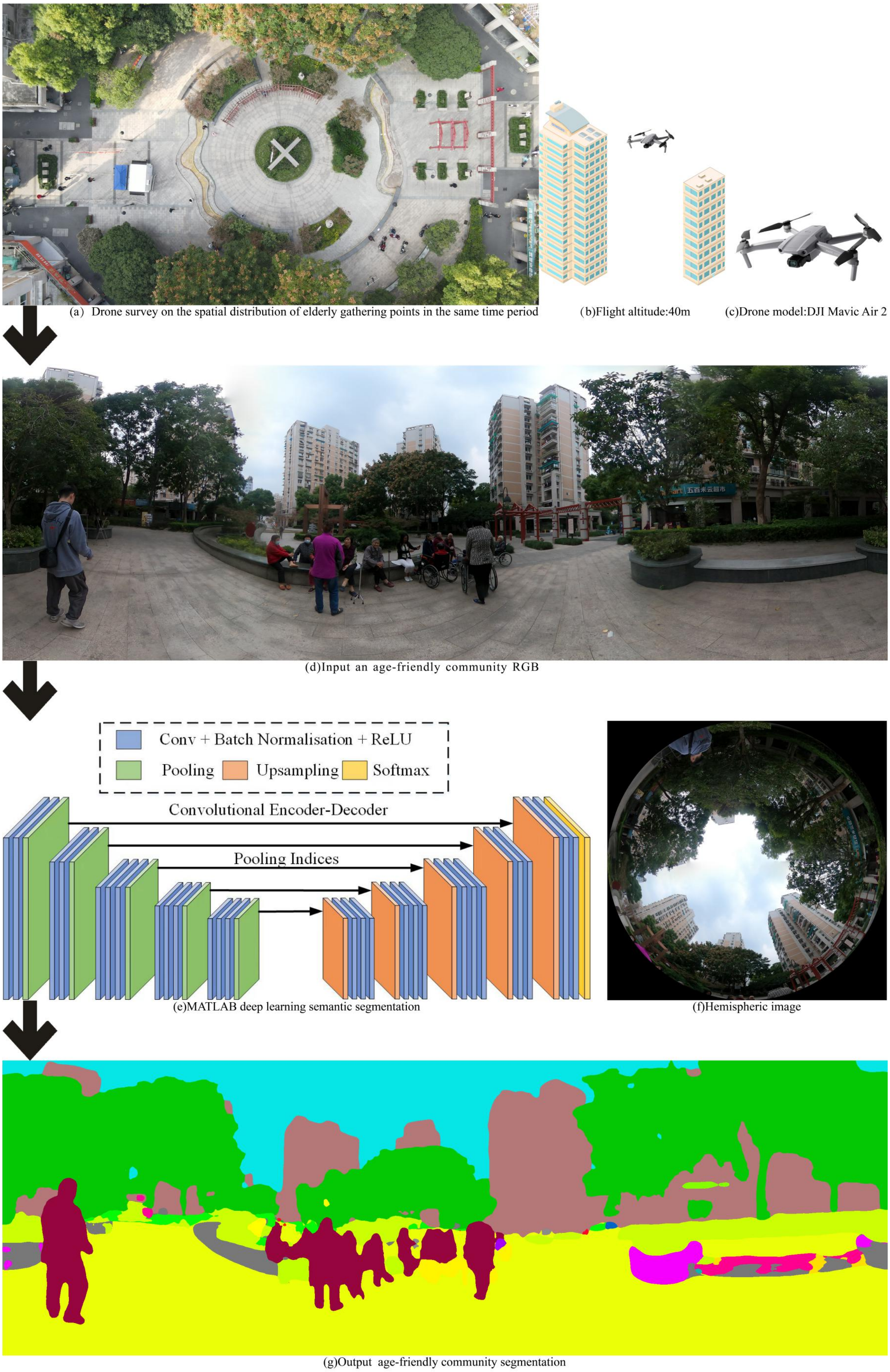



**Figure 2.** Flowchart.

### *3.3. Selection of Influencing Factors*

Outside spatial measurements encompass three components: landscape features, spatial characteristics, and microclimate environment measurement. A GoPro MAX panoramic camera and portable meteorological equipment were chosen for each of these aspects. GoPro MAX panoramic camera photos of the landscape environment at the gathering sites were converted into quantitative indicators of the landscape environment using SEGNET image segmentation to reflect the objective environmental quality. The weather meter recorded the microclimate environmental information of the experience path, including temperature, humidity, and wind speed. The measure is capable of obtaining objective landscape environment data related to the residents' landscape environment collection point. The above data were pre-processed to generate a comprehensive database of the outside spatial distribution and behavior of the elderly-friendly community's spatial trajectory.

### *3.4. Selection of Indicators*

Indexes of landscape environment are quantified and studied from two levels of landscape features and spatial characteristics, based on the recognition and segmentation of panoramic photographs. The environmental element level investigates the effect of the proportion of individual environmental elements, such as buildings, plants, paving, and motor vehicles, on the environmental experience and calculates the $GVI$, paving share, building share, and vehicle share based on image recognition; the spatial characteristic level focuses primarily on $P_{enclosure}$ and $SVF$. The following are the specific index calculation methodologies.

(1) Green vision index ($GVI$): indicating the amount of visible vegetation, research has indicated that "$GVI$" is more closely associated with humans than "green space coverage" and the "normalized vegetation index". It is more ideal for use as a measure of landscape greenery quality in a small local setting [31]. The $GVI$ is determined as the ratio of the number of pixels representing plant elements in a panoramic image to the total number of pixels in the image.

$$GVI = \frac{G_n}{A_n} \times 100\% \tag{1}$$

$G_n$ is the number of plant element pixels in the panoramic image, and $A_n$ is the number of all pixels in the panoramic image. $P_r$ indicates the proportion of pavement share, $P_b$ indicates the proportion of building occupancy, and $P_v$ indicates the proportion of vehicle. The calculation method is similar to that of the green visibility index ($GVI$).

(2) Sky view factor ($SVF$): It is an important index for geometric quantitative analysis to measure the degree of spatial openness, reflecting the degree to which the sky is obscured [32]. It is found that controlling the green vision rate and sky openness is the most important optimization direction to improve the emotional health of the elderly in cold land settlements [33]. It has been widely used in studies related to street quality, urban climate, and woodlands. The estimation of $SVF$ based on hemispheric images is a standard method for $SVF$ calculation [34]. The algorithm for calculating $SVF$ from street view images first converts panoramic images into hemispheric images and later calculates the proportion of unobstructed sky portions using the following equation.

$$SVF = \frac{1}{\pi {r_0}^2} \int_{S^p} \mathrm{d}S^p \tag{2}$$

where $r_0$ is the radius of the hemispherical radiation environment, $S^p$ is the area of the circular sky projected on the ground, the $SVF$ value is between 0 and 1, and the $SVF$ is 0 if the sky is completely obscured and 1 if the sky is completely visible.

(3) Interface enclosure $P_{enclosure}$: It reflects the degree of vertical spatial enclosure from the angle of human eyes and is obtained by calculating the ratio of the sum of pixels

occupied by buildings, plants, facilities, etc. in the panoramic picture to all pixels of the image. The formula for calculating the degree of interface $P_{enclosure}$ is as follows.

$$P_{enclosure} = P_{green} + P_{building} + P_{polo} + P_{fence} \quad (3)$$

$P_{green}$ is the proportion of pixels occupied by all green plants in the panoramic image, $P_{building}$ is the proportion of pixels occupied by all buildings in the panoramic image, $P_{polo}$ is the proportion of pixels occupied by all columns in the panoramic image, and $P_{fence}$ is the proportion of pixels occupied by all fences in the panoramic image.

### *3.5. Data Processing*

A Pearson correlation analysis was used to analyze the correlation between the outdoor space landscape environment of the age-friendly community and the gender and activity types of the elderly at the gathering point, and multiple linear regression was used to analyze the influence factors of the outdoor space indicators of the age-friendly community on the elderly of different genders and different activity types.

## 4. Results

### *4.1. Statistical Description*

Our characterization of outdoor spaces is analyzed in the table below (Table 2).

**Table 2.** Analysis of community outdoor space characteristics.

| Outdoor Spatial Measurement | Metrics | Min. | Max. | Mean | S.D. |
|---|---|---|---|---|---|
| Environmental elements | Building share (%) | 2.49 | 21.20 | 11.20 | 5.40 |
| | $GVI$ (%) | 3.99 | 32.29 | 19.37 | 8.37 |
| | Pavement share (%) | 0.03 | 21.81 | 3.05 | 6.68 |
| | Vehicle share (%) | 0.00 | 2.02 | 0.54 | 0.69 |
| Spatial characteristics | $SVF$ | 0.00 | 0.03 | 0.02 | 0.01 |
| | $P_{enclosure}$ (%) | 10.35 | 41.59 | 30.75 | 10.13 |
| Microclimate environment | Average temperature (°C) | 16.80 | 26.90 | 23.07 | 2.18 |
| | Average humidity (RH) | 45.70 | 78.40 | 59.31 | 8.03 |
| | Average wind speed (m/s) | 0.10 | 2.20 | 0.41 | 0.48 |
| | Total number of elderly people | 0.00 | 29.00 | 7.33 | 6.25 |

Among the types of activities, the most performed types of activities in the aggregation points were chatting (37.49%), and chess and card activities (41.22%). In the type of activity, the number of Chinese women chatting is significantly higher than that of Chinese men, and the number of Chinese elderly women with children to outdoor spaces is much higher than that of men (Figure 3).

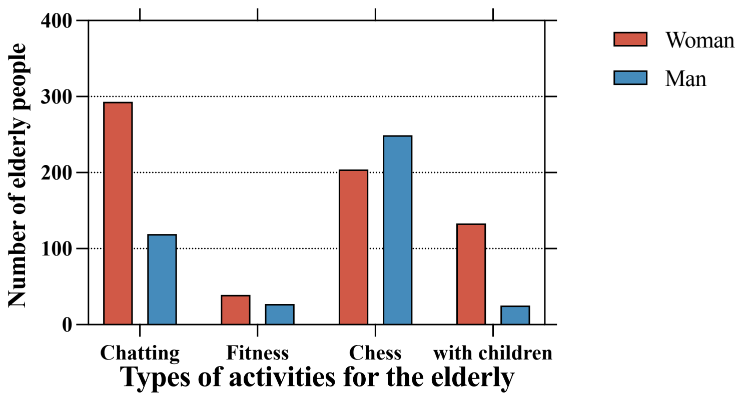



**Figure 3.** Type and number of activities by gathered elderly.

*4.2. Correlation Analysis*

A correlation analysis was performed using SPSS to assess the relationship between dependent and independent variables. Multiple linear regression was then conducted by including the variables that exhibited a significant correlation with the dependent variable. According to the results of the correlation analysis (Figure 4), $GVI$, $P_{enclosure}$, and average humidity are positively correlated with the number of chatting elderly, whereas the average temperature has a negative correlation with the number of chatting elderly. The number of fitness elderly has a significant negative correlation with building occupancy and average temperature. The number of chess elderly has a significant negative correlation with $SVF$ and $P_{enclosure}$, and a significant positive correlation with average temperature. There is a significant and positive correlation between the number of elderly people who have children and both the $SVF$ and pavement share. On the other hand, the total number of elderly people is significantly and positively correlated with the pavement share but negatively correlated with $SVF$. Among the male elderly population, there is a significant and negative correlation with $GVI$, $SVF$, and $P_{enclosure}$, but a significant and positive correlation with average humidity. Meanwhile, the total number of female elderly people is positively correlated with $GVI$, pavement share, and $P_{enclosure}$.

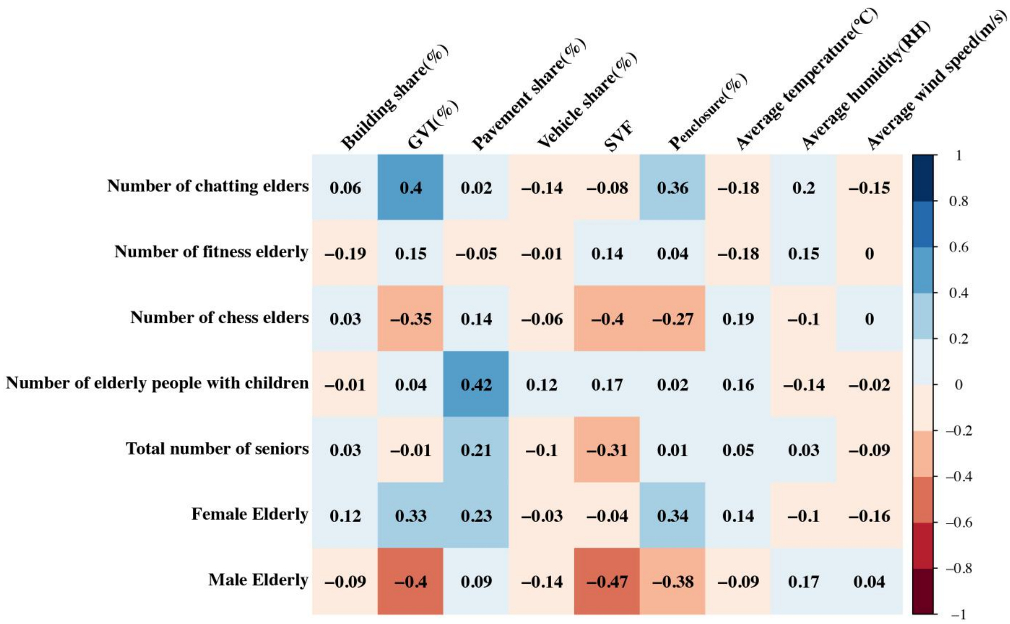



**Figure 4.** Outdoor space index correlation analysis chart.

*4.3. Regression Modeling Results*

4.3.1. Elderly Gender

A multiple linear regression model was developed using the total number of elderly people, the total number of male elderly people, and the total number of female elderly people as dependent variables, and a stepwise regression method was used to investigate the factors impacting the gender of the elderly.

To better understand the impact of environmental factors on the number of elderly people in age-friendly communities, a multiple linear regression analysis was conducted using different independent variables (Table 3). When $SVF$ and pavement share were used as independent variables for the multiple linear regression analysis, Regression model I shows that $SVF$ had a significant negative effect on the total number of elderly people and that pavement share has a significant positive effect on the total number of elderly people. When $P_{enclosure}$, pavement share, and $GVI$ were used as independent variables for the multiple linear regression analysis, Regression model II shows that pavement share and $GVI$ promote positive correlations on the number of female elderly. When $SVF$, $P_{enclosure}$, pavement share, and average humidity were used as independent variables for the multiple linear regression analysis, Regression model III indicates that $SVF$ and $P_{enclosure}$ have significant negative influences on the number of male elderly and that pavement share and average humidity promote positive correlation on the number of male elderly.

**Table 3.** Analysis of factors influencing gender in the elderly.

| **Regression Model I** | | **Dependent Variable: Total Number of Elderly People** | | | |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | t | $p$ |
| $SVF$ | −235.165 *** | 52.924 | −0.339 | −4.443 | 0.000 |
| Pavement share | 0.250 ** | 0.075 | 0.255 | 3.341 | 0.001 |
| R2 | 0.158 | | | | |
| F | 13.820 ($p = 0.000$) | | | | |
| **Regression Model II** | | **Dependent Variable: Number of Female Elderly People** | | | |
| | B | Std. Error | Beta | t | $p$ |
| $P_{enclosure}$ | 0.000 | 0.068 | 0.001 | 0.005 | 0.996 |
| Pavement share | 0.200 *** | 0.056 | 0.292 | 3.598 | 0.000 |
| $GVI$ | 0.208 * | 0.084 | 0.381 | 2.479 | 0.014 |
| R2 | 0.192 | | | | |
| F | 11.587 ($p = 0.000$) | | | | |
| **Regression Model III** | | **Dependent Variable: Number of Male Elderly People** | | | |
| | B | Std. Error | Beta | t | $p$ |
| $SVF$ | −227.135 *** | 24.989 | −0.556 | −9.090 | 0.000 |
| $P_{enclosure}$ | −0.171 *** | 0.023 | −0.448 | −7.331 | 0.000 |
| Pavement share | 0.118 ** | 0.035 | 0.203 | 3.323 | 0.001 |
| Average humidity | 0.069 * | 0.028 | 0.151 | 2.476 | 0.014 |
| R2 | 0.476 | | | | |
| F | 32.964 ($p = 0.000$) | | | | |

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

### 4.3.2. Activity Type

To analyze the influencing factors of various activities of the elderly at the gathering points, we developed a multiple linear regression model using the number of elderly people engaging in fitness activities, the number of elderly people with children, the number of elderly people engaging in chatting activities, and the number of elderly poeple playing chess as dependent variables. We employed the stepwise regression method to identify significant environmental factors, and the results are presented in the table below.

When we chose building share and average temperature as independent variables for the multiple linear regression analysis (Table 4), from Regression model IV, it can be seen that building share has a significant negative effect on the number of elderly people with fitness; when pavement share and $SVF$ were the independent variables for the multiple linear regression analysis, from Regression model V, it can be seen that pavement percentage promotes a positive effect. When the multiple linear regression analysis was conducted with $GVI$, $P_{enclosure}$, average temperature, and average humidity as independent variables, from Regression model VI, it can be seen that $GVI$ and average humidity promote positive chatting with the number of elderly people; and when $GVI$, $SVF$, $P_{enclosure}$, and average temperature were independent variables analyzed via multiple linear regression, Regression model VII shows that $GVI$, $SVF$, and $P_{enclosure}$ have significant negative effects on the number of elderly people who chat.

**Table 4.** Analysis of factors influencing gender in the elderly.

| **Regression Model IV** | | **Dependent Variable: Number of Fitness Elderly** | | | |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | t | *p* |
| Building share | −0.034 * | 0.017 | −0.163 | −2.007 | 0.047 |
| Average temperature | −0.076 | 0.040 | −0.153 | −1.885 | 0.061 |
| R2 | 0.059 | | | | |
| F | 4.631 ($p = 0.011$) | | | | |
| **Regression Model V** | **Dependent Variable: Number of Elderly People with Children** | | | | |
| | B | Std. Error | Beta | t | *p* |
| Pavement share | 0.098 *** | 0.018 | 0.406 | 5.429 | 0.000 |
| $SVF$ | 20.049 | 12.792 | 0.117 | 1.567 | 0.119 |
| R2 | 0.190 | | | | |
| F | 17.29 | | | | |
| **Regression Model VI** | | **Dependent Variable: Number of Chatting Elders** | | | |
| | B | Std. Error | Beta | t | *p* |
| $GVI$ | 0.153 * | 0.066 | 0.318 | 2.306 | 0.023 |
| $P_{enclosure}$ | 0.054 | 0.055 | 0.135 | 0.977 | 0.330 |
| Average temperature | 0.480 | 0.288 | 0.273 | 1.665 | 0.098 |
| Average humidity | 0.182 ** | 0.065 | 0.381 | 2.810 | 0.006 |
| R2 | 0.259 | | | | |
| F | 10.078 | | | | |
| **Regression Model VII** | | **Dependent Variable: Number of Chess Elderly** | | | |
| | B | Std. Error | Beta | t | *p* |
| $GVI$ | −0.182 * | 0.083 | −0.281 | −2.186 | 0.030 |
| $SVF$ | −238.578 *** | 38.820 | −0.417 | −6.146 | 0.000 |
| $P_{enclosure}$ | −0.063 | 0.070 | −0.118 | −0.907 | 0.366 |
| Average temperature | 0.080 | 0.197 | 0.034 | 0.404 | 0.687 |
| R2 | 0.360 | | | | |
| F | 16.174 | | | | |

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

## 5. Discussion

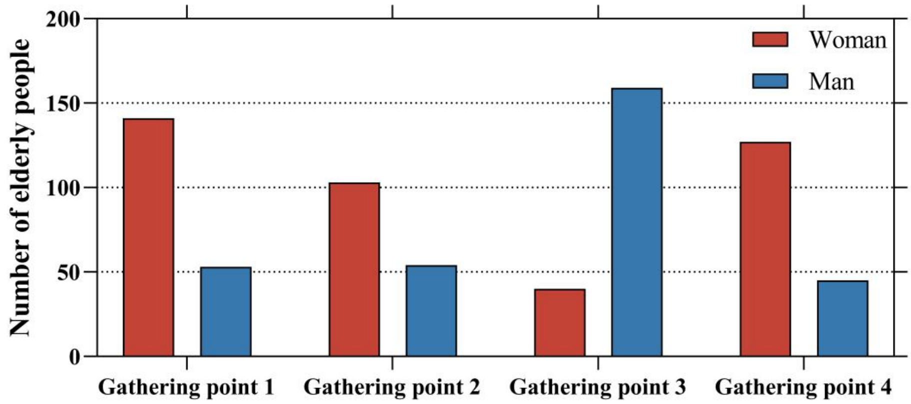
### *5.1. Effects of Sex in Old Age*

We selected four communities with the largest number of people in 3 days: In the Laofangdi Community, gathering point 1, the environment had a high GVI, a high pavement share, a low building share, and a low SVF and had a total of 141 elderly women and 53 elderly men. At gathering point 2, the Xiyuan Community, which had a high pavement share and a low SVF environment, the total number of female elderly people was 103 and the total number of male elderly people was 54. In the Fuyuan Community, gathering point 3, which was a low-SVF, low-$P_{enclosure}$, high-pavement-share, high-average-humidity, and low-average-temperature environment, the total number of female elderly people was 40 and the total number of male elderly people was 159. At gathering point 4, the Jiahe Community, which had a high GVI, a high pavement share, a low SVF, and a high average humidity, the total number of female elderly people in three days was 127 and the total number of male elderly people was 45. Among the four communities, the first three gathering sites had been renovated, and the last community could temporarily adapt to the activity needs of the elderly due to its relatively new age. However, during their next renovation, each community with a large proportion of elderly people should upgrade to an age-friendly design to transform the community (Figure 5). This study indicated that

$SVF$ has a considerable detrimental effect on the total number of elderly citizens. $SVF$ was highly correlated with spatial vitality and exhibited a positive effect, according to related research [35]. Considering the gathering point's propensity for long-term use, the design of outdoor spaces in aging-friendly communities should place greater weight on the incorporation of weather facilities. Pavement share is positively correlated with the total number of elderly people, and a large amount of pavement is the most important spatial factor for elderly people's activities [36]; therefore, paved areas should be expanded as much as possible in the initial design and later maintenance of the sites. This study reveals that the pavement share, $GVI$, and the number of female elderly people increase with an increase in pavement share and $GVI$. According to [37], people tend to favor a $GVI$ of 30–60%, and vegetation elements have a considerable influence on personal space satisfaction. Therefore, the design process of outdoor spaces for female gathering areas in elderly-friendly communities should focus on incorporating green planting to enhance the overall environment. The research conducted determined that $SVF$ and $P_{enclosure}$ had noteworthy adverse impacts on the quantity of male elderly residents, while the proportion of paved area sand mean humidity had a positive impact on the same demographic. $SVF$ plays a crucial role in the selection of exterior locations by elderly people [38]. Consequently, the design of outdoor spaces for male elderly individuals in elderly-friendly communities should prioritize the inclusion of weatherproof amenities and the promotion of interface permeability. Additionally, during the initial planning and subsequent updates, paved areas should be extended and humidity levels should be raised.

### 5.2. Effects of Activity Types in Old Age

This study established that a high building share has a substantial negative impact on the participation of elderly individuals in physical activity. Consequently, when designing and upgrading fitness facilities in outdoor spaces of age-friendly communities, open spaces with a lower building share should be given consideration. In addition, the activity venues for the elderly should be rationally arranged based on their various types of activities, with a shared function between the elderly and children in the activity space [39]. The pavement share, as discovered in this research, has a positive correlation with the number of elderly people who engage in physical activity with children. Therefore, in the design and renovation of activity venues intended for elderly individuals who exercise with children, the amount of paved area should be increased, and an area for elderly individuals to rest should be provided around the venue. The $GVI$ and average humidity, according to this study, are positively associated with the number of elderly people who engage in socializing activities. Although the influence of humidity on the behavior of individuals is typically minor, studies have shown that in high-temperature and high-humidity environments, its effect is significantly increased [40]. Hence, in the design of outdoor spaces intended for elderly individuals to socialize, special attention should be paid to planting more greenery to create a suitable environment for rest and chat while also increasing humidity. Additionally, the $GVI$, $SVF$, and $P_{enclosure}$ have been found to have a significant negative impact on the number of elderly individuals playing chess. Consequently, in designing chess spaces for elderly, it is necessary to construct weatherproof facilities that can prolong the time spent by elderly participating in chess activities, while reducing the number of partitions in the facilities and increasing the hard surface area. Temperature is a crucial variable that influences the level and type of physical activity of the population [41]. The positive correlation between average temperature and the number of elderly people playing chess during chess activities corroborates the findings of previous studies.




(a) The number of elderly people at the gathering point in three days

(b) Laofangdi Community,Gathering point 1

(c) Xiyuan Community,Gathering point 2


(d) Fuyuan Community,Gathering point 3

(e) Jiahe Community,Gathering point 4

**Figure 5.** Panoramic pictures of the gathering points.

### *5.3. Design Recommendations*

Regarding the types of activities in the gathering point, chatting (37.49%) and chess and card activities (41.22%) were found to be the most common activities. The survey on activities conducted in the gathering point for the elderly revealed that chatting, and chess and card activities have the characteristics of a longer duration and are more appealing to the elderly in terms of gathering activities. For elderly individuals with children, the category with the greatest demand is activities that can primarily be conducted in combination with other activities, and fitness-oriented elderly people tend to participate in activities during the morning and evening. Therefore, in the subsequent design and update of age-friendly communities, more emphasis should be placed on developing fields suitable for chatting and chess activities. Additionally, the greater the number and variety of facilities at each gathering point, the more the elderly are attracted to the gathering point. Thus, the subsequent design should increase the diversity of field items as much as possible to foster gathering and communication activities among the elderly. All of the communities involved in the age-friendly community study have barrier-free facilities, and in the subsequent design, attention should be paid to making outdoor activities more accessible for elderly individuals with mobility issues.

## 6. Conclusions

This article employs a multi-method approach to investigate how landscape elements, spatial characteristics, and the microclimatic environment influence the spatial distribution and behavior of elderly individuals in outdoor gathering points of age-friendly communities, in addition to analyzing the differences between the factors affecting males and females. This study analyzes and concludes the many activities that occur in outdoor gathering places for the elderly, as well as the influence of site conditions on these activities. Primarily, air humidity, temperature, and wind speed are the microclimate sub elements that have the most influence on outdoor behavior. The results of the study indicate that average humidity has a favorable influence on the number of elderly people, suggesting that additional investigation is required in this area. Although earlier research has revealed that wind speed affects resting activities in urban public areas [42], the influence of wind speed on outdoor spaces for the elderly is weaker according to the findings of this study. Examining the influence of landscape elements, spatial characteristics, and the microclimatic environment on the spatial distribution and behavior of the elderly in outdoor gathering locations in age-friendly communities, the present study employed a multi-method approach. In addition, this study investigated the differential effects of these elements on male and female participants and provided a summary of the various activities undertaken by elderly people in these outdoor places. It was discovered that the microclimate has a considerable effect on the behavior of elderly people, notably in terms of air humidity, temperature, and wind speed. While wind speed had a minor effect on the behavior of elderly adults in outdoor environments, humidity and temperature had considerable effects, especially on the behavior of elderly males.

In terms of landscape elements and spatial characteristics, outdoor gathering places for the elderly should prioritize weather amenities and broaden the extent of paving and vegetation planting. In the development and refurbishment of outdoor spaces, special attention should be paid to the design of fitness facilities with less building occupancy and weatherproof facilities with less partitioning to support open spaces for elderly. Notwithstanding the significance of this study's findings, there are limitations, such as the impossibility of isolating the impact of temperature on the crowd from other seasonal variations in thermal settings [43]. Although the three-day data collection sample at each location of aggregation was sufficient, it has no bearing on the assessment of microclimate conditions. Future research suggests analyzing outdoor spatial characteristics through qualitative research, such as a spatial analysis of aggregation points. In addition, a closer analysis of the GVI at each site was carried out to address the type of vegetation; its form; and its seasonality, whether the vegetation acts as a canopy, windbreak or visual alteration, etc. Similarly, SVF requires monitoring daytime continuity to enable a broader analysis, especially patterns of change in shade between 7 a.m. and 5 p.m. Future design studies should therefore research the spatial trajectory of elderly folks under high-temperature circumstances in the summer and investigate the effect of seasons on age-friendly community aggregation venues.

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## References

1. WHO. 2016. Available online: https://www.who.int/news-room/fact-sheets/detail/ageing-and-health (accessed on 1 May 2023)
2. Fry, G.; Tveit, M.S.; Ode, Å.; Velarde, M. The ecology of visual landscapes: Exploring the conceptual common ground of visual and ecological landscape indicators. *Ecol. Indic.* **2009**, *9*, 933–947. [CrossRef]
3. Liu, W. Study on Objective Evaluation Index of Human Thermal Comfort. Ph.D. Thesis, Shanghai Jiao Tong University, Shanghai, China, 2007.
4. Lui, C.W.; Everingham, J.A.; Warburton, J.; Cuthill, M.; Bartlett, H. What makes a community age-friendly: A review of international literature. *Australas. J. Ageing* **2009**, *28*, 116–121. [CrossRef] [PubMed]
5. Xie, L.; Wang, B. Social participation patterns and influencing factors of the elderly in China from the perspective of active aging. *Popul. Res.* **2019**, *43*, 17–30.
6. Yu, Q. Research on Spatio-Temporal Trajectory Data Mining and Its Application in the Analysis of Urban Residents' Travel Behavior Patterns. Ph.D. Thesis, Anhui Normal University, Wuhu, China.
7. Lu, F.; Luo, J.; Kang, W. Research on the transformation strategy of environmental suitability for the elderly in cold residential areas based on universal design-Taking clove home in Harbin as an example. *Urban Archit.* **2018**, *15*, 28–33.
8. Shu, P.; Yin, R. Outdoor space renewal strategy of old residential areas in Tianjin from the perspective of healing. *Archit. J.* **2020**, *22*, 67–72.
9. Wang, Y.; Dong, H.; Li, B.; Pan, H. Study on the activities of the elderly and their spatial use in the parks of small and medium-sized cities in western Shanxi—Based on the empirical analysis of Qiuhe Park in Linxian County, Shanxi Province. *New Archit.* **2019**, *182*, 96–101.
10. Bai, H.; Luo, H.; Liu, Y. Study on the suitability evaluation of urban greenway layout under the background of park city. *Chin. Gard.* **2022**, *38*, 93-98.
11. Zhang, Y.; Yao, E. Exploring elderly people's daily time-use patterns in the living environment of Beijing, China. *Cities* **2022**, *129*, 103838. [CrossRef]
12. Zhang, R.; Wulff, H.; Duan, Y.; Wagner, P. Associations between the Physical Environment and Park-Based Physical Activity: A Systematic Review. *J. Sport Health Sci.* **2019**, *8*, 412–421. [CrossRef]
13. Wu, J. Gender disparities in exposure to green space: An empirical study of suburban Beijing. *Landsc. Urban Plan.* **2022**, *222*, 104381. [CrossRef]
14. Zhong, W.; Wang, D.; Xie, D.; Yan, L. Study on the dynamic characteristics of population distribution and spatial activities in Shanghai-An exploration based on mobile phone signaling data. *Geogr. Study* **2017**, *36*, 972–984.
15. Xu, Y.; Xue, J.; Park, S.; Yue, Y. Towards a multidimensional view of tourist mobility patterns in cities: A mobile phone data perspective. *Comput. Environ. Urban Syst.* **2021**, *86*, 101593. [CrossRef]
16. Liu, Y.; Hu, J.; Yang, W.; Luo, C. Effects of urban park environment on recreational jogging activity based on trajectory data: A case of Chongqing, China. *Urban For. Urban Green.* **2022**, *67*, 127443. [CrossRef]
17. Tian, A.; Yang, A.; Zhang, B.; Ai, C.; Wang, D. Characterizing the activity patterns of outdoor jogging using massive multi-aspect trajectory data. *Comput. Environ. Urban* **2019**, *95*, 101804. [CrossRef]
18. Su, R.; Xiao, J.; McBride, E.C.; Goulias, K.G. Understanding senior's daily mobility patterns in California using human mobility motifs. *J. Transp. Geogr.* **2021**, *94*, 103117. [CrossRef]
19. Cunningham-Myrie, C.A.; Royal-Thomas, T.Y.; Bailey, A.E.; Gustat, J.; Theall, K.P.; Harrison, J.E.; Reid, M.E. Use of a public park for physical activity in the Caribbean: Evidence from a mixed methods study in Jamaica. *BMC Public Health* **2019**, *19*, 894. [CrossRef]

20. Derose, K.P.; Han, B.; Park, S.; Williamson, S.; Cohen, D.A. The mediating role of perceived crime in gender and built environment associations with park use and park-based physical activity among park users in high poverty neighborhoods. *Prev. Med.* **2019**, *129*, 105846. [CrossRef]
21. Sarmiento, O.L.; Rios, A.P.; Paez, D.C.; Quijano, K.; Fermino, R.C. The Recreovía of Bogotá, a community-based physical activity program to promote physical activity among women: Baseline results of the natural experiment Al Ritmo de las Comunidades. *Int. J. Environ. Res. Public Health* **2017**, *14*, 633. [CrossRef]
22. Cohen, D.A.; Marsh, T.; Williamson, S.; Derose, K.P.; Martinez, H.; Setodji, C.; McKenzie, T.L. Parks and physical activity: Why are some parks used more than others? *Prev. Med.* **2010**, *50*, S9–S12. [CrossRef]
23. Bai, H.; Wilhelm Stanis, S.A.; Kaczynski, A.T.; Besenyi, G.M. Perceptions of neighborhood park quality: Associations with physical activity and body mass index. *Ann. Behav. Med.* **2013**, *45*, S39–S48. [CrossRef]
24. Gu, X.; Li, Q.; Chand, S. Factors influencing residents' access to and use of country parks in Shanghai, China. *Cities* **2020**, *97*, 102501. [CrossRef]
25. Ren, Z.; He, X.; Zheng, H.; Zhang, D.; Yu, X.; Shen, G.; Guo, R. Estimation of the relationship between urban park characteristics and park cool island intensity by remote sensing data and field measurement. *Forests* **2013**, *4*, 868–886. [CrossRef]
26. Song, Y.; Chen, B.; Ho, H.C.; Kwan, M.P.; Liu, D.; Wang, F.; Wang, J.; Cai, J.; Li, X.; Xu, Y.; et al. Observed inequality in urban greenspace exposure in China. *Environ. Int.* **2021**, *156*, 106778. [CrossRef] [PubMed]
27. Li, X.; Zhang, C.; Li, W.; Ricard, R.; Meng, Q.; Zhang, W. Assessing street-level urban greenery using Google Street View and a modified green view index. *Urban For. Urban Green.* **2015**, *14*, 675–685. [CrossRef]
28. Guo, S.; Yang, G.; Pei, T.; Ma, T.; Song, C.; Shu, H.; Du, Y.; Zhou, C. Analysis of factors affecting urban park service area in Beijing: Perspectives from multi-source geographic data. *Landsc. Urban Plan.* **2019**, *181*, 103–117. [CrossRef]
29. Chen, Y.; Liu, X.; Gao, W.; Wang, R.Y.; Li, Y.; Tu, W. Emerging social media data on measuring urban park use. *Urban For. Urban Green.* **2018**, *31*, 130–141. [CrossRef]
30. Li, F.; Li, F.; Li, S.; Long, Y. Deciphering the recreational use of urban parks: Experiments using multi-source big data for all Chinese cities. *Sci. Total Environ.* **2020**, *701*, 134896. [CrossRef]
31. Wang, M.; Peng, H. New interpretation of green space development in high-density cities. *Park* **2018**, *309*, 28–33.
32. Chapman, L.; Thornes, J. Real-time sky-view factor calculation and approximation. *J. Atmos. Ocean. Technol.* **2004**, *21*, 730–741. [CrossRef]
33. Lu, F.; Han, B.; Wang, B. The effects of the neighborhood-built environment on emotional health of the elderly in severe cold regions on the basis on principal component analysis. *Urban Archi.* **2018**, *24*, 47–50.
34. Li, X.; Cai, Y.; Carlo, L.; Liu, S.; Wang, Y. Urban landscape research based on street image and deep learning. *Landsc. Archit.* **2018**, *6*, 20–29. [CrossRef]
35. Lu, S.; Wang, L. A quantitative study on the perception of morphological characteristics of outdoor public space in urban residential areas based on the perception of the elderly. *J. West. Hum. Settl. Environ.* **2020**, *35*, 56–61.
36. Chen, J.; Zhang, J. Research on the correlation between community park space and outdoor activity characteristics of the elderly. *Chin. Gard.* **2022**, *35*, 56-61.
37. Zheng, L.; Pu, H.; Jiang, Z. Research on urban park space satisfaction based on green view rate. *J. Nanjing For. Univ. Nat. Sci. Ed.* **2020**, *44*, 199.
38. Chen, Y.; Huang, L. Analysis of the influencing factors of the elderly 's choice of park sitting space. *J. Xiamen Univ. Technol.* **2019**, *27*, 89–95.
39. Tan, L. Evaluation and Optimization Strategy of Community Parks in Chongqing. Master's Thesis, Southwest University, Chongqin, China, 2021.
40. Chow, W.T.; Akbar, S.N.A.B.A.; Heng, S.L.; Roth, M. Assessment of measured and perceived microclimates within a tropical urban forest. *Urban For. Urban Green.* **2016**, *16*, 62–75. [CrossRef]
41. Zacharias, J.; Stathopoulos, T.; Wu, H. Microclimate and downtown open space activity. *Environ. Behav.* **2001**, *33*, 296–315. [CrossRef]
42. Yang, W.; Wong, N.H.; Jusuf, S.K. Thermal comfort in outdoor urban spaces in Singapore. *Build. Environ.* **2013**, *59*, 426–435. [CrossRef]
43. Oliveira, S.; Andrade, H. An initial assessment of the bioclimatic comfort in an outdoor public space in Lisbon. *Int. J. Biometeorol.* **2007**, *52*, 69–84. [CrossRef]