Accessibility and Inequality of Park Green Space for Multi-age Distribution in Shanghai, China

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Abstract. The accessibility and inequality of public evaluation parks and green spaces are crucial for Shanghai, which is currently experiencing a continuous influx of new population while an aging society still exists. It helps to achieve better social equity in the allocation of parks and green spaces and the formulation and allocation of subsequent planning and construction. This study conducted a multidimensional test on the urban horizontal inequality of driving and walking in different regions and the overall accessibility of the urban park spaces, using two floating-point moving methods, Gini coefficient, and inequality index via ArcGIS and QGIS. The longitudinal evaluation was conducted on five different age groups. The findings shows that in regions with comparatively low traffic and population density, Shanghai's geographic location with the coverage of park green space is generally low. There are different accessibility situations in different areas because of the division of land use and the uneven distribution of green space in parks. Inequality worsens with age, especially in driving modes of transport and inner city areas. Together with theoretical backing and a basis for future planning, this research offers a succinct analysis and comprehension of the existing state of affairs.

Keywords: Park green space, Spatial accessibility, Spatial inequality, Two-step floating catchment area, Shanghai.

1. Introduction

Urban green spaces are urban green infrastructure, an important element that constitutes the natural environment, and a crucial factor in ensuring sustainable urban development. They have important ecological, entertainment, leisure, and social-cultural functions, such as providing recreation and amusement spaces, lowering the urban heat island effect, conserving biodiversity, and easing the workload of city dwellers [1]. As lifestyles have changed in recent years, there has been a gradual growth in demand for parkland and other natural settings. A number of announcements about the standards for greenery and parkland have been made by the federal government as well as municipal governments, such as a notice from the General Office of the Ministry of Housing and Urban Rural Development on Launching Pilot Projects for Open and Shared Urban Parks and Green Spaces, Increasing Accessible and Experiential Activity Venues. In order to provide crucial recommendations for future park and outdoor area planning and layout, this highlights the significance of creating parks and green spaces while also reflecting the need to measure their accessibility and address disparities within different communities.

Accessibility is a numerical representation of people's willingness and capacity to go over barriers like travel time and distance to get to service locations or event locations. The concept of accessibility began with classical location theory and continues to enrich its connotation. Its focus gradually shifts from macro to micro and from spatial efficiency to spatial fairness. Additionally, China has seen a surge in availability research in recent years. For example, Song et al. believe that one of the best instruments for evaluating the rationality of the spatial distribution of public sector resources is accessibility [2]. The accessibility research methods mainly include buffer analysis, network analysis, minimum proximity distance method, cost-weighted distance method, etc. In recent years, scholars have mostly used the gravitational potential energy simulation method [3] and the two-step floating catchment area method [4] to increase the approaches' accuracy and make accessibility estimations more consistent. The two-step floating catchment area method is widespread particularly when assessing the accessibility of public service facilities, because it is easy to calculate and has low data collecting difficulties [5]. It is optimized by incorporating extended forms such as distance and diversified transportation.

Being a municipality and administrative region at the provincial level directly under the control of China's central government, this article takes Shanghai as the research object and conducts a certain analysis of various communities. This research integrates the optimization of transportation, the complexity of the transportation network, and studies the accessibility of city parks and nature reserves for various age groups. Through vertical and horizontal analysis, it seeks to close the knowledge gap about the direction of the impact of various factors on the accessibility of green spaces and nature areas.

2. Background of Study Area

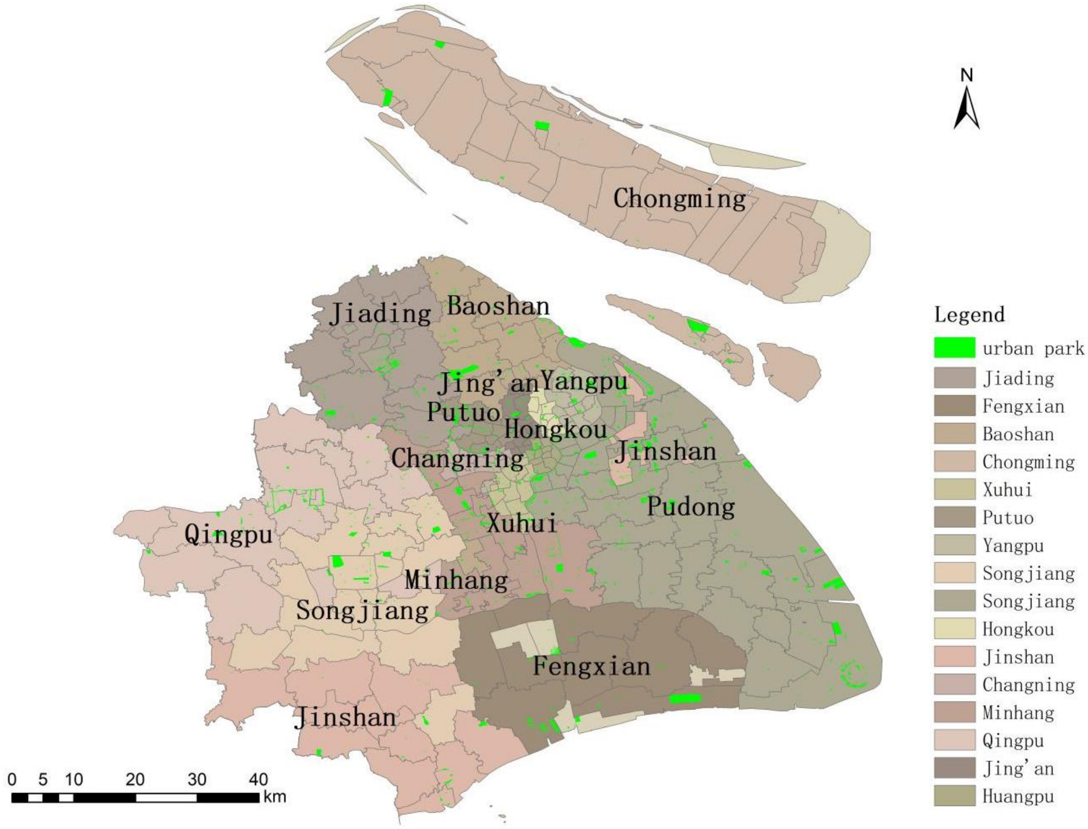

Figure 1. Shanghai's geographical region (Original figure)

The study site Shanghai, as shown in the Figure 1 above, contains 16 districts the geographical distribution of green parks in each region of Shanghai is uneven. The central parts, such as Hongkou, Putuo, Changning, Xuhui, and other areas, are denser than other areas. In terms of green space, although the density of it in the central area is higher, the average area is not large. On the contrary, Chongming, Pudong, Fengxian, and other areas of individual green areas are larger. Moreover, due to the different economic development goals in each region, the artificial or natural park space constructed is different as a result of the various purposes of green space construction under the planning conditions. In particular, some large areas of green space are not studied and calculated as park green space because they have other special uses.

Shanghai's population is mainly concentrated in the central region. The highest concentration area of each age group was in the middle. In particular, over 80 years and under 14 years may be due to the concentration of medical and educational facilities. While there is a tendency for those between the ages of 15 and 59 and 60 and 65 to be dispersed, there are also some who choose to live in the surrounding areas.

3. Data and methods

3.1. Data

The demographic data includes population size and age groups, and is the demographics of the residents by region in the seventh population census of the Shanghai Statistical Yearbook 2023. Each region divides the age into five age groups: 0-14, 15-59, 60-65, 65-80 80 years old and above for analysis, and lays out the data (https://tjj.sh.gov.cn/tjnj/nj23.htm?d1=2023tjnj/C0212.htm)

Park green spaces include large squares, theme parks, and residential surrounding parks. Parks that allow for relaxation and leisure are all considered, and the park area is calculated. The design of the park should determine the visitor capacity and park area as the basis for calculating the scale, quantity, and management of various facilities. The amount of green spaces in parks is measured using this method (https://www.soujianzhu.cn/NormAndRules/NormContent.aspx?id=368).

There are 19 classifications of raw data on transportation networks, including different levels of public transportation, which can be generally divided into two categories: (1) public transportation and drivable roads, including railway and bus lines, highways, first, second, and third level roads, main roads, and residential streets; (2) walkable/cyclizable roads, including intersections, bike lanes, sidewalks, trails, and other pedestrian accessible roads. At the same time, assigning corresponding attributes to the above three types of roads, including connection method, turning method, and driving direction, reduces the actual error of road network data and makes the overall research more realistic and accurate.

Figure 2 observes the size and distribution of green space in each block through the size of points, Figure 3 represents the distribution of population through the color depth and distribution of each point.

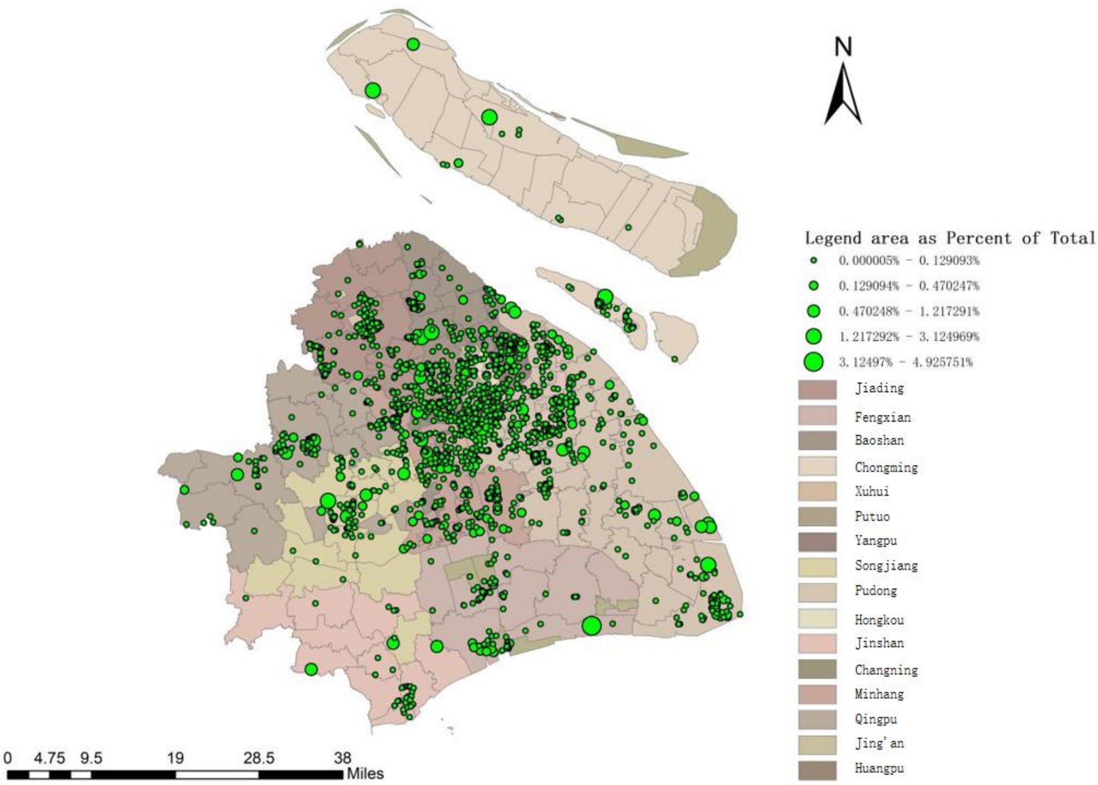

Figure 2. Size and layout of green space areas within parks (Original figure)

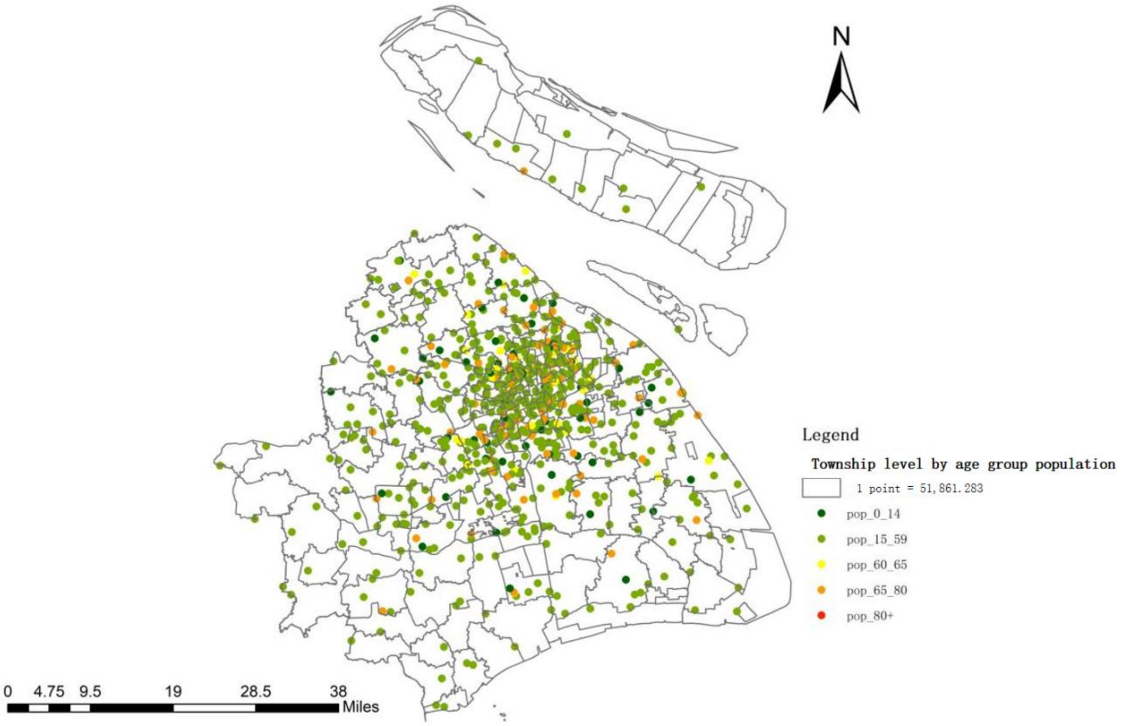

Figure 3. Population density distribution across different age groups (Original figure)

3.2. Methods

The 2SFCA method is used in this article to examine the accessibility of parks and green spaces [6]. Based on the following principles, this study defines the service scope and transportation mode of public transportation and drivable roads within 1km, using walking or self-driving roads within 1km, and the overall road network, and limits the park service capacity as a consideration range.

Step 1 is to determine the ratio between urban park area and population, R_j, in the area that falls within the designated catchment zone:

$$R_j = \frac{S_j}{\sum_{k\in\{d_{kj}\leq d_0\}} P_k} \tag{1}$$

Where S_j is the area of the urban park at position j, and P_k is the population of tract k whose centroid is inside the catchment that iss$\{d_{kj} \leq d_0\}$, d_0 is the distance traveled, using various means, in a single kilometer between two objective places, and d_{kj} is the duration of journey from k to j.

Step 2 is to determine the park green space's accessibility index for the populace at the center site i using different modes of transportation F as A_i^F. Sum up the urban park area to population ratios, R_j, at these locations. For each population i, search all urban parks j that are within the threshold travel time (d_0) from the site that is, catchment region i):

$$A_i^F = \sum_{j\in\{d_{ij}\leq d_0\}} R_j = \sum_{j\in\{d_{ij}\leq d_0\}} \frac{S_j}{\sum_{k\in\{d_{kj}\leq d_0\}} P_k} \tag{2}$$

The distance between j and i is d_{ij}, which is where it is denoted.

This study utilizes park maps to determine the area of each park and adds regional characteristics to each park. Finally, the park area and percentage of each district are calculated and summarized. The population data is processed to obtain specific values for different age groups and the total population value and corresponding percentage of each district. The horizontal and vertical fairness analysis can be conducted by Gini index [7]:

$$\mathrm{Gini}=\frac{\mathrm{Area_A}}{\mathrm{Area_B}}=1-\sum_{k=1}^{n}(X_k-X_{k-1})(Y_K+Y_{k-1}) \quad (3)$$

Where $\mathrm{Area_A}$ represents the area between two curves, $\mathrm{Area_B}$ depicts the region that is bordered by the curve situated between the y-axis and the x-axis, X_i shows the total percentage coefficient of the population of diverse ages, Y_i represents the sum of the park's green space's cumulative percentage coefficient. Each district and county has their own representative, with k being one of them.

4. Results and Discussion

4.1. Accessibility of Parks and Green Spaces in Different Age Groups

Figures 4 and 5 show the accessibility of parks and green spaces in different age groups under public transportation, driving, walking, and cycling. The chart shows that, in driving circumstances, overall accessibility is high., while accessibility is low under walking conditions. It implies that in certain places, the design of gardens and other landscaping needs to be strengthened. Overall, except for the higher accessibility in the eastern part of the park compared to the western part and the higher accessibility in the northern part compared to the southern part, the overall accessibility of Chongming is relatively low compared to other areas. The reason may be that compared to other areas, Chongming is mostly a natural and tourist resort landscape, and many land properties are classified as other areas that are not considered park green spaces. Compared to other areas, Pudong, Xuhui, Jiading, Minhang, Fengxian, and Qingpu have higher accessibility of urban green areas while driving. Pudong and Jiading have much higher accessibility to green land when walking, as the two areas have many coastal parks. The land area is relatively large in the calculation process and actual situation, making it very suitable for leisure and relaxation. The accessibility of some central areas, such as Yangpu, Jing'an, Xuhui, Huangpu, Changning, is also higher. These areas have dense urbanization and various types of land are more concentrated. The overall planning and design ensure the accessibility and park area of parks and green spaces. Due to the gathering of people, traffic conditions were not considered. Therefore, it is still necessary to thoroughly assess how accessible nature preserves and nature reserves are in the central region.

From the overall and driving perspective, it can be seen that the accessibility of park green spaces in the 0-14, 15-59, and 60-65 age groups is higher compared to the other two age groups. In general, the eastern and northern regions have more connectivity to these locations than the southern and western regions. It should be noted that the 60+ age group has higher accessibility to the Chongming area than the other two age groups. Chongming is more suitable for vacation and rest due to its many resorts and better natural environment. Walking, on the other hand, reflects a difference between driving and overall accessibility. When compared to other age groups, the 0–14 age group has significantly more accessibility for outdoor natural environments. On the contrary, the accessibility in the 15-59 age group is the lowest, only higher in the Jiading area. As shown in the figure, the overall accessibility in the Jiading and Pudong areas is higher compared to other areas. This may be due to the above reasons and the construction of many new types of park green spaces in these two areas in recent years [8]. Except for these two areas, the accessibility of park green spaces in the central region is still relatively high through walking, making walking to the park more appropriate.

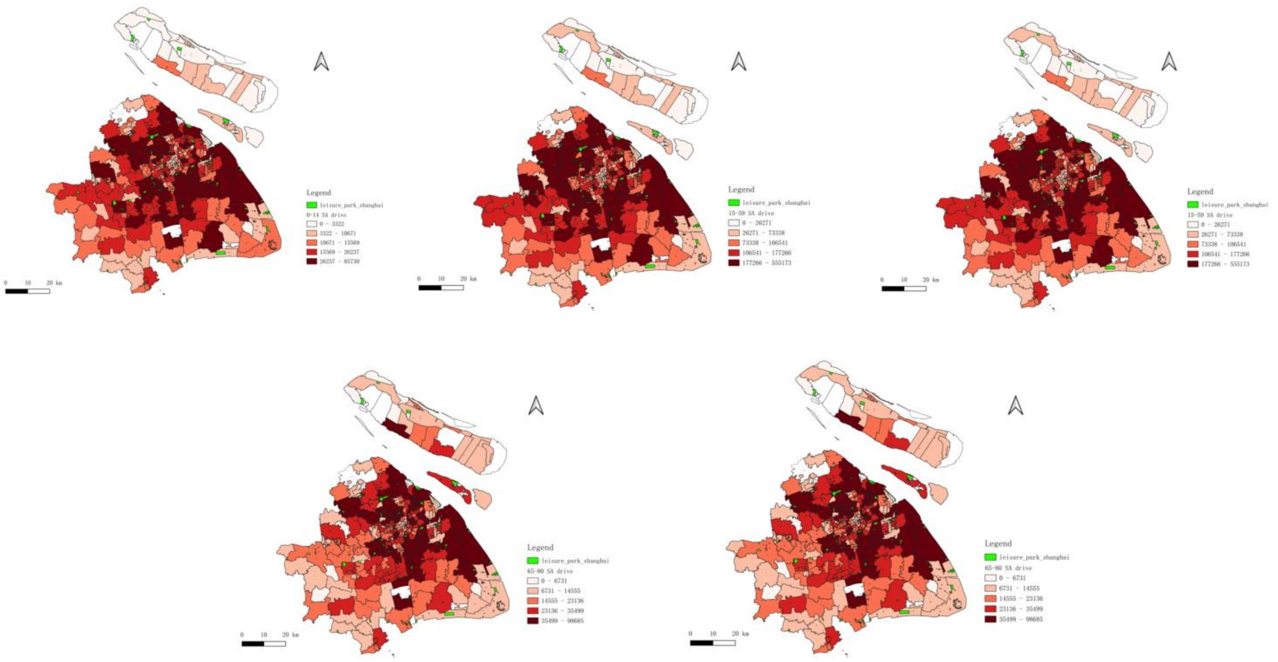

Figure 4. Parks and natural habitat connectivity layouts for five age groups through driving and public transportation (Original figure)

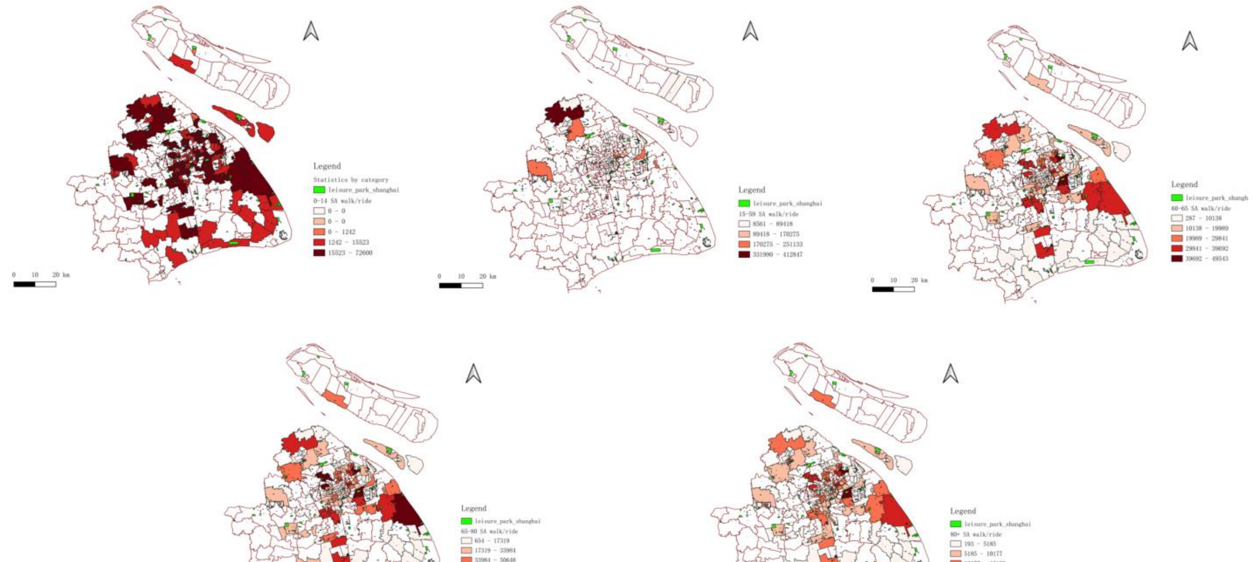

Figure 5. Walking accessibility of green environments and parks in terms of spatial patterns for five age groups (Original figure)

4.2. Inequality of Parks and Green Spaces in Different Age Groups

Before conducting inequality analysis, standard deviation ellipses were drawn for five age groups and the overall park green space. Figure 6 shows that the volume of outdoor space in overall parks is relatively concentrated in the north, middle, and east, while there are still few or scattered park green spaces in Chongming District, south, and west, which need to be strengthened in subsequent construction. The population aggregation at different ages is relatively consistent, mainly distributed in the middle, which overlaps with the standard deviation ellipse of green space aggregation, reflecting the high utilization rate of construction planning in the actual situation, and the overall park green space planning is good. Observing the standard deviation ellipse between different age groups again, it can be seen that age gradually shifts from the central to the northeast direction, which may be related to many practical situations and represents the overall residential bias of different age groups [9].

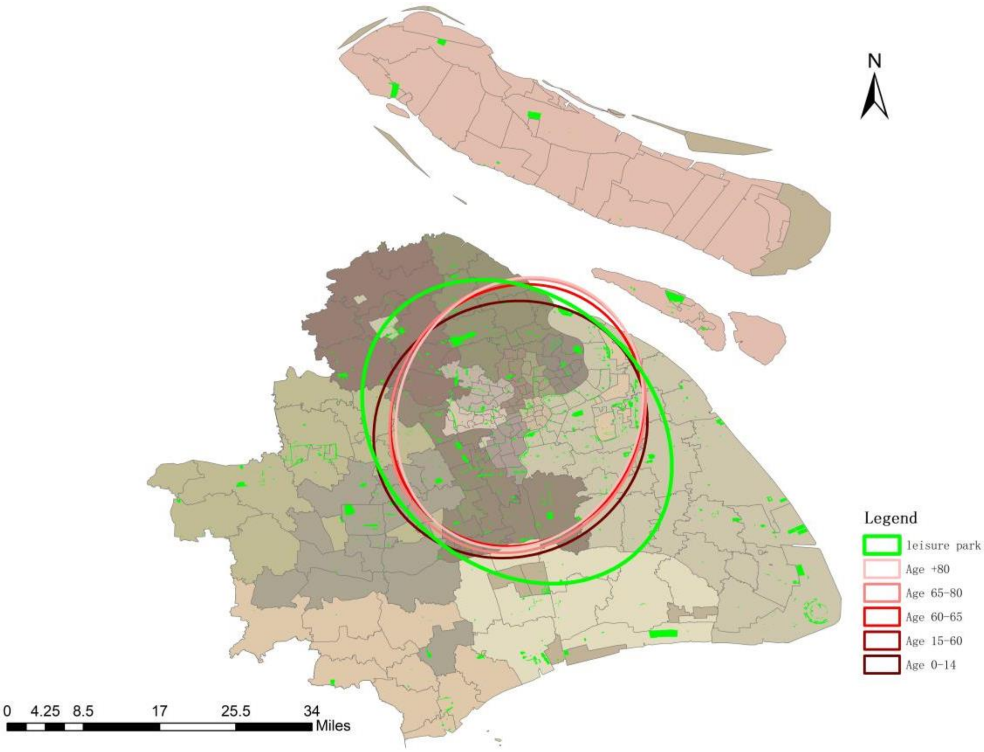

Figure 6. Regarding the standard deviation ellipse of different age groups and park distribution (Original figure)

Figure 7 shows that the overall Gini coefficient of 0.4474 is relatively close to the ideal line in the graph. The accessibility distribution of Shanghai's park green space is rather unbalanced, and a few issues need to be resolved.

By drawing images horizontally and vertically for different spaces and different groups of the entire population, it can be seen that in terms of the closeness of parks and other natural spaces varies somewhat among the five age groups in terms of vertical balance. Overall, except for the 80+age group, the Gini coefficients of the rest are less than 0.5. The overall balance is relatively low, and the images of 0-14 years old and 15-59 years old are significantly closer to the ideal equilibrium state than the other three age groups. The Gini coefficient is relatively low, and 15-59 years old has the best balance in the case of an extensive age range. The inequality widens with age group over 60. It could be important to give the accessibility requirements of the elderly population in natural areas more consideration and to add them to the construction as much as possible. Regarding horizontal balance, a bar chart is drawn for different regions based on the overall population. As can be seen from the chart, there is a similar situation as mentioned above, with regional inequality. Chongming District has the best balance, while Hongkou District has a weaker balance, and further planning adjustments need to be made according to the actual situation of each district.

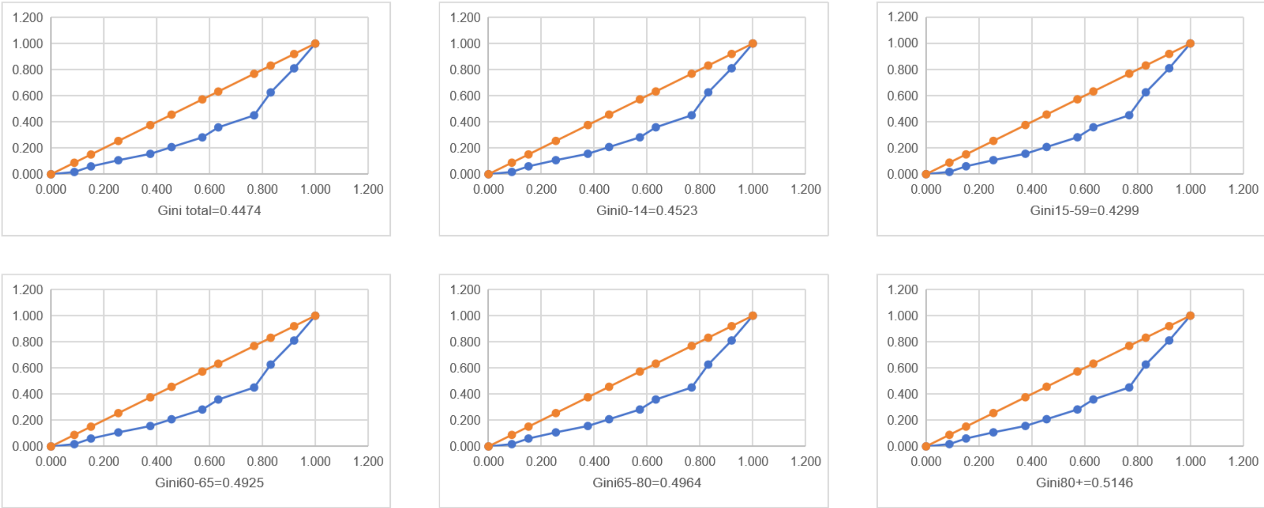

Figure 7. Gini index for different age groups (Original figure)

4.3. Suggestions and Limitations

Through analysis and research on different age groups and regions mentioned above, accessibility still needs to be further improved, especially within a 1km walking distance where more parks and green spaces need to be added to spend people's daily leisure time and relaxation needs [10]. Accessibility needs vary for different age groups, and special needs must be considered for subsequent renovation or new construction. In terms of balance, there are imbalances in both geography and age. The minor age differences are mainly due to the greater impact of accessibility, and it is necessary to adapt to local conditions. Based on the research results obtained from different regions and the feasibility of actual situations, the government provides a certain theoretical basis for park and green space construction.

There are certain limitations to the research, as it only considers road conditions such as speed, direction, connectivity, etc. in transportation, without taking into account actual situations, which has certain limitations in influencing factors. Secondly, the research area has a large plot of land, and there is a certain degree of error in converting the center of the research area into a point for research, which makes it difficult to conduct a rigorous analysis of the actual situation within the area. The age group data is the same, and the selection of the number of people is calculated using the average value, which is more idealized. More detailed analyses and calculations of the above issues can be conducted in the future.

5. Conclusion

This study conducted accessibility analysis and imbalance analysis of urban space in different regions of Shanghai for different age groups, and found differences in accessibility among different age groups.

Compared with younger age groups, older people have lower spatial accessibility, and their needs need more attention and satisfaction. Significant differences exist in the accessibility of space in different regions. The north is generally more accessible than the south in terms of accessibility, and there is higher accessibility in the east than in the west. Further construction needs to be carried out according to the actual situation. There is a horizontal and vertical imbalance, with little difference between different age groups. The subsequent functions and service needs can be managed and improved according to actual conditions. There are significant differences within each region, which are consistent with the regional situation described in accessibility. If subsequent construction is needed, it should be taken into consideration. A functional evaluation of the whole will be provided by analyzing the parks and green spaces in Shanghai overall. In order to provide guidance and suggestions for future construction, it can be used as a reference in the future, and it also has a certain reference value for other regions.

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