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# A Method for Optimizing the Layout of Public Service Facilities Based on the Needs of Different Age Groups: An Analysis of Hongkou District, Shanghai

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**Abstract:** This study focuses on the equity of spatial layout for public service facilities targeting different age groups and proposes a systematic analytical approach. The method mainly includes the following steps: (1) collecting spatial distribution data of population and various types of public service facilities for each age group; (2) establishing demand matrices for different groups regarding different types of public service facilities and calculating supply-demand density; (3) calculating the level of public service accessibility for different population groups at any spatial location; (4) introducing the Gini coefficient to assess the spatial equity of public service accessibility for different age groups; (5) evaluating whether the Gini coefficient meets the planning objectives and identifying areas with inadequate public service accessibility for optimization of facility layout. Choosing Hongkou District in Shanghai as a case study, the analysis process and results indicate the technical feasibility of the proposed method and its supportive role in public service facility planning. Furthermore, the article discusses the importance of a systematic analysis perspective, the applicability of the methodology in planning decisions, and the enhancement of facility supply levels in weak areas.

**Keywords:** public service facilities; different age groups; spatial layout; supply and demand; Gini coefficient

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## 1. Introduction

The Sustainable Development Goals (SDGs) in "*Transforming Our World: The 2030 Agenda for Sustainable Development*" pay particular attention to building an equal society for all, not only in SDG10, which is dedicated to reducing inequality, but also in SDG11, SDG1, SDG3, SDG5, and SDG7, which are dedicated to making basic rights available to all [1]. In recent years, many cities around the world have also paid more attention to people's sense of access when formulating their long-term development strategies, and are committed to letting everyone enjoy the benefits of urban development. The theme of New York City's strategic plan released in 2015 is "*One New York: The Plan for a Strong and Just City*", which sets forth four visions for a thriving, equitable, sustainable, and resilient city for all [2,3]. In the *Mayor of London's Culture Strategy* released in 2018, which proposed to make cultural services accessible to all Londoners, the city outlined its plans to improve cultural engagement and participation [4]. In China, the concept of putting people first is also gradually being integrated into urban development strategies. Shanghai has recently made great efforts to promote the construction of a "people's city", aiming to create a city where everyone has the opportunity to shine in life, where everyone can actively participate in governance, where everyone can enjoy a high-quality life, where everyone can truly feel warmth, and where everyone can have a sense of belonging and identity [5]. In order to enable all residents to enjoy basic public services with equal opportunities at their doorstep, Shanghai proposed to build a 15-min community living circle so that residents can enjoy basic public services such as health, elderly care, education, culture, and sports within a

15-min walk [6]. In order to further meet the needs of different groups, many cities have put forward the goal of building friendly cities for specific groups, and have proposed implementation paths in the direction of building child-friendly cities, youth-friendly cities, and senior-friendly cities. For example, Shanghai has proposed in its latest round of master planning to provide comprehensive public service guarantees covering all age groups, with a focus on ensuring public facilities for the elderly, children, individuals with disabilities, and providing more open and accessible public service facilities for young people [6].

In recent years, the scientific operation of urban public affairs has been increasingly emphasized [7–10]. The academic community also attaches great importance to spatial equity in the allocation of resources such as public services during the urban development process [11–16]. Scholars have conducted a certain level of research on the differences in demand for public service facilities among different groups. Scott et al. (1996) argued that the configuration of park green space should not only consider the equity of spatial distribution, but also meet the needs of different groups in order to more reasonably meet the requirements of fair and equitable configuration [17]. Some studies have focused on the relationship between the attributes of economic characteristics such as income level of social groups and the level of public services. For example, Omer (2006) found significant spatially divergent characteristics of both income levels and park service levels of social groups [18]; Panter et al. (2008) found that attention should be paid to the improvement of sports facility service levels for low-income groups by studying the relationship between household income and sports facility use [19]. The growth of the youth population is particularly important for enhancing urban vitality, and the demand of this group for public services is also a focal point of much research. Under the concept of healthy city and inclusive city, some scholars have proposed a framework for spatial planning work oriented to the health needs of the population [20]. Xia et al. (2020) focused on the effective use of accessibility facilities for people with disabilities [21]. Wang et al. (2022) proposed a strategy for the configuration of public service facilities for the autistic population [22].

Due to the widespread existence of differences in demand among different age groups and the universality of these patterns on a global scale, many scholars are paying attention to the variations in demand for public service facilities among different age groups. For the child group, it is generally accepted that attention needs to be paid to their health, safety, education, and environmental needs [23]. Allen et al. (2017) paid high attention to children's needs for medical and health services [24]. Nong Yun (2022) argues that the layout of public service facilities also needs to consider the higher safety care facilities needed by infants and children aged 0–3 years [25]. Chen et al. (2023) argued that basic public services such as health, safety, education, culture and leisure, and green space are more important for children [23]. The growth of youth groups is particularly important for the enhancement of urban vitality, and the needs of this group for public services have been the focus of many studies [26]. Ries et al. (2011) argued that recreational facilities are crucial for youth groups [27]. Yin et al. (2022), on the other hand, argued that young people are in a changing stage of the life cycle, which generates cyclical and dynamic changes in demand as their life stages change [28]. Middle age is the age group between youth and old age, and is an important life stage in which family responsibilities are assumed. Established studies have discussed relatively little about the needs of the middle-aged group for public service facilities, and some studies in related fields have suggested that middle-aged people should pay more attention to the needs of health and sports [29,30]. With an increasing number of cities entering the stage of population aging, there has been a growing body of research on the demand for public services among the elderly population. Medical and elderly care services are generally considered to be the types of facilities that are in high demand by the elderly population. Medical services and elderly services are generally considered to be the types of facilities highly demanded by the elderly population, in addition to cultural and sports facilities that are relatively necessary [31–34].

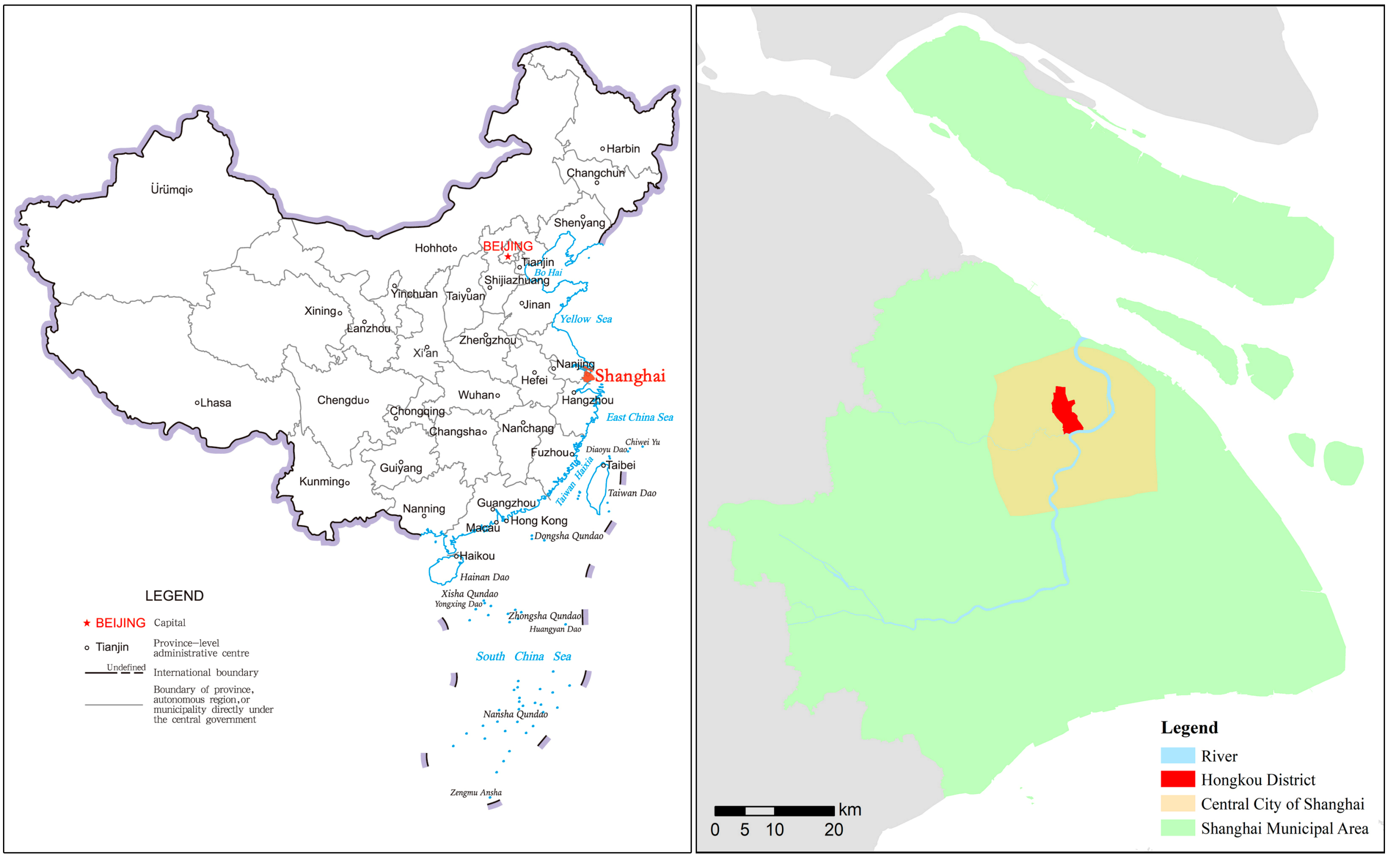
In response to spatial planning needs, many scholars have conducted research on the layout and configuration of public service facilities based on people's demands. For example, Talen et al. (1998) studied the accessibility of children's groups and activity spaces [35]; Hua (2015) conducted a study on the layout of public service facilities in residential areas based on the travel characteristics of the elderly, and suggested that both dispersed and mixed layouts are more suitable for the needs of the elderly [36]; He et al. (2010) and Shao et al. (2016) respectively analyzed the demand characteristics of public service facilities in social housing communities based on the characteristics of resident groups and behavioral preferences [37,38]; Ge et al. (2009) explored the planning of public service facility systems in development zones based on the needs of residents and enterprises [39]; Wang et al. (2014) studied the layout of basic public service facilities from the perspective of socio-spatial differentiation [40]. The analysis of the rationality of facility layout and the optimization of layout decisions to meet practical needs generally makes use of spatial quantitative analysis methods and tools such as Geographic Information Systems (GIS) [35,41–43]. These methods and tools provide important support for measuring facility accessibility [44–48]. Fairness is the fundamental orientation of the layout of public service facilities, and it is also a crucial focus of spatial quantitative research in this field. According to the review of existing literature, it can be observed that spatial analysis methods are often combined with indicators such as the Gini coefficient to measure distribution equity, to analyze the fairness of facility layout in the spatial context [49]. For example, Delbosc et al. (2011) used Lorenz curves to measure the fairness of public transportation services [50]; Tang et al. (2015) analyzed the social performance of public green space distribution based on the Gini coefficient [51]; Cheng et al. (2022) studied the fairness of elderly care facility distribution [52]. Analyzing the spatial distribution of service supply and demand levels for public service facilities and further comparing the relationship between supply and demand is beneficial for identifying critical supply-demand contradictions from a spatial perspective. This is also a common approach to utilize spatial quantitative analysis methods to assist in optimizing facility layout decisions. For example, Xiong et al. (2022) conducted research on the supply-demand conflicts of rural public sports facilities [53]; Song et al. (2014) studied the optimization of spatial layout in primary and secondary schools based on the relationship between student demand and facility supply levels [54]; Cui et al. (2022) conducted research on the distributional disparities of public service facility supply and demand by combining the Urban Network Analysis toolbox (UNA) [55]. In addition, location allocation models can be used to make siting decisions based on certain principles related to the spatial supply and demand of facilities. They can also provide essential support for research on optimizing facility spatial layouts. For example, Suarez-Vega et al. (2011) conducted multi-criteria optimization allocation research based on the proportional choice rule [56]; Han et al. (2014) conducted primary school layout optimization research based on the minimization impedance model and maximization coverage model [57]; Mishra et al. (2019) conducted research on healthcare location decision-making with the objective of enhancing spatial efficiency [58].

In general, there has been a lot of mature research on the optimization of the layout of a single type of public service facility, or a single group of people. However, the layout of public service facilities in cities is a systematic project, and the layout of different types of facilities needs to be coordinated with each other, and a single type of facility may also take into account the needs of different groups at the same time. In other words, different types of public service facilities do not exist in isolation, but in fact have interlinked relationships. Therefore, it is necessary to plan the spatial layout of public service facilities based on a systematic approach, ensuring that all groups can access basic public services more fairly. The main objectives of this study are as follows: (1) To explore and design a systematic planning and decision-making method based on spatial quantitative analysis, which can systematically respond to the spatial layout demands of different groups for public service facilities; (2) Through the application of this method, to effectively support urban public service facility planning and systematically enhance the equity of planning schemes for different groups. Based on this purpose, this study selects Hongkou District in Shanghai as a case study to carry out research on the spatial layout optimization methods for different age groups. The relevant content includes the introduction of case characteristics, the proposal of methods, application analysis based on the methods, discussion of results, and conclusions.

## 2. Materials and Methods

### 2.1. Study Area

The area of this study is Hongkou District, Shanghai, and its spatial location in Shanghai are shown in Figure 1. Hongkou District is located in the central urban area of Shanghai and is entirely developed as an urban area. Hongkou District has an area of 23.45 square kilometers and a resident population of 852,476 (2010). Hongkou District is divided into eight sub-districts, namely Sichuanbeilu, Tilanqiao, Jiaxinglu, Ouyanglu, Quyanglu, Guangzhonglu, Liangchengxincun, and Jiangwanzhen.




(a) Location of Shanghai in China (b) Location of Hongkou in Shanghai

**Figure 1.** Location of Hongkou District (Note: the base map of China uses data from the Standard Map Service Website of the Ministry of Natural Resources of China, with the number GS(2019)1651).

### 2.2. Materials

The main data materials required for this study include: (1) Spatial location data of various types of basic public service facilities in Hongkou District; (2) Population spatial distribution data of different age groups in Hongkou District. The types of public service facilities include basic education (primary and junior high schools), medical services, cultural services, sports services, elderly care services, and green spaces. All facilities have the attributes of spatial location and land area. The spatial layout of various types of public service facilities in Hongkou District is shown in Figure 2. The spatial distribution of population data is derived from the sixth population census, and the scale of spatial units is subdivided to the community level. The resident population in each spatial unit is categorized into four age groups: 0–14 years, 15–29 years, 30–59 years, and 60 years and above, corresponding to children, youth, middle-aged, and elderly groups, respectively.

The spatial distribution of the resident population density in Hongkou District is shown in Figure 3, and the spatial distribution of the population proportions of different age groups is shown in Figure 4. Due to research constraints, all data is based on the time period between 2010 and 2015. It should be noted that in order to ensure the reliability of the analysis results for the peripheral areas of the administrative divisions, the collection scope of facility and population data has been expanded by 1 km beyond the boundaries of Hongkou District. All data is stored in a GIS database, but the data within the expanded range is not displayed in the maps.

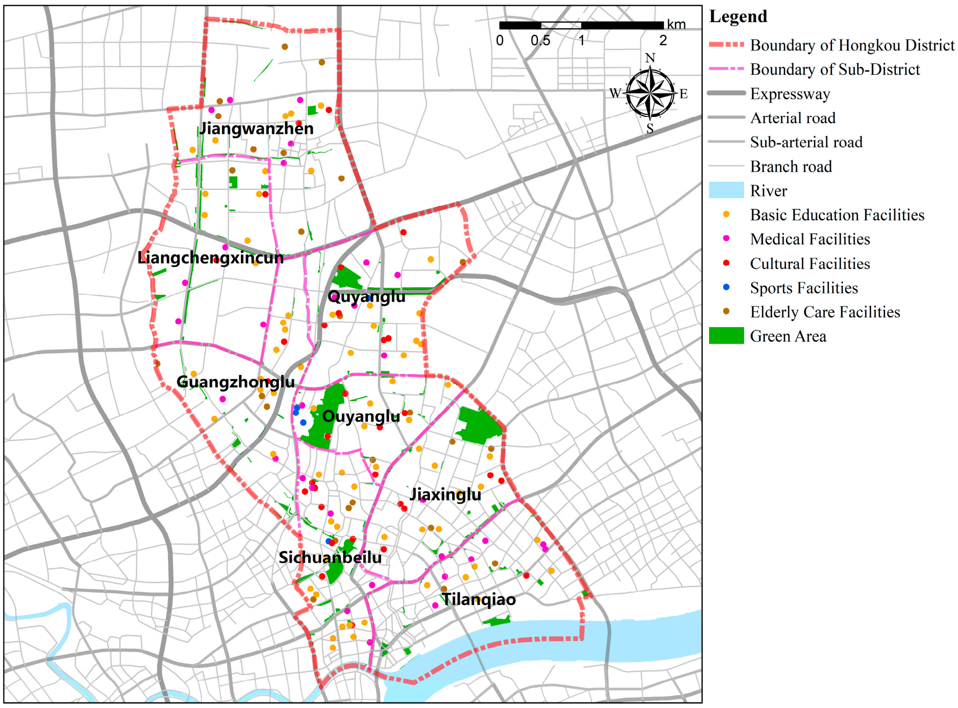



**Figure 2.** Layout of public service facilities within the study area.

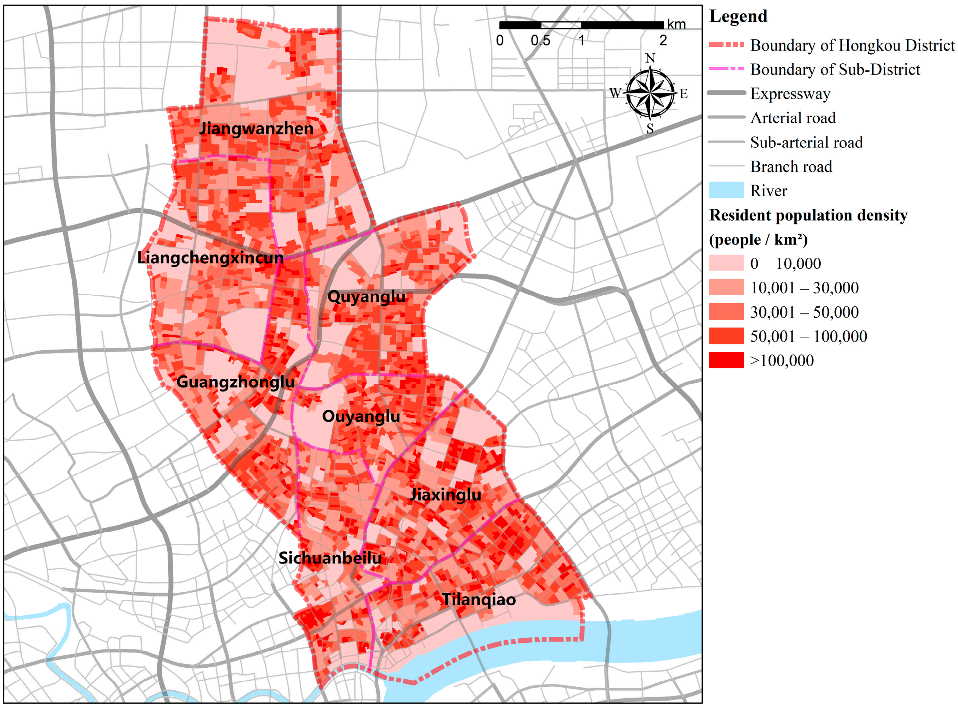



**Figure 3.** Density of resident population within the study area.

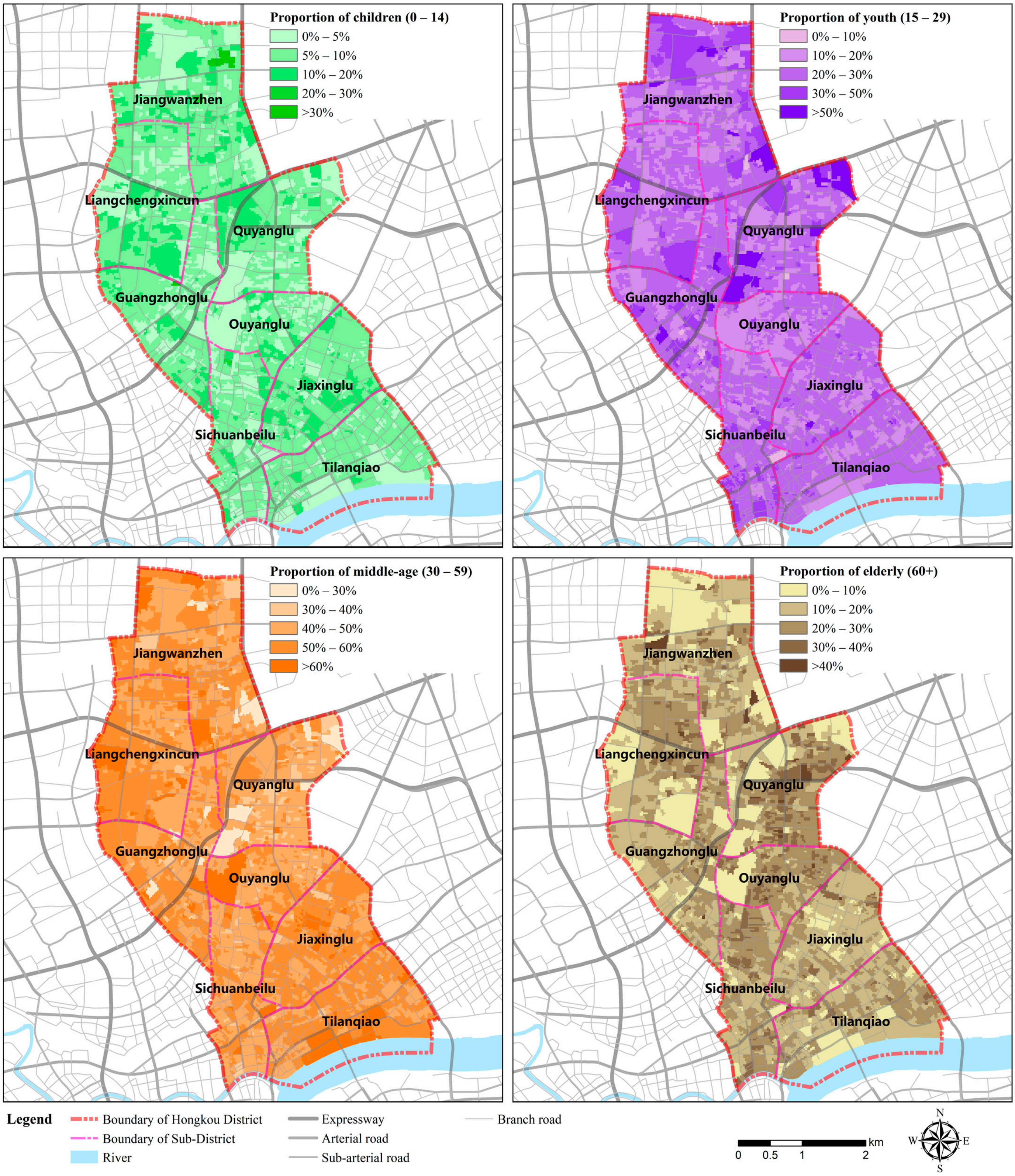



**Figure 4.** Proportion of population in different age groups.

## *2.3. Methods*

A method for optimizing the layout of public service facilities based on the needs of different age groups is the focus of this study. This study proposes a systematic approach with the process shown in Figure 5.

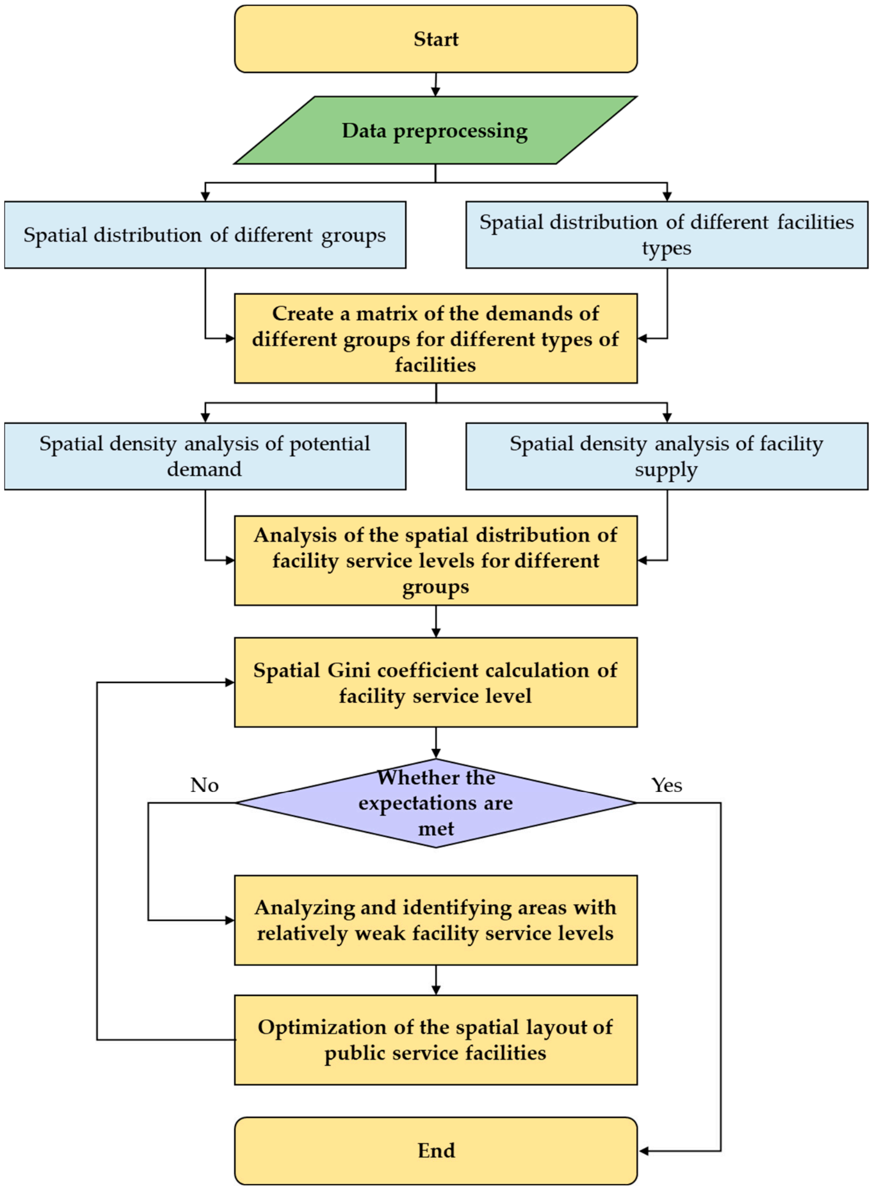



**Figure 5.** Analysis Method Flowchart.

First, the data need to be pre-processed. For data on the spatial distribution of public service facilities, classification and sorting are carried out. It should be noted that data on public service facilities include not only spatial location, but also scale attributes of the facilities. In this study, the scale related attribute that can be obtained is the area of the facility site. ArcGIS software was used to conduct the spatial analysis.

Second, a matrix of different groups' needs for different types of public service facilities is established. This matrix can be determined by a combination of literature analysis, resident surveys, and other methods. The matrix proposed in this study is shown in Table 1. The facility demand is categorized into three types: highly needed (class A), relatively needed (class B), and not needed (class C). In general, green space is important for all age groups. In addition, the children's group is more in need of basic education facilities; the youth group is more in need of cultural and sports facilities; the middle-aged group is more in need of medical, cultural, and sports facilities; and the elderly group is more in need of medical and elderly care facilities. Based on this matrix, the following calculations are performed: (1) the density distribution of different age groups, and (2) the spatial supply density of public service facilities targeting different age groups. The search radius for density calculation is set as the service radius of the facility, which is 1 km. For any point in space (raster cell or vector grid), the population density of different groups ($D_P$) and integrated capacity supply density of public service facilities ($D_F$) within a radius of 1 km are calculated with it as the center of the circle. The calculation method of $D_F$ is as follows: normalize the capacity density values of various facilities to a range of 0–1; assign different weights to different demands based on the matrix table, with a weight of 1 for Class A, 0.5 for Class B, and 0 for Class C; calculate the integrated capacity supply density of public service facilities for different population groups by combining the density values of various facilities with their corresponding weights.

**Table 1.** Public service facilities needed by different age groups.

| Groups by Age | Green Area | Basic Education Facilities | Medical Facilities | Cultural Facilities | Sports Facilities | Elderly Care Facilities |
|---|---|---|---|---|---|---|
| Children (0–14) | A | A | B | B | B | C |
| Youth (15–29) | A | C | B | A | A | C |
| Middle-aged (30–59) | A | C | A | A | A | B |
| Elderly (60+) | A | C | A | B | B | A |

A represents "highly needed", B represents "relatively needed", and C represents "not needed".

In the third step, the level of public service ($L_G$) for different population groups is calculated for each point in space (raster cell or vector grid). Based on the $D_P$ values and $D_F$ values obtained in the previous step for each point (raster cell or vector grid), $L_G$ is calculated as $L_G = D_F/D_P$. This calculation method takes into account the relationship between the supply capacity of facilities within the service range (1 km) and the potential demands of the population at any given location. In other words, if the capacity of public service facilities in a community (and its surrounding area) is low, but the corresponding population within the range is also low, the service level received by the group may not necessarily be low. The specific situation needs to be determined based on the calculated $L_G$ values.

In the fourth step, the spatial equity of the level of public services received by residents of different age groups is calculated. The Gini coefficient method is an important tool used to measure inequality in social distribution, and its application has gradually expanded from income inequality to the study of inequality in other areas such as the economy and society. Combining the existing literature on quantitative measurement of spatial equity, the Gini coefficient is introduced into the calculations in this stage [49–52]. The spatial Gini coefficient G of the level of public services received by a group is calculated by taking the $L_G$ values of all points (raster cells or vector grids) in the study area and the population count value $P_G$ of a group.

$$G = 1 - \sum_{i=0}^{n-1} (P_{i+1} - P_i)(L_{i+1} + L_i) \quad (1)$$

where $n$ is the number of all points (raster cells or vector grids) in the study area; $P_i$ is the cumulative proportion of $P_G$ values for the first $i$ points (raster cells or vector grids); and $L_i$ is the cumulative proportion of $L_G$ values for the first $i$ points (raster cells or vector grids). The value of Gini coefficient $G$ is in the interval from 0 to 1. The smaller the value, the more equal the distribution of public services in space.

The fifth step is to judge whether the calculation result of Gini coefficient G meets the planning objective. The interpretation of Gini coefficient values in terms of fairness can be referenced from international standards used to measure income distribution fairness. Generally, when the Gini coefficient is below 0.2, it indicates a very high level of fairness. However, when the Gini coefficient exceeds 0.4 or even 0.5, it suggests a significant presence of income inequality. If the calculated Gini coefficient of the facility service level is low and meets the planning objectives, it indicates that major adjustments to the existing facility layout are not necessary. If the Gini coefficient is high, this indicates that the layout of facilities needs to be adjusted in response to optimization. The spatial distribution of public service levels received by different groups can be analyzed comprehensively to identify relatively weak areas, some of which may have weak service levels for a single group and some of which may have weak service levels for multiple groups. Based on this analysis, the focus should be on enhancing the facility layout in the areas with weak service levels, resulting in an optimized plan. Furthermore, the optimized plan should be analyzed using the Gini coefficient again. If there is a significant decrease in the value and it meets the planning objectives, this indicates that the plan is viable. However, if it still fails to meet the planning objectives, further optimization of the plan is required.

## 3. Process and Results

The analysis process and results of the case study conducted in Hongkou District, Shanghai are presented in the following text.

### *3.1. Analysis of the Spatial Distribution of Facility Service Levels for Different Groups*

First, the focal statistical analysis was carried out based on the population density distribution of each group. The search radius is set to 1 km, and the average density within 1 km (radius of the circular area) around any point (raster image element) on the space is calculated. This result can reflect the potential demand intensity at any location (considering the service radius of the facility). Figure 6 shows the spatial distribution of the population density of the elderly group in Hongkou District (search distance = 1 km). It can be seen that the area with higher density is near Ouyanglu sub-district, and the relatively lower areas are in the north and south. The densities of other groups were also calculated by the same method, and the relevant pictures are not shown due to the limitation of the length of the article.

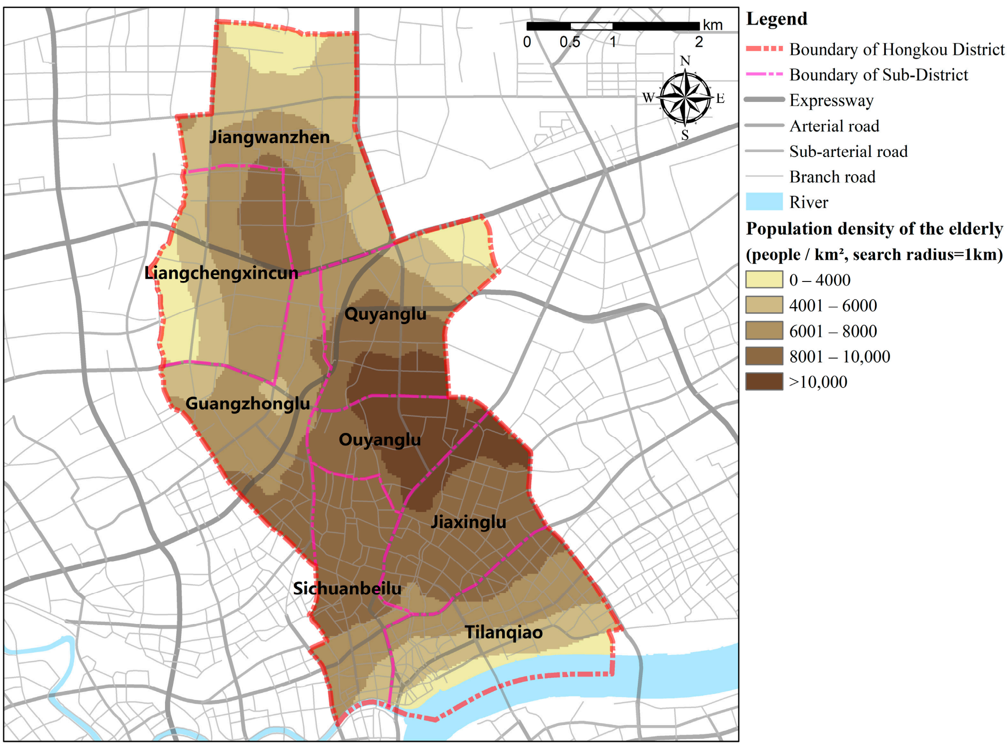



**Figure 6.** Population density of the elderly group (search radius = 1 km).

Next, density analysis is carried out based on various types of facilities. Similarly, the search radius is set to 1 km, and the density of facility capacity within 1 km (the radius of the circular area) around any point (raster image element) on the space is calculated. The capacity of the facility is measured in terms of the area of the site. This result can reflect the level of facility supply at any location. Figure 7 shows the spatial distribution of the density of park green space in Hongkou District. It can be seen that the areas with higher density are the central areas, and the areas with lower density are some areas in the southeast, north, and west. The density of other facilities is also calculated by the same method, and the relevant pictures are not shown due to the limitation of the text.

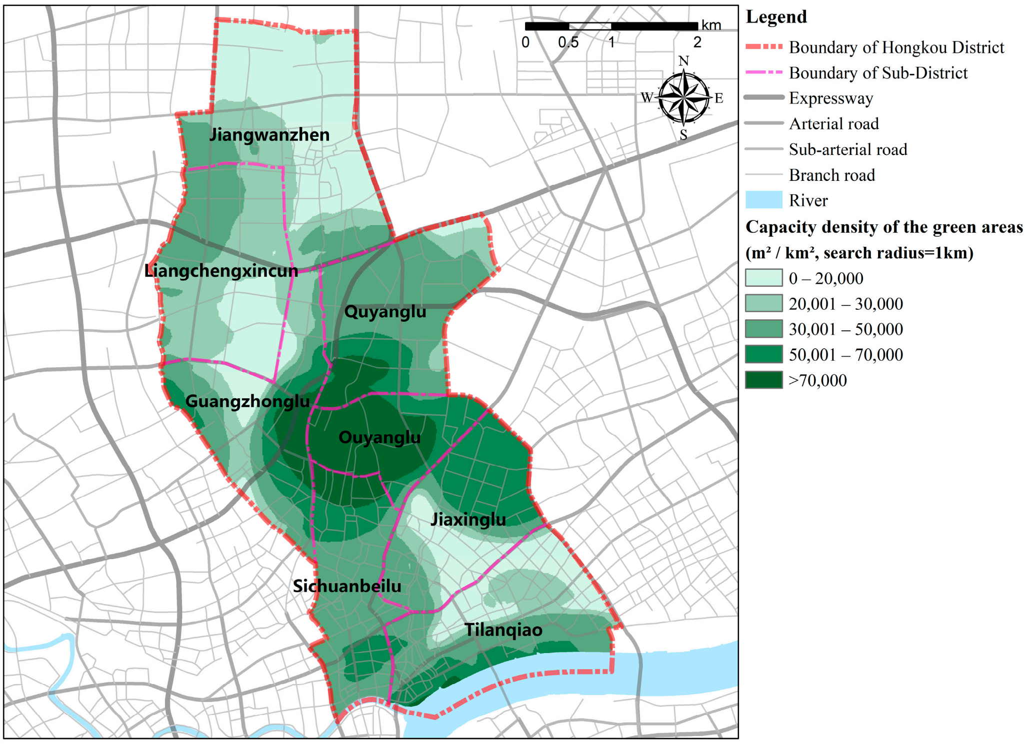



**Figure 7.** Capacity density of the green areas (search radius = 1 km).

To facilitate data storage and analysis, starting from this stage, the study area was divided into 100 m × 100 m vector grids, with each grid serving as the basic spatial unit. The values of the above two density calculation results are aggregated into the grid polygon by zonal statistics. The attribute table of the grid polygon can store multiple fields, including population density of various groups and density values of different types of facility capacities. The facility capacity density values are standardized, and the comprehensive capacity supply density of public service facilities for different groups ($D_F$) is calculated based on the weights in the matrix table (Table 1), as shown in Figure 8. In general, the values are generally higher in the central region, and there is some commonality in the spatial distribution of $D_F$ values for different groups, but there are also significant differences.

It should be noted that higher values of $D_F$ in an area do not necessarily indicate a higher level of service. This is because $D_F$ only reflects the density of facility capacity and does not consider the degree of availability or scarcity of these resources for the surrounding population to share and access. Therefore, further calculations were carried out to determine the level of public service facilities received by different population groups in the region, denoted as $L_G$. The results are shown in Figure 9. It can be observed that the $L_G$ values in the central region are not as prominent as the high $D_F$ values. This is because, although the central region has a higher capacity of facilities, the population density is also relatively high, which leads to a more average level of service that can be accessed per capita. From Figure 9, it can be observed that the regions with generally higher $L_G$ values include the eastern part of Guangzhonglu sub-district and the southern part of Tilanqiao sub-district (riverside area). Different age groups show variations in $L_G$ values. The $L_G$ values for the children group are relatively higher in the eastern part of Quyanglu sub-district. The $L_G$ values for the youth group are relatively higher in the northern part of Sichuanbeilu sub-district and the southern part of Ouyanglu sub-district. The $L_G$ values for the middle-aged group are relatively higher in the eastern part of Quyanglu sub-district. The $L_G$ values for the elderly population are relatively higher in the northwestern part of Jiangwanzhen sub-district and the eastern part of Quyanglu sub-district.

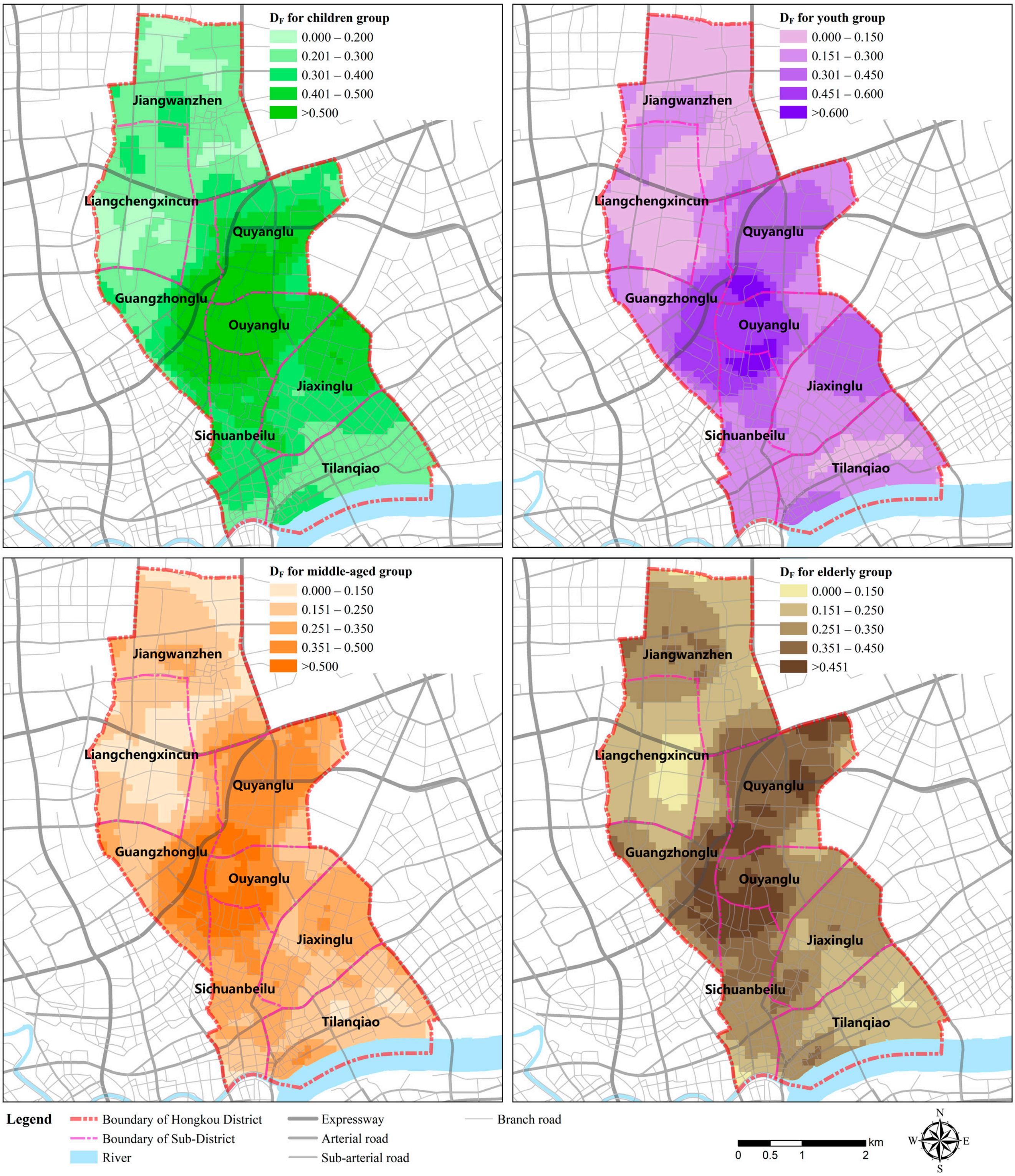



**Figure 8.** Spatial distribution of $D_F$ values for different groups.

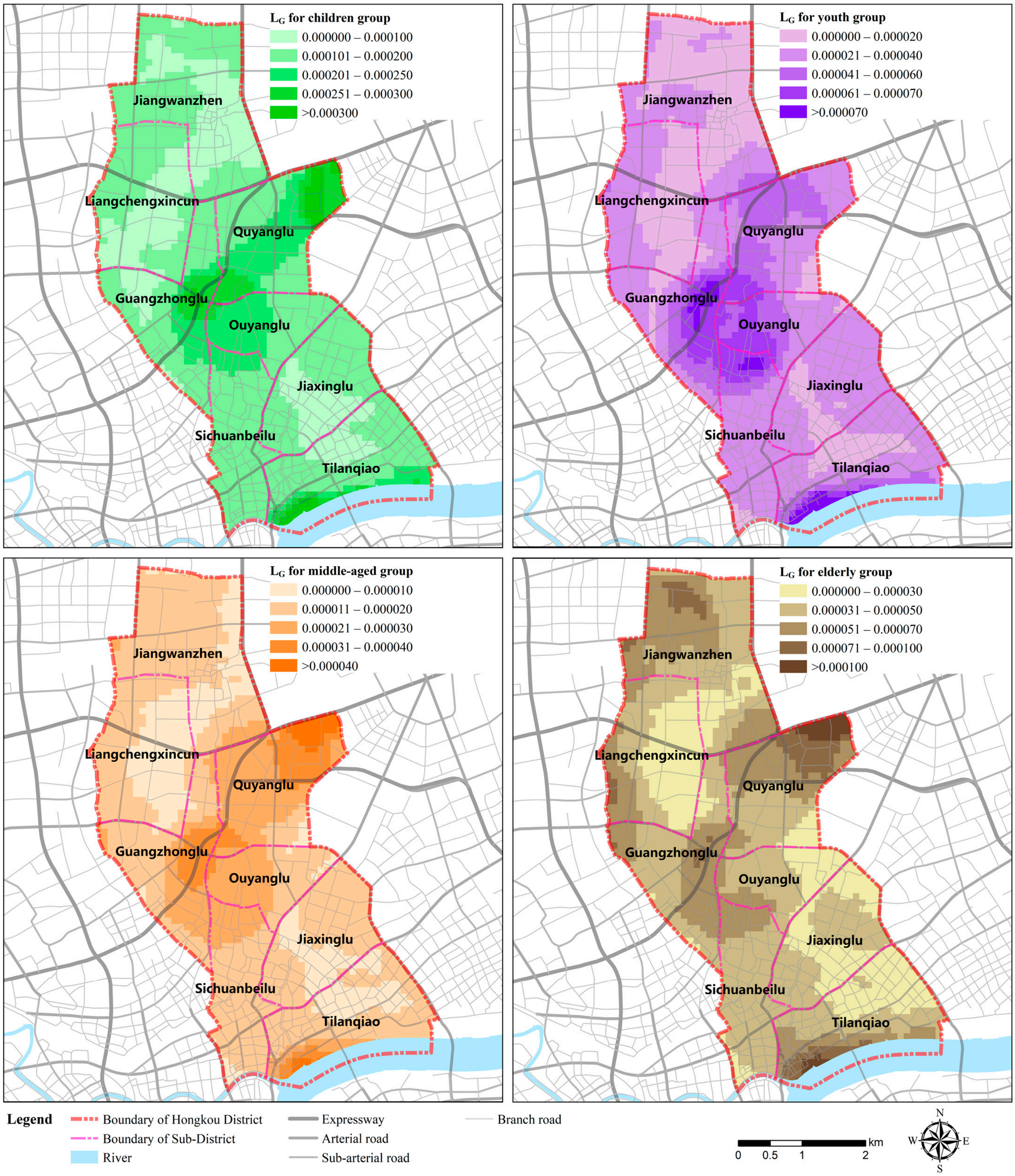



**Figure 9.** Spatial distribution of $L_G$ values for different groups.

## *3.2. Spatial Gini Coefficient Calculation of Facility Service Level*

Further, the Gini coefficient of the level of public services received by the inhabitants of different age groups is calculated. Lorenz curves were plotted based on the $L_G$ values of the level of public services of facilities received by different groups of people on all grid polygons (2499 in total) and the $P_G$ values of the population size of the corresponding groups. As shown in Figure 10, the horizontal axis is the cumulative proportion of $P_G$ values and the vertical axis is the cumulative proportion of $L_G$ values. If the Lorenz curve passes through the coordinate point of (0.5, 0.3), it means that the cumulative 50% of the population enjoys only 30% of the cumulative amount of the service level, and this situation shows a certain degree of inequity. In case of absolute equity, it should be the case that the cumulative 50% of the population enjoys 50% of the cumulative amount of the service level, and the Lorenz curve should be presented as a straight line with y = x. Therefore, if the Lorenz curve is farther away from y = x and closer to the lower right, it indicates less fairness. The Gini coefficient G can be calculated based on the Lorenz curve. The formula for calculating G has already been described in the previous section. If viewed from a plane geometry perspective, the value of the Gini coefficient is the ratio of the area enclosed by the y = x line and the Lorenz curve to all the area to the lower right of y = x. According to the calculation, the spatial Gini coefficients G for the level of public services received by the children, youth, middle-aged, and elderly groups are 0.1992, 0.2538, 0.2518, and 0.2107, respectively. It can be seen that: (1) the level of public services in Hongkou District is generally fair; (2) the public services received by the children group are the most equitable, followed by the elderly group; (3) the public services received by the youth and middle-aged groups are relatively less equitable in terms of the public services they receive. The main reasons for the differences in Gini coefficients between population groups may be as follows: (1) for the children group, the basic education facilities (primary and junior high school), which are of great importance, usually require careful consideration of the coverage of residents by facility service radius and the matching of facility capacity with student demand during planning and layout; (2) for the elderly group, the planning and layout of elderly care facilities, which are of great importance, also need to fully consider the convenience of service provision; (3) the distribution and layout of cultural and sports facilities, which are important for the young and middle-aged groups, are not sufficiently balanced, and the facility service radius does not adequately cover the relevant residents.

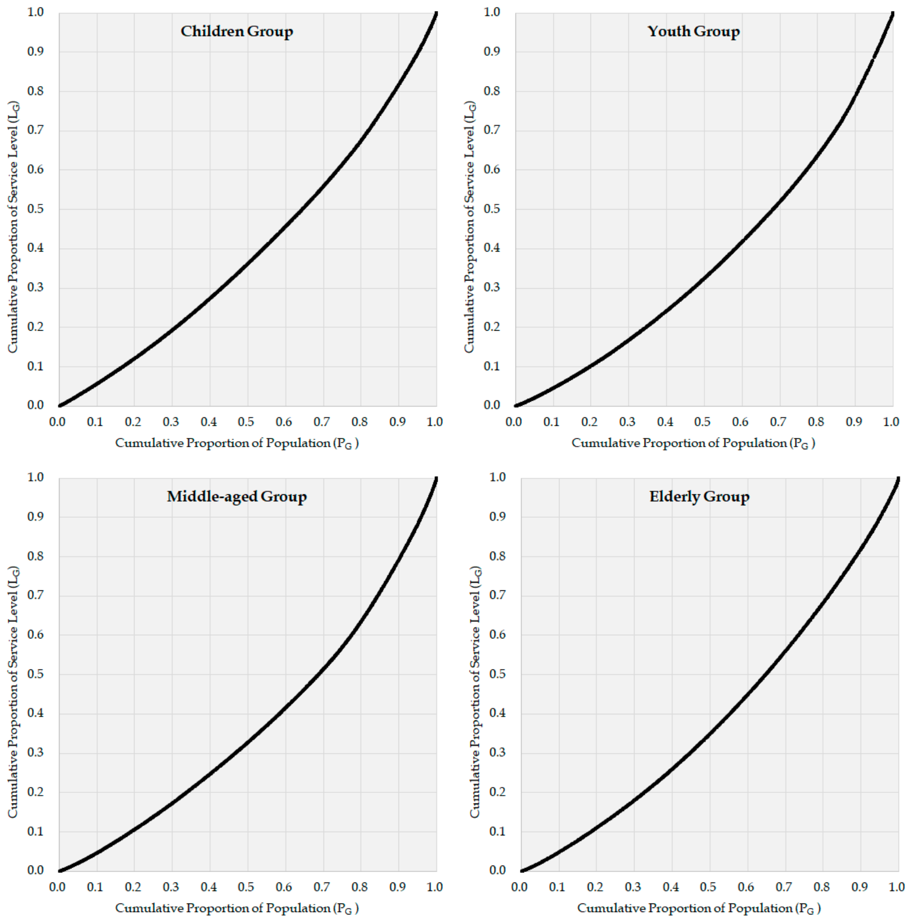



**Figure 10.** Lorenz curve of service levels for different groups.

### 3.3. Analysis of Areas with Relatively Weak Facility Service Levels

If the Gini coefficient obtained from the above analysis meets the planning objectives, the distribution pattern of public service facilities can be maintained. However, if further reduction of the Gini coefficient is desired to enhance the fairness of public service levels for different population groups, it is necessary to identify areas with relatively weak public service levels. This identification will provide support for optimizing facility layout.

If it is only necessary to identify areas with weak public service levels for a single population group, the Ordinary Least Squares (OLS) method can be used to perform simple linear regression analysis on the population density ($D_P$) and comprehensive facility capacity supply density ($D_F$) values for different groups. The residuals can be calculated from this analysis. The residuals can then be used to identify areas where the actual service levels are significantly lower than the predicted values. These areas should be given special attention and the supply of relevant service facilities should be increased. Taking the elderly population as an example, with $D_P$ as the explanatory variable and $D_F$ as the dependent variable, the residuals obtained from the OLS analysis are shown in Figure 11. The areas with negative residuals indicate regions where the public service levels relatively fail to meet the needs of the elderly group.

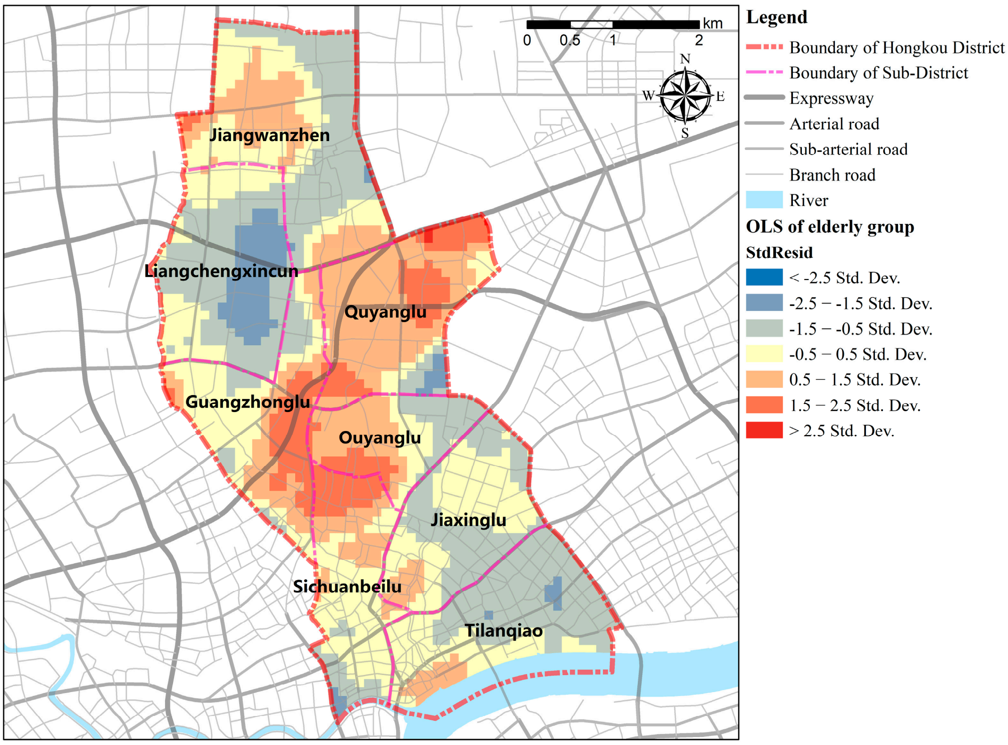



**Figure 11.** Ordinary least square (OLS) of supply and demand of public service facilities for elderly group.

If it is necessary to identify areas with weak public service levels comprehensively for multiple population groups, the identification can be based on the vector grid as the basic spatial unit to identify regions with low comprehensive facility public service levels ($L_G$). In this study, the regions where $L_G$ values for each of the four age groups fall within the lowest one-third range are selected and summarized to form the comprehensive identification results of regions with relatively weak public service levels. This is shown in Figure 12. The white areas within the research area indicate no population group with weak public service levels. The blue, green, and orange areas represent regions where one, two, and three groups, respectively, have weak public service levels. The red area indicates that all four groups have weak public service levels. The legend in Figure 12 explains which specific population groups have weak public service levels, indicated by the corresponding color blocks. "C," "Y," "M," and "O" represent children, youth, middle-aged, and elderly population groups, respectively.

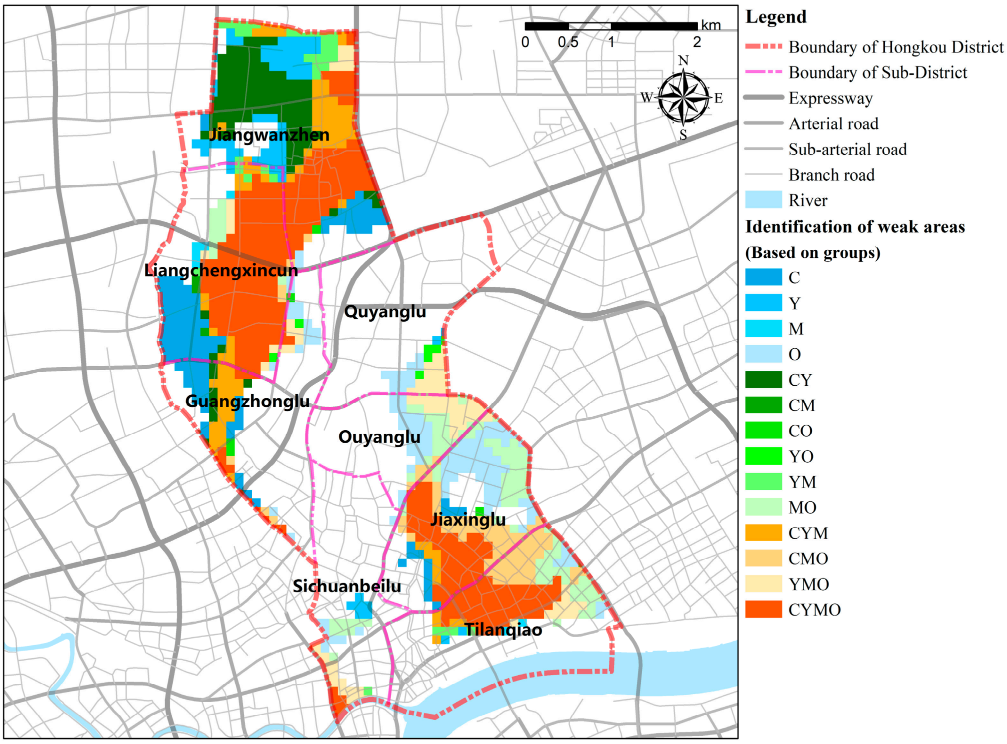



**Figure 12.** Comprehensive identification of areas with relatively weak public service levels.

### 3.4. Optimization of the Spatial Layout of Public Service Facilities

Based on the comprehensive identification of public service level weak areas for multiple population groups shown in Figure 12, optimization of the layout of public service facilities is carried out. The main focus is to increase the layout of relevant public service facilities in the weak areas. The optimization plan proposed in this study is shown in Figure 13, where the star symbols represent the added locations of public service facilities. All facilities are assigned capacity attributes. It should be noted that this is a hypothetical plan and not an actual implementation plan. The main purpose of proposing this plan is to test the method proposed in this study. Furthermore, based on this optimized plan, the previous spatial analysis is conducted, and the Gini coefficients for the public service level of each population group are calculated. The results are shown in Table 2. It can be observed that the Gini coefficients have generally decreased, with the values for the youth and middle-aged groups dropping below 0.2. Taking the youth group as an example, Figure 14 demonstrates a significant shift of the Lorenz curve towards the line y = x. This result indicates the feasibility of the systematic optimization method proposed in this study for the layout of public service facilities targeting different age groups.

The text continues here.

**Table 2.** Gini coefficient before and after public service facilities layout optimization for different age groups.

| Groups by Age | Gini Coefficient before Layout Optimization | Gini Coefficient after Layout Optimization |
|---|---|---|
| Children (0–14) | 0.1992 | 0.1601 |
| Youth (15–29) | 0.2538 | 0.1914 |
| Middle-aged (30–59) | 0.2518 | 0.1890 |
| Elderly (60+) | 0.2107 | 0.1593 |

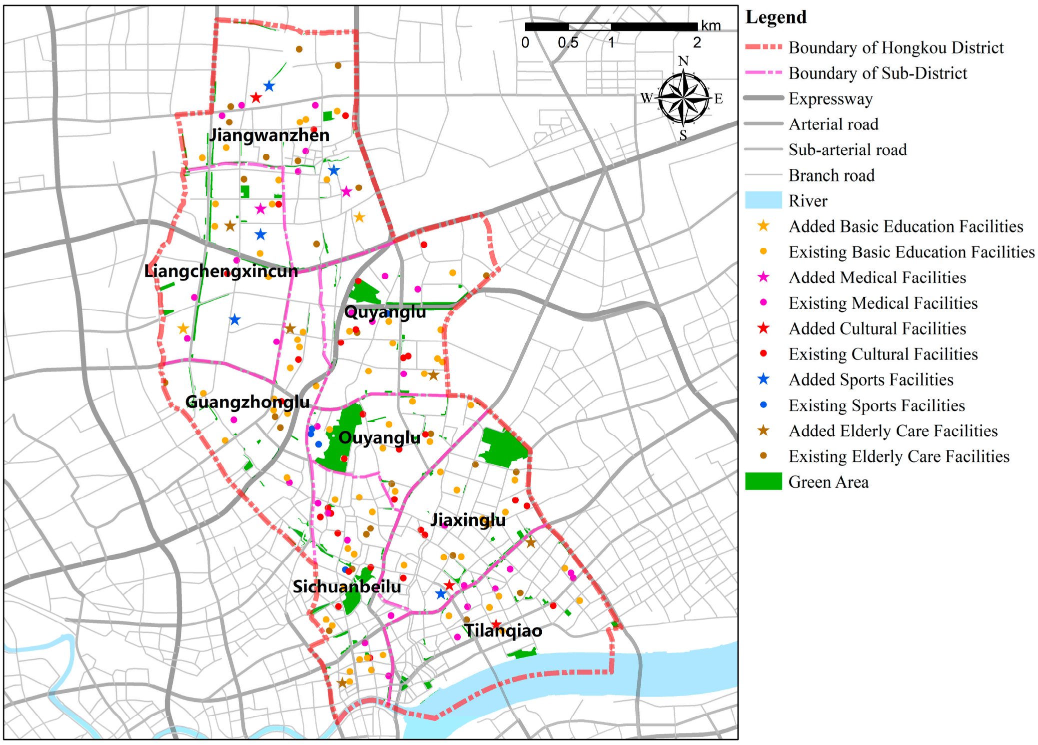



**Figure 13.** Optimized layout plan for public service facilities (used for testing purposes in this method, not a real plan).

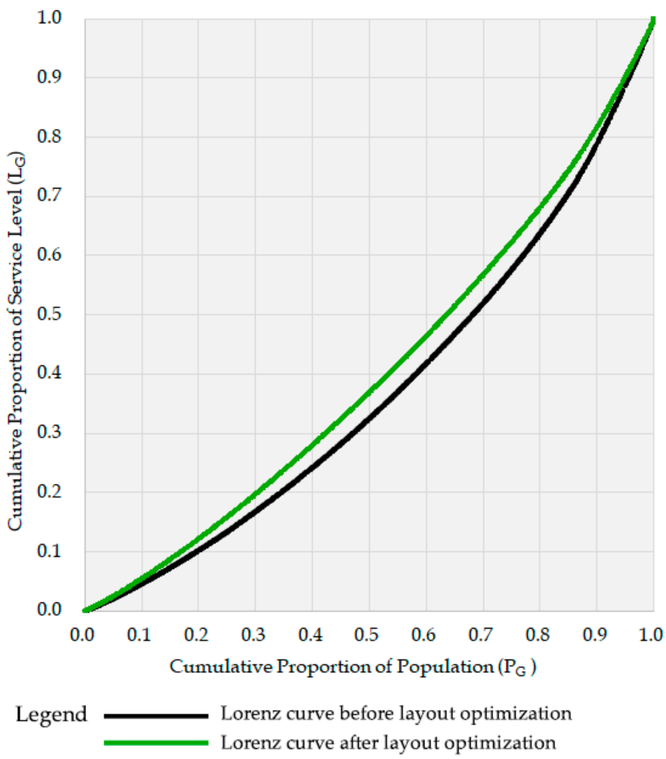



**Figure 14.** Changes in the Lorenz curve based on the optimized facility layout plan of youth group.

## 4. Discussion

### 4.1. The Importance of an Integrated Analysis with a Systemic Perspective

This methodology emphasizes the systemic approach, which is due to the fact that the planning and layout of public service facilities is a systemic project, and thus requires a systemic perspective for integrated decision-making. Two aspects are emphasized here. On the one hand, different types of public service facilities do not exist spatially in isolation, but need to be laid out in coordination with other facilities. As urban space resources are limited, the land space available for the layout of various types of public service facilities is also limited. If various types of facilities are selected and evaluated separately during spatial layout planning, although it may be easier to obtain a better layout plan for a single type of facility, when summarizing the layout plans for various types of facilities, how to coordinate the land resources for the location of the facilities is also a complex and comprehensive task. On the other hand, there is an interconnected relationship between the needs of different groups for public service facilities. Certain types of facilities may satisfy the needs of multiple groups at the same time, although there may be differences in importance. In this case, adjusting the layout scheme of a certain type of facility is likely to have an impact on the spatial distribution of service levels for multiple groups. The methodology proposed in this study, which is based on systemic thinking, is capable of identifying the spatial balance and equity of the level of basic public services received by different groups in an integrated manner within a set of analytical processes. Therefore, the progress of this study also focuses on systemic thinking. For example, compared with Tang's (2015) study focusing on public green spaces, this study expands the range of types of service facilities and realizes the systematic coverage of facilities such as education, healthcare, culture, sports, elderly care, and green spaces, which are closely related to the 15-min living circle [51]; compared with Cheng's (2022) study focusing on the elderly, this study expands the scope of the groups and realizes the coverage of all-age groups [52].

### 4.2. Applicability of the Methodology to Practical Planning Decisions

The process and results of this study, which chose Hongkou District in Shanghai as a case study, show that the methodology proposed in the study is operational and can systematically support the work of planning the layout of public service facilities for different groups. Although the case of this study was chosen at the district level, it is equally applicable to most districts at the municipal level. This is determined by the following aspects: (1) the categories of basic public service facilities are the same; (2) the logic of the basic needs of different groups is the same; (3) the citywide basic public service facilities also need to consider the coverage of the 15-min community living circle scale. In addition, for some special areas within the city where the distribution of the resident population is small and density is low, such as large industrial zones, large-scale scope of infrastructure, large ecological space and other areas, they can be exempted from the analysis of the Gini coefficient of the service level. For rural areas, it is also necessary to meet the coverage needs of basic public services for different groups. However, considering the characteristics of the settlement pattern and spatial distribution of construction land in rural areas, the spatial coverage based on the transportation network can be preferred to analyze the service level of facilities. With regard to the needs of different groups for basic public service facilities and the method of measuring the spatial Gini coefficient, which reflects the fairness of the level of service of facilities, the basic logic is the same in both urban and rural areas.

### 4.3. Extended Discussion on Enhancing the Level of Facility Provision in Weak Areas

One of the results of the methodology proposed in this study that has key decision support value in practical application is the comprehensive identification result of areas with relatively weak public service levels (corresponding to Figure 12 in the case study). This identification result can be directly used to assist decision-making on the optimization of the layout of public service facilities in weak areas. However, in actual planning decisions, it is still necessary to comprehensively consider multiple factors, including spatial, ecological, and social aspects. When planning new facilities in weak areas, it is necessary to comprehensively consider whether there is suitable construction space in the site selection area based on the analysis results. For newly developed areas of the city, site selection is less difficult when there are more land resources available for construction. However, for mature urbanized areas, it may be difficult to find idle land that can be developed. These areas have moved from the stage of new space-led development to the stage of stock space-optimized development. Urban renewal has gradually become one of the main directions for the optimized development of urban space. Therefore, in the context of urban renewal, the siting of new public service facilities can tap the potential from the stock of space, and enhance the utilization efficiency of space resources through the composite use of existing space. It is also necessary to consider the impact of facility operation on the ecological and social systems when selecting new sites, so as to promote the sustainable development of the community as far as possible. In addition, in practical application, it is necessary to comprehensively judge the overall level of provision of public service facilities in the light of the equity situation, so as to avoid a low level of equity.

## 5. Conclusions

This study proposes a systematic method to evaluate and optimize the equity of public service facility layout for different age groups' demands. Firstly, spatial distribution of population and various types of public service facilities for each age group are collected. Secondly, demand matrices for different groups regarding different types of public service facilities are established, and supply-demand density is calculated. Thirdly, the level of public service accessibility for different population groups at any spatial location is calculated. Furthermore, the Gini coefficient is introduced to assess the spatial equity of public service accessibility for different age groups. Finally, the Gini coefficient is evaluated against planning objectives, and if it does not meet the objectives, areas with inadequate public service accessibility are identified for facility layout optimization.

There are also limitations in this study. The division of the resident population into groups by age structure is one of the main features of this study. However, the age structure of the population is not fixed due to natural population growth and population migration occurring at all times. For certain regions, significant changes can occur on a decadal time scale. These changes can largely impact the supply-demand relationship of public service facilities. The dynamic changes in demographic structure, which were not considered in this study, are the primary limitation.

For the future, there are several directions for optimization and improvement in this study. In addition to the dynamic change factors of population structure being introduced, the capacity calculation rules of public service facilities can be optimized, the pedestrian accessibility of public service facilities can be considered more rationally, and the optimization methods of facility layout can be improved, etc. In addition, on the basis of methodological refinement, the standardization of technical processes can be further promoted and a user-oriented planning and decision-making platform can be developed.

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## References


1. *Transforming Our World: The 2030 Agenda for Sustainable Development*; United Nations: New York, NY, USA, 2015.
2. One New York: The Plan for a Strong and Just City. The City of New York. 2015. Available online: https://a860-gpp.nyc.gov/downloads/2b88qc334?locale=en (accessed on 25 June 2023).
3. OneNYC 2050 Building a Strong and Fair City. The City of New York. 2019. Available online: https://onenyc.cityofnewyork.us/wp-content/uploads/2020/01/OneNYC-2050-Full-Report-1.3.pdf (accessed on 25 June 2023).
4. *Culture for All Londoners: Mayor of London's Culture Strategy*; Greater London Authority: London, UK, 2018.
5. The People Build the City, and the City Belongs to the People. 24 July 2020. Available online: http://sh.people.com.cn/n2/2020/0724/c375987-34181219.html (accessed on 26 June 2023).
6. Shanghai Municipal People's Government. *Shanghai Master Plan (2017–2035)*; Shanghai Scientific & Technical Publishers: Shanghai, China, 2018.
7. Nasi, G.; Choi, H.; Cucciniello, M.; Christensen, R.K. A systematic literature review of city competitiveness: A 30-year assessment and future agenda for public administration. *Public Manag. Rev.* **2023**, *25*, 1562–1586. [CrossRef]
8. Lebrument, N.; Zumbo-Lebrument, C.; Rochette, C.; Roulet, T.J. Triggering participation in smart cities: Political efficacy, public administration satisfaction and sense of belonging as drivers of citizens' intention. *Technol. Forecast. Soc. Chang.* **2021**, *171*, 120938. [CrossRef]
9. Dušek, J. Data Boxes as a Part of the Strategic Concept of Computerization of Public Administration in the Czech Republic. *Adm. Sci.* **2023**, *13*, 154. [CrossRef]
10. Jankelová, N.; Joniaková, Z.; Čajková, A.; Romanová, A. Leadership competencies in communal policy. *Politické Vedy* **2021**, *24*, 181–204. [CrossRef]
11. Lucy, W. Equity and Planning for Local Services. *J. Am. Plan. Assoc.* **1981**, *47*, 447–457. [CrossRef]
12. Wicks, B.E.; Crompton, J.L. Citizen and Administrator Perspectives of Equity in the Delivery of Park Services. *Leis. Sci.* **1986**, *8*, 341–365. [CrossRef]
13. Hay, A.M. Concepts of Equity, Fairness and Justice in Geographical Studies. *Trans. Inst. Br. Geogr.* **1995**, *20*, 500–508. [CrossRef]
14. Ren, P. Space Justice—Contemporary China towards the Sustainable Urbanization. *Urban Dev. Stud.* **2006**, *5*, 1–4.
15. Jiang, H.; Zhou, C.; Gao, J. Advance in the Equity of Spatial Distribution of Urban Public Service in Western Countries. *City Plan. Rev.* **2011**, *35*, 72–77.
16. Li, A.; Zhang, J. Equal Urban Rural Public Service Facility Development. *Planners* **2011**, *27*, 5–11.
17. Scott, D.; Jackson, E.L. Factors that limit and strategies that might encourage people's use of public parks. *J. Park Recreat. Adm.* **1996**, *14*, 1–17.
18. Omer, I. Evaluating accessibility using house-level data: A spatial equity perspective. *Comput. Environ. Urban Syst.* **2006**, *30*, 254–274. [CrossRef]
19. Panter, J.; Jones, A.; Hillsdon, M. Equity of access to physical activity facilities in an English city. *Prev. Med.* **2008**, *46*, 303–307. [CrossRef]
20. Wang, L.; Jia, Y.; Zhu, X.; Wang, X.; Li, J.; Gu, H. Integrating Health in Territorial Spatial Master Planning: Methodology and Practice. *Urban Plan. Forum* **2021**, 81–87.
21. Xia, J.; Chen, H.; Wang, X. Study on the Low Utilization Frequency of Barrier-Free Facilities from the Perspective of People with Disabilities: With Nanjing City as an Example. *City Plan. Rev.* **2020**, *44*, 47–56.
22. Wang, J.; Zhu, W. Allocation Strategies for Asd-Friendly Urban Public Service Facilities. *City Plan. Rev.* **2022**, *46*, 75–86.
23. Chen, T.; Shi, C.; Zhang, R. A Comparative Study on the Spatial Layout of Public Service Facilities in Chinese and Foreign Cities from the Perspective of Children's Needs: Tianjin and Singapore as Examples. *Urban Dev. Stud.* **2023**, *30*, 32–40.
24. Allen, E.P.; Muhwezi, W.W.; Henriksson, D.K.; Mbonye, A.K. Health facility management and access: A qualitative analysis of challenges to seeking healthcare for children under five in Uganda. *Health Policy Plan.* **2017**, *32*, 934–942. [CrossRef]
25. Nong, Y. Improvement Strategies of Public Service Configuration for 0–3 Years Old Infants Based on Behavior Analysis. *Planners* **2019**, *35*, 20–25.
26. Zhu, F.; Zhang, J.; YI, Y. The Reasons for the Rise, the Evaluation Strategies and the Enlightenment of Youth-friendly Cities in Developed Countries. *Youth Res.* **2019**, 71–80.
27. Ries, A.V.; Yan, A.F.; Voorhees, C.C. The Neighborhood Recreational Environment and Physical Activity Among Urban Youth: An Examination of Public and Private Recreational Facilities. *J. Community Health* **2011**, *36*, 640–649. [CrossRef]
28. Yin, Z.; Jiao, J.; Wang, D.; Liu, Z.; Zhang, Y.; Ouyang, L. Study on Youth Living Space and the Demand for Public Service Facilities in Hangzhou. *Shanghai Urban Plan. Rev.* **2021**, 85–90.

29. Tomiak, M.; Gentleman, J.F.; Jette, M. Health and gender differences between middle and senior managers in the Canadian Public Service. *Soc. Sci. Med.* **1997**, *45*, 1589–1596. [CrossRef]
30. Burton, N.W.; Haynes, M.; Wilson, L.M.; Giles-Corti, B.; Oldenburg, B.F.; Brown, W.J.; Giskes, K.; Turrell, G. HABITAT: A longitudinal multilevel study of physical activity change in mid-aged adults. *BMC Public Health* **2009**, *9*, 76. [CrossRef]
31. Shen, S.; Hu, T.; Luan, A. Research Progress and Construction Practice of Urban Elderly Public Service Facilities. *Mod. Urban Res.* **2014**, 26–33.
32. Wang, S.; Yung, E.; Hiu, K.; Yu, Y.; Tsou, J.Y. Right to the city and community facility planning for elderly: The case of urban renewal district in Hong Kong. *Land Use Policy* **2022**, *114*, 105978. [CrossRef]
33. Wu, Y.; Dai, Z. A Population-diversity-oriented Survey on the Adaptability of Public Facilities in Urban Community for the Aged. *Archit. J.* **2014**, *5*, 60–64.
34. Zhao, Z. Research on Configuration of Public Service Facilities in Hainan Based on Migratory Bird Crowd. *Urban Archit. Space* **2022**, *29*, 86–88.
35. Talen, E.; Anselin, L. Assessing spatial equity: An evaluation of measures of accessibility to public playgrounds. *Environ. Plan. A* **1998**, *30*, 595–613. [CrossRef]
36. Hua, C. A Study of Residential Public Service Facilities Layout Based on Travel Characteristics of the Elderly. *Traffic Transp.* **2015**, *31*, 92–96.
37. He, F.; Li, X. Empirical Study on Demand and Supply Characteristics and Satisfaction Factors of Public Service Facility in Social Housing Community—A Case Study of Gucun Town Sigao Community in Baoshan Shanghai. *Urban Plan. Forum* **2010**, 83–90.
38. Shao, L.; Yuan, Z.; Zhan, H. An Analysis of The Character and Satisfaction of Public Housing Service Facilities for Varied Needs. *Planners* **2016**, *32*, 106–111.
39. Ge, D.; Chen, Y. Controversy on the Public Service Facilities Planning of Economic and Technologic Development Area: A Case Study of Hangzhou Bay Economic Development Zone in Zhejiang Province. *J. Zhejiang Univ. Sci. Ed.* **2009**, *36*, 340–345.
40. Wang, X.; Hu, P.; Shen, S.; Lu, Y.; Shao, D.; Huang, N. Spatial Characters of Public Service Facilities from Social Differentiation Viewpoint. *Planners* **2014**, *30*, 17–24.
41. Joel, E. GIS-based Network Analysis for Optimisation of Public Facilities Closure: A Study on Libraries in Leicestershire, United Kingdom. *J. Geogr. Environ. Earth Sci. Int.* **2019**, *23*, 1–18.
42. Talen, E. Visualizing Fairness: Equity Maps for Planners. *J. Am. Plan. Assoc.* **1998**, *64*, 22–38. [CrossRef]
43. Ribeiro, A.; Antunes, A.P. A GIS-based decision-support tool for public facility planning. *Environ. Plan. B Plan. Des.* **2002**, *29*, 553–569. [CrossRef]
44. Langford, M.; Higgs, G.; Radcliffe, J.; White, S. Urban population distribution models and service accessibility estimation. *Comput. Environ. Urban Syst.* **2008**, *32*, 66–80. [CrossRef]
45. Zhu, H.; Yan, H.; Li, Y. An Optimization Method for the Layout of Public Service Facilities Based on Voronoi Diagrams. *Sci. Surv. Mapp.* **2008**, *33*, 72–74.
46. Comer, J.C.; Skraastad-Jurney, P.D. Assessing the Locational Equity of Community Parks through the Application of Geographic Information Systems. *J. Park Recreat. Adm.* **2008**, *26*, 122–146.
47. Wang, F. Why Public Health Needs GIS: A Methodological Overview. *Ann. GIS* **2020**, *26*, 1–12. [CrossRef]
48. Liu, J.; Zhu, Q. Research of Equalizing Layout of Public Service Facilities: Take Health Facilities of Central Six Districts of Beijing for Example. *Urban Dev. Stud.* **2016**, *23*, 6–11.
49. Niu, X.; Chen, C. Measuring Spatial Equality and Justice of Basic Public Services in Suburban Towns. *Front. Public Health* **2018**, *42*, 42–50.
50. Delbosc, A.; Currie, G. Using Lorenz curves to assess public transport equity. *J. Transp. Geogr.* **2011**, *19*, 1252–1259. [CrossRef]
51. Tang, Z.; Gu, S. An Evaluation of Social Performance in the Distribution of Urban Parks in the Central City of Shanghai: From Spatial Equity to Social Equity. *Urban Plan. Forum* **2015**, 48–56.
52. Cheng, T.; Liu, C.; Yang, H.; Wang, N.; Liu, Y. From service capacity to spatial equity: Exploring a multi-stage decision-making approach for optimizing elderly-care facility distribution in the city centre of Tianjin, China. *Sustain. Cities Soc.* **2022**, *85*, 104076. [CrossRef]
53. Xiong, L.; Xiang, J. The Generation Logic and Governance Enlightenment of Contradictions between Supply and Demand of Rural Public Sports Service—Based the Analysis Perspective of Village Spatial Morphological Environment. *China Sport Sci. Technol.* **2022**, *58*, 94–104.
54. Song, X.; Chen, C.; Zhou, J.; Zhai, Y.; Li, S. Exploration and Improvement of Planning Methods for the Distribution of Primary and Secondary Schools. *City Plan. Rev.* **2014**, *38*, 48–56.
55. Cui, X.; Ma, L.; Tao, T.; Zhang, W. Do the supply of and demand for rural public service facilities match? Assessment based on the perspective of rural residents. *Sustain. Cities Soc.* **2022**, *82*, 103905. [CrossRef]
56. Suárez-Vega, R.; Santos-Peñate, D.R.; Dorta-González, P.; Rodríguez-Díaz, M. A multi-criteria GIS based procedure to solve a network competitive location problem. *Appl. Geogr.* **2011**, *31*, 282–291. [CrossRef]

57. Han, Z.; Du, P.; Wang, L.; Yu, Y.; Zhao, D.; Cong, Y.; Ren, Q. Method for Optimization Allocation of Regional Public Service Infrastructure: A Case Study of Xinghua Street Primary School. *Sci. Geogr. Sin.* **2014**, *34*, 803–809.
58. Mishra, S.; Sahu, P.K.; Sarkar, A.K.; Mehran, B.; Sharma, S. Geo-spatial site suitability analysis for development of health care units in rural India: Effects on habitation accessibility, facility utilization and zonal equity in facility distribution. *J. Transp. Geogr.* **2019**, *78*, 135–149. [CrossRef]