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# Optimizing the Layout of Service Facilities for Older People Based on POI Data and Machine Learning: Guangzhou City as an Example

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**Abstract:** Population aging is a global issue. China is facing the same challenge, especially in its megacities, with more than 10 million permanent urban residents. These densely populated cities urgently need the scientific planning and optimization of the layout of service facilities for older people. Taking Guangzhou, a megacity in China, as an example, this study uses point-of-interest (POI) data and the ID3 machine learning decision tree algorithm to train a site selection model for service facilities for older people. The model can help to select appropriate locations for new service facilities for older people more scientifically and accurately, and it can provide targeted suggestions to optimize the layout of the service facilities for older people in Guangzhou. First, Guangzhou city is divided into 29,793 grids of 500 m × 500 m based on the range of activities of older people, and 985 grids are found to contain service facilities for older people. Then, the POI data of the grid are fed into the ID3 algorithm for training to obtain a prediction model for the selection of sites for service facilities for older people. The effective prediction rate of the model reaches 87.54%. Then, we apply the site selection model to predict the whole city of Guangzhou, and 4534 grids are suitable for service facilities for older people. In addition, considering the degree of concentration of the elderly population in each street, we further filter out 1066 priority grids as the final site selection. Finally, taking into account the situation of the streets in different districts, we propose several strategies to optimize the layout of the construction of service facilities for older people.

**Keywords:** older people; service facilities; Guangzhou; POI; machine learning; layout optimization; aging



**Citation:** Feng, H.; Tang, X.; Zou, C. Optimizing the Layout of Service Facilities for Older People Based on POI Data and Machine Learning: Guangzhou City as an Example. *Land* **2024**, *13*, 700. https://doi.org/10.3390/land13050700

Academic Editors: Vanessa Zorrilla-Muñoz, Maria Silveria Agulló-Tomás, Eduardo Fernandez, Sonia de Lucas Santos, Jesus Cuadrado Rojo and Blanca Criado Quesada

Received: 12 April 2024
Revised: 7 May 2024
Accepted: 15 May 2024
Published: 16 May 2024



## 1. Introduction

Population aging is a prevalent social issue worldwide. According to the United Nations Population Report, the global population of individuals aged 65 and over was expected to reach approximately 771 million in 2022, accounting for 10% of the world's total population. By 2050, this proportion is expected to rise to 16%, or approximately 1.6 billion people [1]. China, as the world's most populous country, is also facing the challenges of an aging population. The Seventh National Population Census conducted by the National Bureau of Statistics of China in 2020 revealed that the population of individuals aged 65 and above in China was 190.64 million, comprising 13.5% of the total population [2]. Furthermore, China's densely populated megacities, such as Shanghai, Beijing, Guangzhou, Shenzhen, Chongqing, Chengdu, and Tianjin (Figure 1), which have urban populations exceeding 10 million, are particularly affected by the issue of aging [3]. In 2020, the average proportion of people aged 60 and over in these cities had reached 17.32%. In response to the growing demand for older people's services, the Chinese government has implemented a series of policies. In February 2022, the National Planning for the Development of the Aging Career and the Elderly Service System [4] clearly incorporated the integration of old-age affairs into its economic and social development planning, as well as sustainable

development strategies. The plan proposes an increase in investment for various types of service facilities for older people and the scientific planning and allocation of new ones. For densely populated megacities like Guangzhou, finding an optimal approach to plan and optimize the distribution of urban facilities for older people is an urgent task. This study is of great practical significance for a timely, scientific, and comprehensive response to population aging.

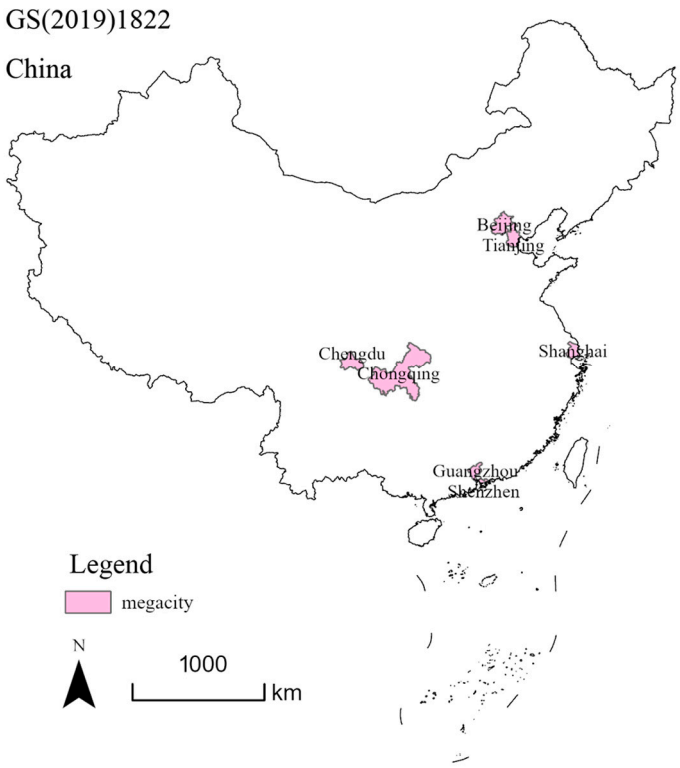


**Figure 1.** Locations of megacities in China.

Service facilities for older people are a crucial component of urban public services. With the accelerated development of urban aging, the planning and construction of these facilities has become a new issue in urban planning. The layout of service facilities for older people needs to be gradually matched with the development of the city and the needs of its citizens [5]. Much research has been conducted on the layout of service facilities for older people [6–8]. The first type of study is the arrangement of land sites for service facilities for older people in urban planning. The traditional layout planning of such facilities usually adopts the perspective of the land supply in urban master planning [9,10]. The study of the land demand for service facilities for older people mainly considers factors such as the demand for land by older people in plots around the city [11] and the matching of the supply and demand for older adults [12]. The second type of study aims to evaluate and optimize the allocation efficiency of existing service facilities for older people [13,14]. The studies cover various aspects, including the geographical environment and spatial factors affecting the balanced layout of service facilities for older people [15,16], the distribution characteristics of service facilities for older people and the coupling relationship between facilities and people [17,18], the accessibility of facilities, and the spatial coordination and continuity of service facilities [8,19,20]. The third category of studies focuses on modeling and forecasting the sizes and types of future service facilities for older people [21,22], mainly based on the natural growth rate of the local population [23,24]. However, the current forecasts focus mainly on the city and county level and do not sufficiently consider the street level and the correlation with other existing public services in the city. Current research on urban service facilities for older people in Guangzhou focuses on the spatial layout of

existing facilities and assessing their coupling with population growth projections [25–28]. However, simulating and predicting the distribution of future service facilities for older people is an important research direction. In particular, as emerging urban data, POI data have been widely used in studies in areas such as urban function and land use planning, and many studies have used POI data to attempt to analyze the distribution of urban public facilities [29–31]. Faced with a large amount of urban data that need to be analyzed, machine learning has been widely applied to the mining of urban big data [32]. Compared with traditional linear and mathematical modeling methods, machine learning has unique advantages in the analysis of non-linear problems in big data [33]. Machine learning algorithms learn large amounts of urban data, from which they can discover complex patterns close to reality and predict future developments [34]. Machine learning methods are widely used to analyze correlations between urban elements, and machine learning algorithms are applied according to different urban data and problems [35–37]. In addition, studies using POI data and machine learning to assess the current locations of urban public services and to make predictions about future locations are beginning to emerge [38,39]. These studies are an important foundation for this research.

The aim of this study is to provide a more rational, objective, and efficient means of siting service facilities for older people by using POI big data and machine learning algorithms in combination with high-density street-scale demographic data in Guangzhou city [40,41]. The paper is organized as follows. Section 2 introduces the study area and data sources, and Section 3 presents the methodology of the study. Section 4 illustrates the results of the study in the form of graphs. Finally, we discuss and conclude our research. The study provides a reference for the layout optimization and future planning of service facilities for older people in Guangzhou and related megacities.

## 2. Study Area and Data

### *2.1. Study Area*

Guangzhou is located in the central part of Guangdong Province, with a total area of about 7434 square kilometers. Guangzhou contains 11 administrative divisions, namely the Yuexiu, Liwan, Haizhu, Tianhe, Baiyun, Huangpu, Panyu, Nansha, Zengcheng, Conghua, and Huadu districts. Guangzhou is the capital city of Guangdong Province, and, as an economically developed and densely populated metropolis, the aging problem is more concentrated, and its demographic problems are typical of megacities in China [42]. According to the urban development pattern of the successive versions of the master plan, Guangzhou is divided into three circles: the central urban area (Liwan, Yuexiu, Haizhu, and Tianhe districts), the suburban area (Baiyun, Huangpu, and Panyu districts), and the remote suburban area (Huadu, Nansha, Conghua, and Zengcheng districts) (Figure 2). The ageing population in Guangzhou city shows a trend of rapid and unbalanced growth in all districts, which poses specific requirements for the adjustment and optimization of the spatial layout of the social service system for older people. For the administrative area data, we divided Guangzhou into 29,793 grids of 500 m by 500 m, based on the 15-min walking distance of older people [43], and the service radius of service facilities for older people should not be more than 500 m [44,45]. Each grid has a unique number, which offers convenience for the subsequent exploration of the spatial distribution of service facilities for older people and other types of urban public service facilities.

### *2.2. Research Data*

POI data are data based on the core location-based services, which essentially cover all aspects of urban life, and are suitable for research related to urban public facilities [46]. POI data for this study were obtained via the acquisition of relevant POI information within the study area in November 2020 on Gaode Map, including the type, name, latitude and longitude, category, address and other relevant attribute information about urban public facilities. Due to the large amount of raw POI data acquired, there were duplications or intersections in the data in terms of classification, so it was necessary to pre-process

the POI data. The pre-processing included deleting duplicated points and points with missing attributes. Then, based on the relationships among the service facilities for older people, the various types of facilities in the city, characterized by the POIs, were classified into 14 categories, namely transport, hotels, sports and leisure, business and enterprises, medical services, real estate, government institutions, living services, science, education and culture, shopping, finance, tourist attractions, catering and food, and facilities for older people, with a total of 664,031 data (Table 1). From the above POI data, a total of 1369 data were filtered out as service facilities for older people. Service facilities for older people include nursing homes, elderly care centers, homes for the aged, older people's universities, elderly apartments, elderly service centers, social welfare centers, etc.

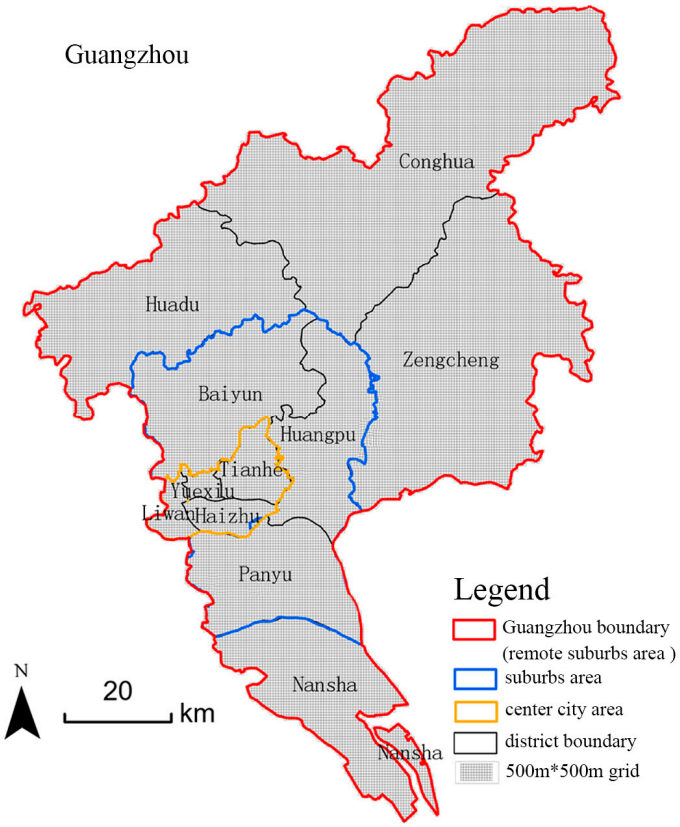


**Figure 2.** Map of Guangzhou city districts.

**Table 1.** Categories and quantities of POI data related to service facilities for older people.

| Data Source | Category | Quantity |
|---|---|---|
| POI data | Accommodation | 21,287 |
| | Attractions | 6891 |
| | Catering facilities | 72,961 |
| | Corporations | 126,000 |
| | Governmental facilities | 29,750 |
| | Financial facilities | 12,572 |
| | Life services | 101,446 |
| | Medical services | 17,493 |
| | Real estate | 11,676 |
| | Scientific, educational, and cultural facilities | 31,167 |
| | Sports and leisure facilities | 3521 |
| | Shopping facilities | 225,541 |
| | Transportation | 2357 |
| | Service facilities for older people | 1369 |

Census data contain a wealth of spatial geographic information, combined with information on individuals, households, and dwellings, and are widely used in studies of the spatial distribution of urban facilities [47]. The census is an inevitable requirement for an accurate picture of China's demographic situation, an objective necessity in solving demographic and related social problems, and provides important basic information for the implementation of the national strategy of actively addressing population aging and promoting high-quality development [2]. The latest Seventh Population Census of Guangzhou in 2020 showed that the city's total population had reached 18.67 million, of which 2,130,598 were aged 60 and above, accounting for 11.41% of the city's total population, while 1,460,333 were aged 65 and above, accounting for 7.82% of the city's total population. Compared with the 2010 Sixth Population Census, the proportion of people aged 60 and over and 65 and over has increased by 1.67% and 1.15% respectively [48]. Data on the specific elderly population in 171 streets are shown in Figures 3 and 4. Figure 3 shows the number of people aged 65 and over in each street, while Figure 4 shows the aging rate in each street. In terms of the number of older people, there are 50 streets where the number of people aged 65 and over exceeds 10,000, with the highest number of older people in a street reaching 29,601. Regarding the aging rate, there are 107 streets where the aging rate exceeds 7%, and 40 streets where the aging rate exceeds 14%, indicating severe aging. These detailed population data serve as important bases for the setup of service facilities for older people.

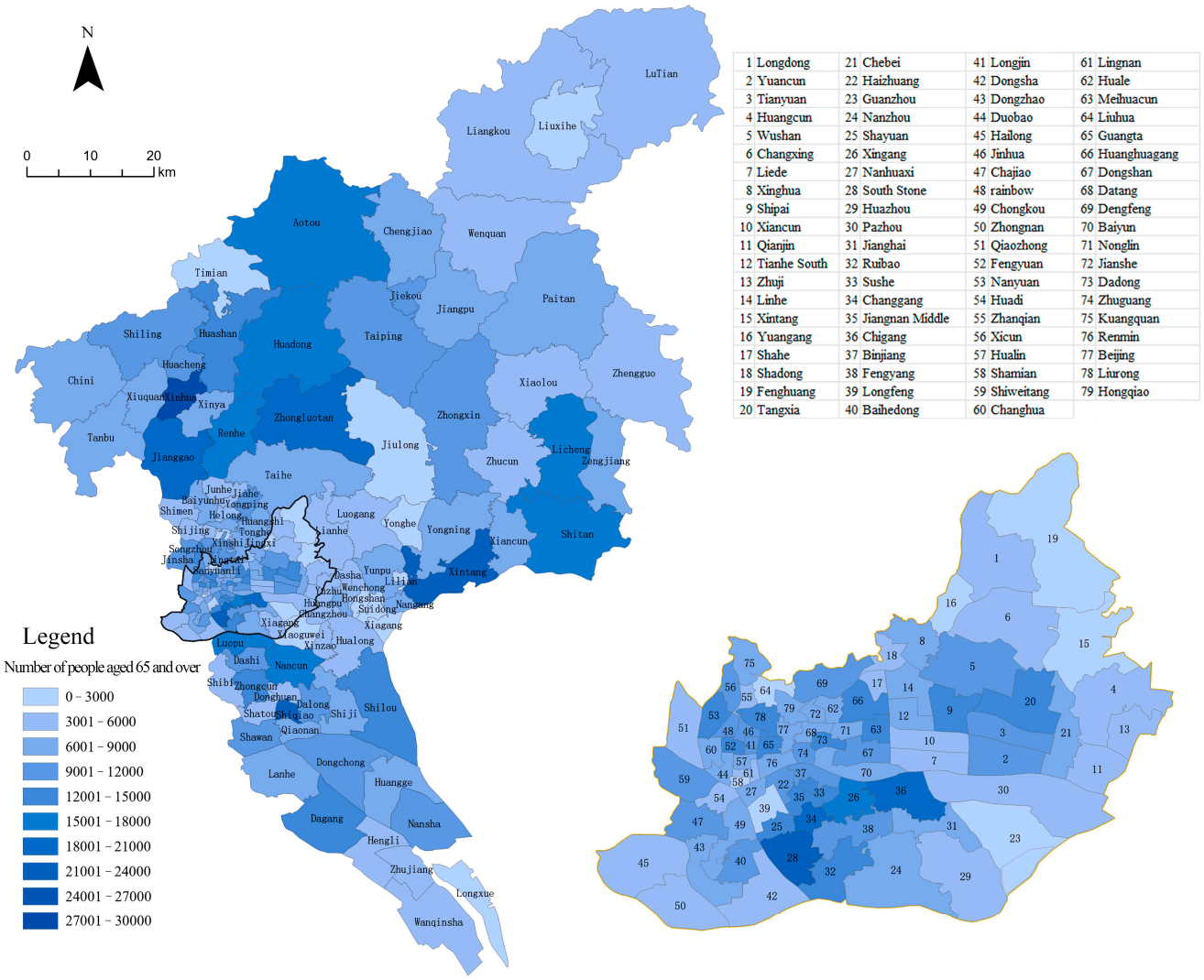


**Figure 3.** Size of elderly population in each street in Guangzhou.

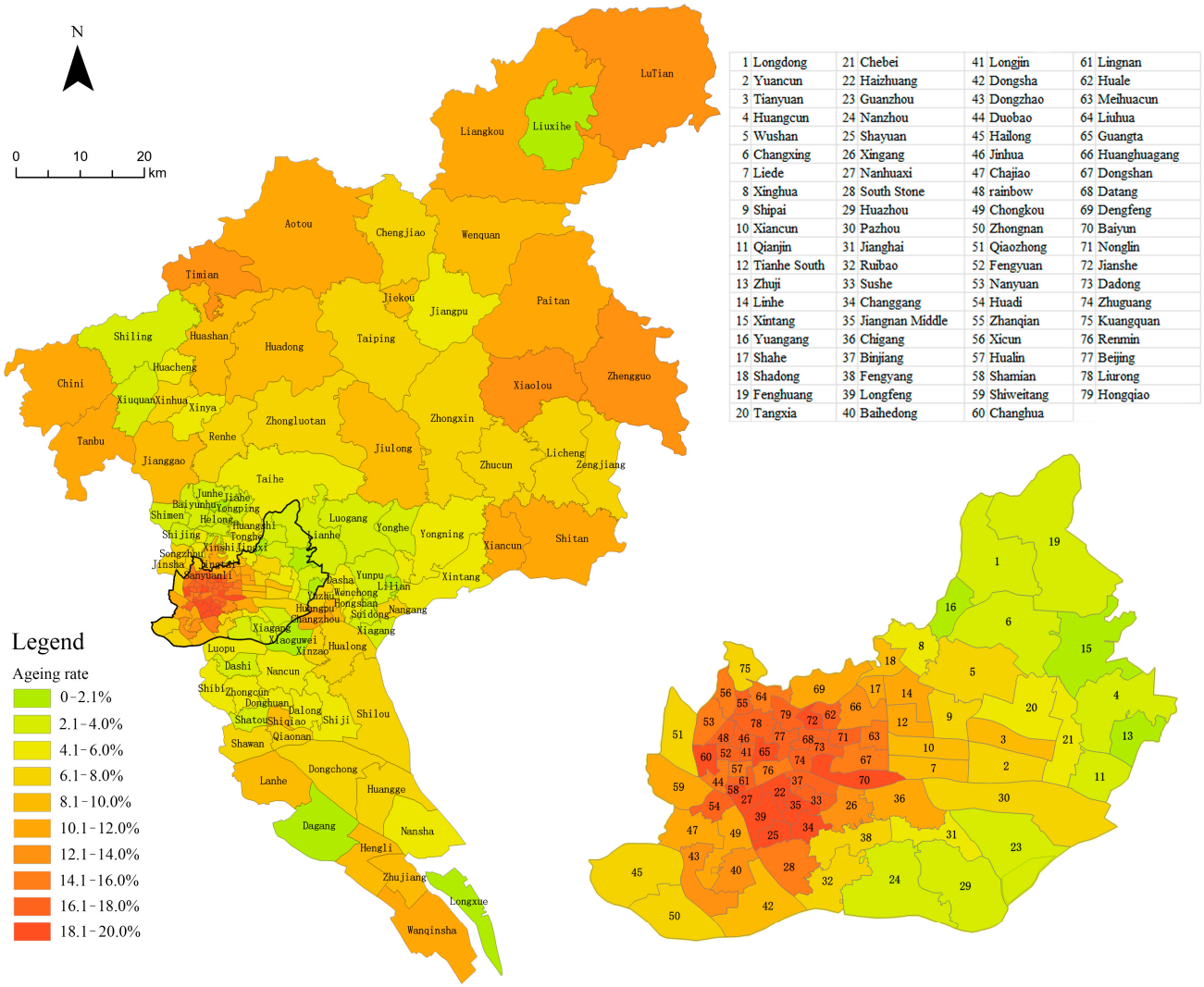


**Figure 4.** Aging rate of each street in Guangzhou.

## 3. Methodology

Service facilities for older people, as a type of basic functional facility in the city, are closely related to the distribution of other public facilities. Therefore, it is reasonable and relevant to analyze the current distribution characteristics of service facilities for older people and optimize the future layout of these service facilities in Guangzhou through POI big data. This paper also draws on similar research methods [39]. The methodological framework of this study is shown in Figure 5 and described in detail below.

### *3.1. Gridding the Distribution of Urban Public Service Facilities*

First, using the spatial overlay function of the ArcGIS 10.2 software, the POI location information is overlaid on a 500 m × 500 m urban grid to obtain the distribution status of the urban public service facilities in each grid. Among the 29,793 grids in Guangzhou, there are 15,771 valid grids containing public service facilities, of which 985 grids contain service facilities for older people. These 985 grids containing service facilities for older people are used as positive samples in the dataset, while the same number of grids not containing service facilities for older people are randomly selected as negative samples to construct the dataset for machine learning. Then, 80% of the grids from this dataset are randomly selected as the training set and 20% of the remaining dataset is used as the validation set to verify the accuracy of the model. Excluding the dataset for the training of the model, the rest of the grid data are used as the final test set.

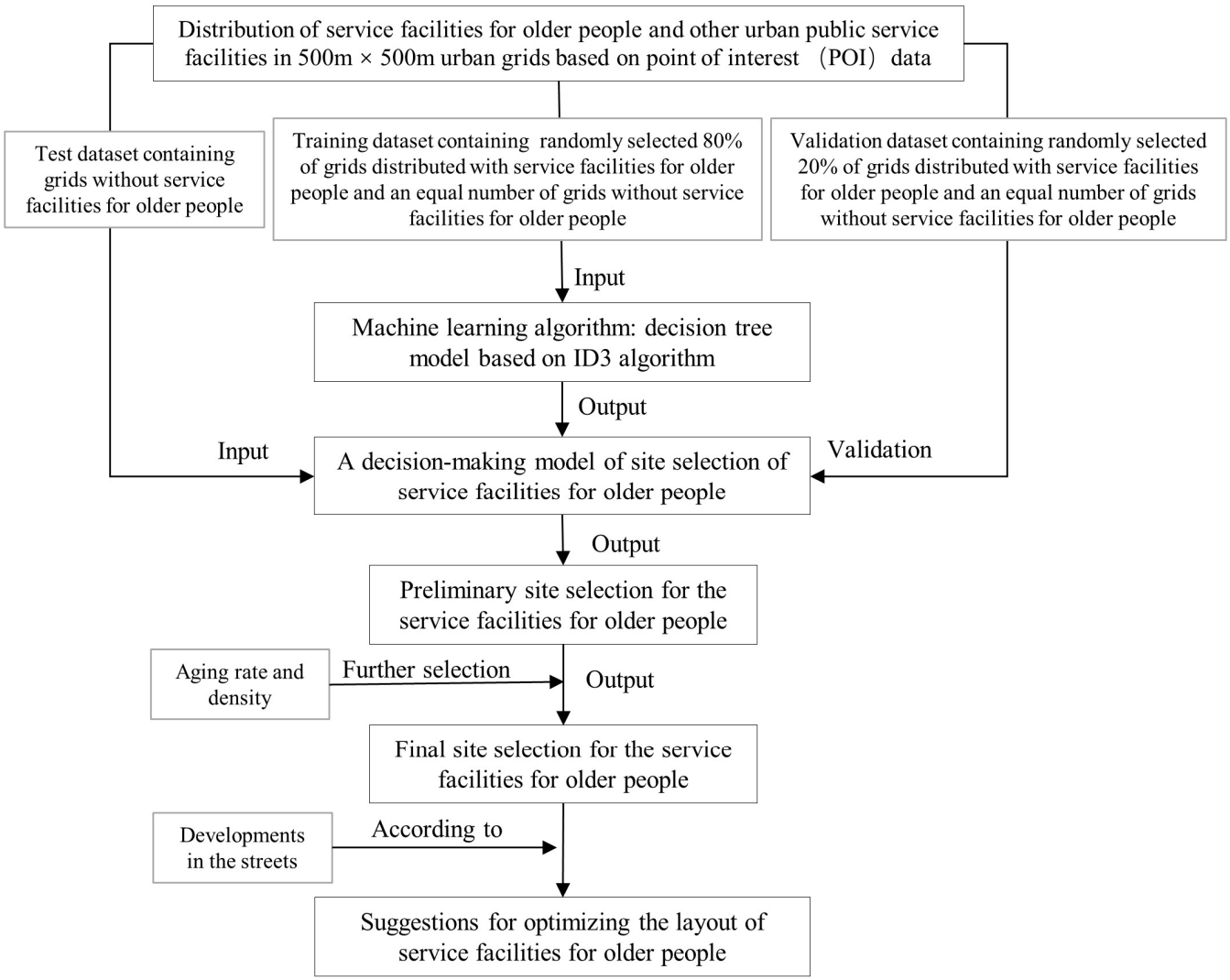


**Figure 5.** Methodological framework.

### *3.2. Training of the Prediction Model for the Siting of Service Facilities for Older People*

Second, the machine learning ID3 algorithm is used to simulate the distribution pattern of facilities for older people and obtain a preliminary site selection decision model. The ID3 decision tree algorithm is a supervised learning algorithm [49,50] that is widely used in data mining work such as the classification and prediction of POI big data [51]. The ID3 machine learning algorithm is mainly based on the distribution of public service facilities in the urban grid, seeking to determine whether the urban grid is suitable for the implementation of service facilities for older people. According to the POI data, 13 types of existing facilities in the grid are used as the independent variables, and the availability of service facilities for older people is used as the dependent variable, to train the decision tree based on the ID3 algorithm for siting [39]. Using the above-prepared training set data, a decision tree model for the location of urban service facilities for older people in Guangzhou is trained, and then the validation set is used to evaluate its accuracy. The result shows that the accuracy of the model is as high as 87.46%. This result indicates that the configuration of the existing service facilities for older people is highly consistent with the predictions of the model. Therefore, the model is reliable and suitable for the prediction of sites for new service facilities for older people.

### *3.3. Prediction of the Siting of Service Facilities for Older People and Recommendations for the Optimization of the Layout*

Third, the data of the grid that does not contain service facilities for older people are input into the above-trained older people service facility site selection model to predict the overall older people service facility sites in Guangzhou city, so as to obtain the preliminary site selection suitable for service facilities for older people. Then, according to the population data on the existing streets, the site selection is optimized and filtered to determine the final predicted sites for the service facilities. The final site selection is compared with the current facilities and the urban development of each district and street to give recommendations for the optimization of the layout of service facilities for older people.

## 4. Results

### *4.1. Preliminary Site Selection for Service Facilities for Older People*

The test set data were fed into the trained model, and 4534 grids of suitable service facilities for older people were obtained as the preliminary site selection (Figure 6). The results have the following characteristics. The preliminary site selection is consistent with the distribution of service facilities for older people in the current situation. Overall, there is a clear difference in the number of predicted points in the three circles, which are mainly clustered in the central city area, with a gradual decrease in the number of predicted points as the distance to the central areas increases. For the same reason, other preliminary sites are clustered in the central streets and townships of each district. Specifically, the Liwan and Yuexiu districts, the oldest districts in the central urban areas, have the largest number of preliminary sites and also the largest number of existing service facilities for older people. In contrast, newer urban areas such as Tianhe district, where commerce and education are the main functions, have fewer existing service facilities for older people and more sites for new service facilities for older people. Baiyun district and Panyu district, in the suburban area, are also relatively well developed in terms of urban public service facilities. The distribution of site points is also relatively even, with the prediction points in Huangpu mainly concentrated in the southern part of the district, mainly affected by the natural geographical environment, and in the northern part of the district, mainly in the natural mountainous terrain. The prediction points are scattered in the centers of villages and towns that have a certain level of infrastructure. The preliminary site distribution characteristics of the Huadu and Nansha districts among the far-suburban districts are similar to those of the near-suburban districts, while the more peripheral Conghua and Zengcheng districts are restricted by their hilly natural environments, with the predicted sites mainly concentrated in the center of each district and the other predicted sites mainly scattered. The preliminary site distribution also has a distinctive feature in that it is closely connected with the city's major transportation, mostly built around the highway, subjected to the spillover of the pressure of the center of the city's aging population.

Based on the decision tree model and POI data, it is possible to obtain a preliminary selection of sites for the new service facilities for older people, which is predicted on the basis of the public facility situation in the city. However, in order to obtain a more accurate selection of locations, we also need to consider direct factors such as the elderly population and the aging rate in each region. This process helps to determine the final site selection and to prioritize areas of high construction demand in the government's decision-making process.

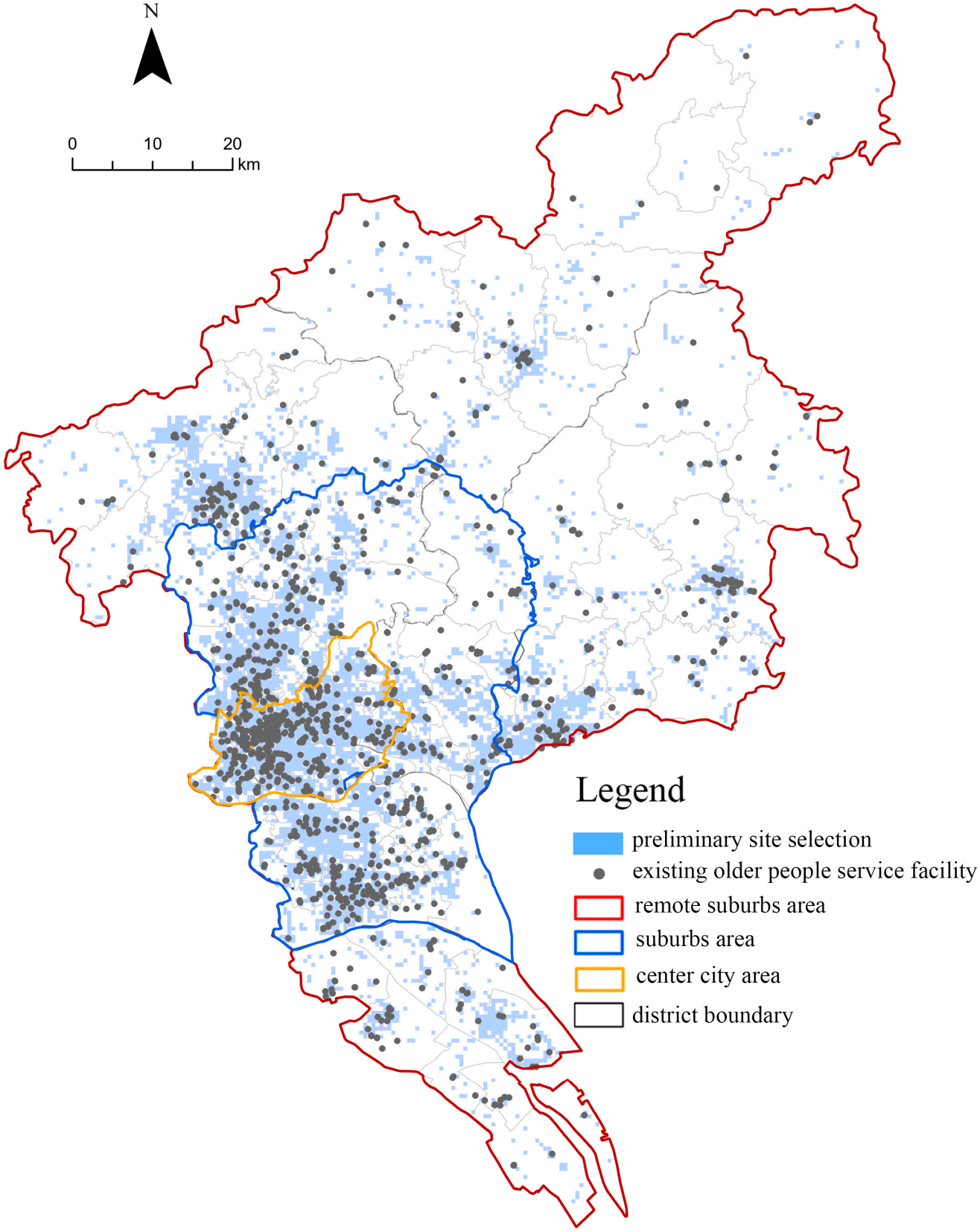


**Figure 6.** Preliminary site selection for service facilities for older people.

### *4.2. Final Site Selection for Service Facilities for Older People*

One of the main considerations when choosing the location of a new service facility for older people is to meet the demand for older people's services of the population in the area [45]. Once the proportion of people aged 65 and over exceeds 7%, it means that the region has entered the stage of an aging society; therefore, the construction of new service facilities for older people in such a region should be prioritized. In addition, the size of the elderly population is also an important consideration in deciding whether or not to build service facilities for older people. The average number of people aged 65 and above in each street in Guangzhou has exceeded 8000; therefore, those streets with a population of more than 8000 should be the key areas for the construction of service facilities for older people in Guangzhou. The aging rate of each street was calculated based on the total populations of 171 streets and the number of older people aged 65 and above, and the selected neighborhoods with aging rates of more than 7% and streets with populations of 65 and above exceeding 8000 people. The results showed that 62 streets in Guangzhou city met the requirements. Then, using ArcGIS, all grids covered by the 62 streets were searched for suitable sites, and the grids with an existing layout of senior living facilities were removed. Finally, 1066 grids suitable for new service facilities for older people were obtained as the final site selection.

As shown in Figure 7, 62 streets in Guangzhou have an aging population of more than 7%, which need to be considered primarily as new sites for the building of service facilities for older people. Among these streets, 24 streets have an elderly population aged 65 and above exceeding 14%, making them severely aging neighborhoods. Three of these streets even have an elderly population of more than 15,000. These streets are mainly concentrated in the Haizhu and Liwan districts, among which the aging problem on Shayuan Street is the most severe, with the aging rate of the district reaching 20%. Reviewing the above situation, the aging problem in the Liwan and Haizhu districts is more prominent. However, they have complete public facilities; hence, there are many potential locations for new service facilities for older people.

For the suburban area of Guangzhou, the influx of the working-age population attracted by the modern service industry and strategically emerging industries has reduced the degree of aging in the area. In this area, eight streets have reached an aging level, including three in Baiyun district, four in Panyu district, and one in Huangpu district. Although the degree of aging in the suburbs is relatively low, there is still a considerable number of older people. For example, the elderly population on Shiqiao Street, Panyu district is as high as 23,400. As the area is well equipped with infrastructure, abundant medical resources, and convenient transportation, there are many suitable locations in which to introduce elderly service facilities.

In the remote suburban area, the streets with a high degree of aging are mainly located on the border between the near suburbs and the far suburbs. The aging situation of the streets is similar to that of the suburban area, with some streets having very large elderly populations, such as Xinhua Street in Huadu district, where the aging rate is 7.45% but the number of older people reaches 29,601. Many streets in the far suburbs have not yet been listed as priority areas. However, because these streets are far from the cities, have a large elderly population and relatively outdated facilities, and are scattered, the need for new facilities for older people in the suburbs is even more important. It is necessary to build new facilities for older people in these suburban areas based on preliminary site selection.

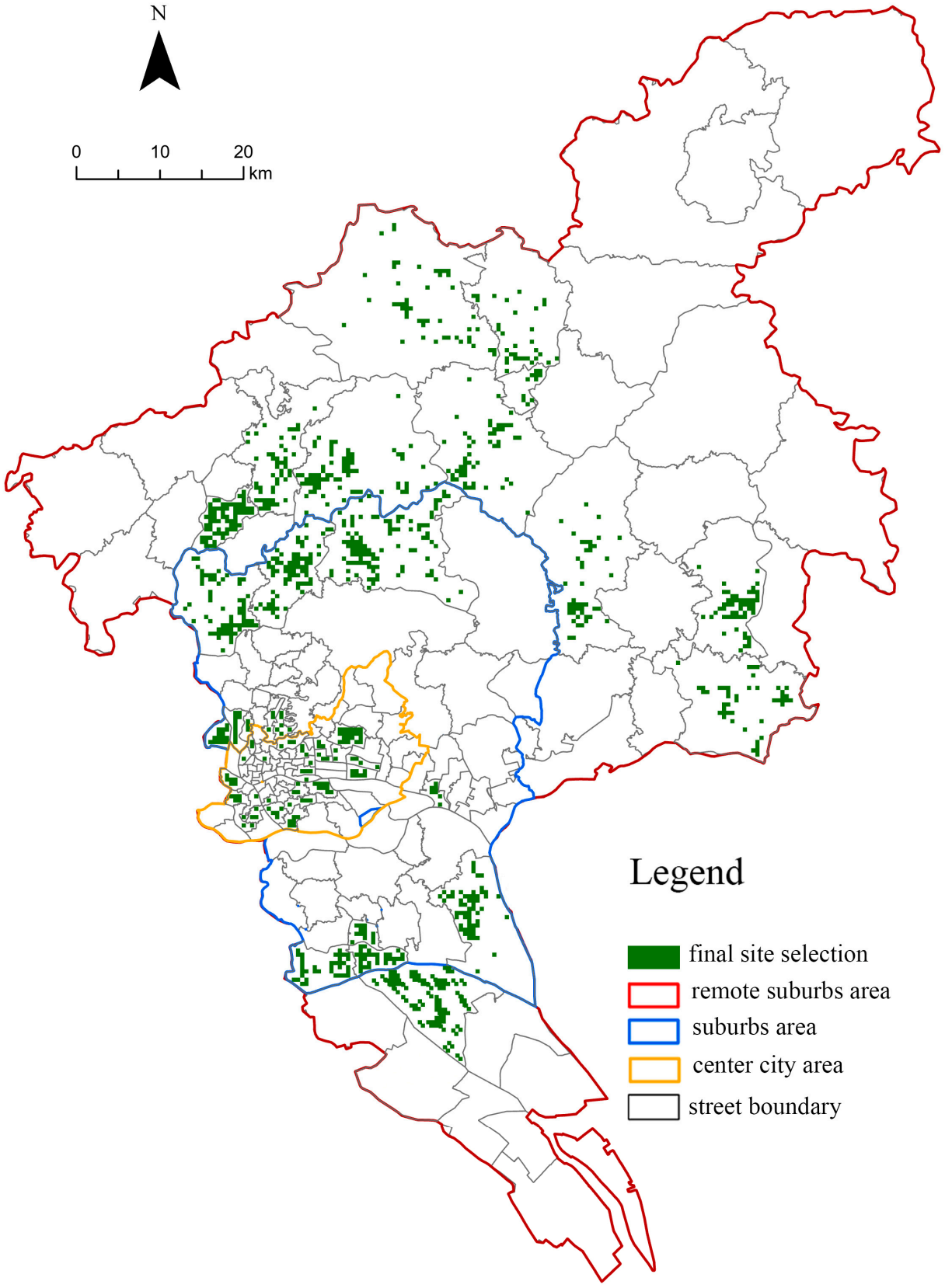


**Figure 7.** Final site selection for service facilities for older people.

### *4.3. Suggestions for the Optimization of the Layout of Service Facilities for Older People*

The site selection of service facilities for older people mainly considers the number and the aging rate of the population of each street. The implementation of the optimization of the layout of service facilities for older people must also take into account the actual conditions of each street. The central urban areas are seriously aging, with a concentrated demand for service facilities for older people, but there is a shortage of land for new construction. Therefore, the existing institutions in these areas should be renovated and upgraded, and advanced medical equipment should be introduced to improve the service quality and maximize the use of existing resources. In addition, more community services for older people should be established in densely populated areas to complement institutional services for older people. Especially in the resource-poor Yuexiu district, more community elderly care centers should be established to improve the home-based elderly care services. At the same time, it should also be considered to transfer older people to large-scale elderly care centers in other districts to alleviate the pressure on elderly care. As for Tianhe district, which is dominated by commerce, due to the high land prices, it can be considered to use high-rise and large-scale facilities to save land and fully utilize the city's public facilities. According to the characteristics of different regions, various types of service facilities for older people can be built. For example, Wushan Street in Tianhe district is a university cluster, so we can make use of its rich educational resources to build community schools for older people.

The suburban areas are rich in land resources, and new residential areas are plentiful and affordable. As a result, Guangzhou's suburban areas are likely to welcome a large number of residents in the future. In view of this, we propose that suburban areas be the key areas for the construction of future service facilities for older people, while medium and large service facilities for older people should be built in residential areas. Furthermore, the planning and layout of services for older people in the suburbs should be tailored to the local conditions, continuously adjusting and optimizing the spatial layout according to various indices like the structure and density of the resident population, rather than simply establishing large-scale facilities due to issues of land use or funding.

For remote suburban areas, considering their relatively inexpensive land prices and excellent natural environment, large-scale elderly care institutions can be built in conveniently located areas. High-end commercial elderly care institutions can be introduced to these areas to meet the vacation and leisure needs of some older people. In more remote towns, taking into account their large populations and sparsely populated nature, large service facilities for older people can be established around township centers, taking advantage of the well-developed transportation networks and expanding the scope of the services.

## 5. Discussion and Conclusions

In this study, POI data are combined with machine learning algorithms to more scientifically and comprehensively consider the factors influencing the site selection of service facilities for older people, and, at the same time, the study refines the site selection to the accuracy of 500 m squared at the street level. In contrast, most of the previous planning for urban senior service facilities was based on urban land use planning [52] and natural population growth matching [53], as well as the evaluation of the current situation [27]. The predicted site selection in this study is more objective, more effective and precise for the site selection of urban service facilities for older people in Guangzhou, and more targeted towards the urban construction suggestions.

The methodology and results of this study also have important implications for planning and allocation decisions for public facilities in cities in general. First, by dividing the city grid more precisely, we can provide more accurate results for the location of service facilities for older people, which will help to avoid wasting public resources and land resources [54]. Second, with the help of machine learning methods on large amounts of current urban data, we can now better simulate the patterns of these urban forms. The use of machine learning has been proven to make some urban economic infrastructure

more efficient, resilient, and inclusive, thus providing better quality of life for residents [32]. Furthermore, the creation of smart, digital, and connected cities is the main direction of modern urban development. It is not only service facilities for older people but also other healthcare and public service facilities that face the same digitization needs, which require the collection and simulation of rich urban big data, and the use of machine learning methods is beneficial in addressing the integration of facility planning in digital and smart cities [40].

This study also has some limitations. It is based on urban POI data, which are applicable to the more mature development and data coverage of the city; however, for the city's new districts or departmental infrastructure, where the construction is not complete, the POI data will exhibit incomplete coverage and insufficient data, and the results of the analysis will have a certain degree of bias. This study also does not separate service facilities for older people, and, in future research, urban service facilities for older people can be further subdivided according the level and service scope the facilities. Moreover, the differences in the location and layout of different types of service facilities for older people need to be further explored [39]. In addition to the issue of facility distribution, the impact of individual preferences, gender differences, and other subjective perspectives on service facilities for older people is a direction worth considering for future research [55].

This study focuses on the megacity of Guangzhou in China. Using POI data and machine learning algorithms, we develop a street-level location selection model for new service facilities for older people in Guangzhou. Based on the range of activities of older people, we divide Guangzhou into 29,793 grid units of 500 m $\times$ 500 m. Among these grids, 985 grids contain service facilities for older people and are selected as the model training dataset. Then, we use the ID3 decision tree algorithm to train a site prediction model for service facilities for older people. Through this model, we identify 4534 grids within Guangzhou as the preliminary site selection for new service facilities for older people. Taking into account the aging rate and the number of older people in each street, we further narrow the scope and finally select 1066 grids as priority sites. Finally, based on the selected sites and the actual social conditions of each district and street in Guangzhou, we propose optimal construction strategies for service facilities for older people.

**Author Contributions:** Conceptualization, H.F. and X.T.; methodology, H.F. and C.Z.; software, C.Z.; validation, H.F. and C.Z.; formal analysis, H.F. and C.Z.; investigation, H.F.; resources, H.F.; data curation, H.F.; writing—original draft preparation, H.F.; writing—review and editing, H.F. and X.T.; visualization, C.Z.; supervision, X.T. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy restrictions.

**Conflicts of Interest:** The authors declare no conflicts of interest.

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