Abstract: Care facilities are the mainstay of social services for the elderly. As the trend of empty nesting among elderly families intensifies due to the aging population, it is becoming difficult for families to take on the responsibility of caring for the elderly on their own, and the elderly need more formal care to be provided by society. The contradiction between the lag in the construction of care facilities and the growth in the social demand for elderly care has been highlighted, and the spatial equality of care facilities is an important means of achieving an optimal allocation of resources for elderly care. In this paper, we use the two-step floating catchment method to measure the spatial accessibility of care facilities from a fine-grained perspective, using big data, including mobile phone signaling data and points of interest. Then, we use the Gini coefficient to analyze the equality of the spatial allocations of different types of urban care facilities. The results of the study show that, first, the spatial equality of care facilities is good in terms of the Gini coefficient, but the overall spatial accessibility of care facilities is at a relatively low level compared to that in developed cities. This means that the layout of Changchun’s care facilities is good, but there is insufficient service capacity. Second, the spatial accessibility of residential care facilities is characterized by a gradual decline, with high levels in the core and low levels in the periphery. Fewer facilities are located in the peripheral areas of the city, and spatial accessibility is at a lower level, a characteristic different from that seen in cities with a higher level of economic development, such as Beijing. Third, the spatial accessibility of community care facilities showed a polycentric, contiguous distribution. The effect of the study scale on the spatial accessibility of community care facilities was more pronounced, with large scales obscuring the high values of the spatial accessibility of community care facilities in peripheral areas. Fourth, Changchun has better overall equality of care facilities, with differences in the different types and areas of care provided. The spatial balance of care facilities in the core area is better than that observed in other regions. In conclusion, this paper underscores the value of big data, such as mobile phone signaling data, in supporting refined urban research. Furthermore, our comprehensive analysis of social care facility equality can inform policy making and spatial planning.

Keywords: care facilities; refinement; spatial equality; two-step floating catchment method; spatial accessibility

1. Introduction

As the global demographic landscape transforms, the demand for formal care intensifies across countries. Middle-income nations, such as China, are facing significant pressures on their economic and physical foundations due to aging populations [1]. Presently, China possesses the world’s largest elderly population [2]. China’s seventh national census indicated that by 2020, 264 million individuals aged over 60 would comprise 18.7% of the total population [3]. China’s aging is distinguished by its vast scale, rapid emergence, and
considerable diversity [4]. The country is experiencing an increase in seniors with illnesses, disabilities, and advanced ages [5].

Concurrently, family structures are shifting, with a marked trend toward smaller families, complicating the task of independently caring for elderly family members. The decline in family care is inevitable, necessitating increased formal care from society and rendering care facilities increasingly essential [6]. The restricted supply of care services and lagging construction of care facilities contrast with the burgeoning societal demand for care [7], a phenomenon more conspicuous in middle-income countries [1].

In China, for instance, 39,800 diverse residential care facilities provide only 19.0 beds per 1000 individuals over 60 years of age [8], a substantial disparity compared to the United States (34.8 beds per 1000 people) [9]. With 340,000 community care facilities and nascent daycare centers, meeting the escalating demand for senior care proves challenging [10]. China’s 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives Through the Year 2035 urge the government to expedite the promotion of spatial equality in care facility provision [11].

Taking into account the multiple needs of the elderly, the rational allocation of resources to care facilities is one of the goals of effective urban planning [12]. Care facilities are the general term for buildings that provide specialized or comprehensive services for the elderly in terms of housing, life care, health care, culture, entertainment, etc., and they play an important role in promoting the mental and physical health of the elderly [13]. Such facilities are categorized as either residential care facilities (RCFs), which are long-term care facilities for the elderly, or community care facilities (CCFs), which are daily care facilities for the elderly. The two types of CCFs complement each other to support the social needs of the elderly. The spatial distribution of CCFs is an important part of urban management. Some existing studies focus on analyzing the provision of RCFs, while other studies emphasize the spatial distribution of CCFs. However, there have been fewer studies on multiple care facilities. Each type of care facility meets the needs of different groups regarding services for the elderly, and efforts to make care facilities in the city more equal cannot consider the needs of only a single group of elderly persons [14]. Unlike the existing studies, our study targets two key care facilities; we posit that analyzing the spatial distribution of care facilities from a more comprehensive perspective can provide more reasonable conclusions for urban planning.

Equal access to care resources is an expression of social justice. Equality is a controversial concept that has been discussed in a number of areas [15]. The equality of care facilities can be categorized as non-spatial and spatial equality. Non-spatial equality focuses more on differences in group access to resources based on individual differences such as race, gender, and age characteristics. This does not take into account spatial impediments. Spatial equality means that residents should have roughly equal distance barriers to reach the point of supply [16]. The equality of the spatial distribution of care facilities reflects the effectiveness of the distribution of public resources in the city and affects the well-being of the elderly population [17]. Scholars have conducted numerous studies on the measurement of spatial equality. When evaluating the spatial equality of care facilities, two aspects are considered: first, differences in care facilities, encompassing factors such as location, type, and size; and second, the spatial distribution, needs, and preferences of the users [18] (see Figure 1). Existing research indicates that facility size is a crucial factor; larger facilities can provide a broader range of services to more seniors. Different types of care facilities cater to varying elderly needs and possess distinct service coverage scales. Community care facilities that do not provide accommodation have a smaller service radius compared to residential care facilities. Additionally, the proximity of care facilities to seniors’ living environments is a key factor in their choice of formal care facilities [19,20]. If a facility is far from a senior’s living environment, it may distance them from their existing social circle, making them less likely to choose that facility. A large spatial distance between the facility and the senior can decrease the likelihood of them utilizing the facility. Spatial proximity to care facilities varies regionally, resulting in differing opportunities for seniors to access care.
facilities, i.e., variations in spatial accessibility [5,21]. Geographical differences in spatial accessibility provide an effective description of care facility spatial equality [22].

Figure 1. Spatial equality evaluation criteria for care facilities.

The distributional characteristics of spatial accessibility can effectively characterize the distribution of the spatial resources of care facilities [15]. The concept of accessibility, originating from the field of transportation, evaluates individuals’ potential opportunities to reach other areas through the transportation system [23]. In the context of public service facilities, spatial accessibility refers to the potential of care facilities to interact with seniors, focusing on measuring service access disparities between supply and demand due to spatial separation [24,25]. The nearest neighbor method [26], the gravity model method [27,28], and the two-step floating catchment area (2SFCA) method are the primary approaches used to study spatial accessibility [29,30]. The 2SFCA method provides a joint measurement from both the supply and demand perspectives, considering both the supply potential of available care facilities and the competitive pressure on care resources, making the measurement more realistic [31,32]. The traditional 2SFCA method has been heavily criticized for not accounting for the decay of distance within the search area [33,34]. As a result, researchers have considered the influence of distance decay on accessibility and introduced a distance decay function into the model to address the issue of distance impedance [35,36]. The analysis of the spatial accessibility of care facilities is an important reference for guiding the rational allocation of spatial resources in cities. In addition, in order to visualize the spatial equality of elderly service facilities, scholars often use equality evaluation methods, mainly the Theil index, the Kakwani index, the Lorenz curve, and the Gini coefficient. Among them, the Lorenz curve and the Gini coefficient are some of the most commonly used indicators [37–39]. Therefore, we use the Lorenz curve and Gini coefficient to evaluate the spatial equality of elderly service facilities.

The research scale significantly influences the measurement of urban care facilities’ spatial equality [40]. Traditional studies conducted on larger scales such as sub-districts or districts [41–43], typically assume a uniform population concentration at a central point, with equal geographical distances between the population and service facilities. This approach implies equal service access and spatial accessibility for the entire population, potentially leading to biased results at larger study scales [13]. The adoption of GIS technology has allowed for smaller study scales, such as living circles or 1 km × 1 km grids, offering a more accurate depiction of the spatial inequality of urban care facilities [36,44]. With the acceleration of urban modernization and the intensification of urbanization construction, traditional rough and empirical management methods can no longer cope with complex
urban problems, and there is a growing demand for urban refinement management. Urban refinement management refers to a fine, precise, and delicate mode of urban management.

Refined urban management requires high-resolution data as its basis [45]. Among the big data of most concern in urban management are data on the locations of services and facilities and data on population activities. Point-of-interest (POI) data are the most important data for location-based services, containing service facility names, categories, latitude and longitude information, and address names; they are often used to describe the distribution of service facilities. The primary types of big data currently employed for population distribution include nighttime lighting data and mobile phone signaling data [46,47]. Nighttime light data necessitates accounting for factors such as shadow bias and weather, yielding relatively rough descriptions. Mobile phone signaling data, on the other hand, refines population activity characteristics and is widely utilized [48].

The possible innovations of this paper are as follows. Although scholars have already analyzed the spatial equality of different care facilities to a certain extent, these studies are limited to a single care facility only. In this paper, this study starts from a refined perspective, constructs an improved 2SFCA model with the Gini coefficient, and explores the fairness of spatial equality in the spatial distribution of urban formal care based on the complementarity of different types of care facilities. We analyze the complementarity of different types of care facilities to address the aforementioned research gap. Simultaneously, compared with traditional data, big data can provide a high-resolution distribution of urban resources. Starting from a refined perspective, this study uses mobile phone signaling data with POI and other big data in this paper, which we use to quantify and map the equality of urban resource distribution. This can provide theoretical support for local governments to build a smart city management service system supported by grids.

2. Materials and Methods

2.1. Study Area

This paper focuses on the downtown area of Changchun, the capital city of Jilin Province in northeast China. The downtown area of Changchun encompasses five districts: Chaoyang District, Nanguan District, Kuancheng District, Erdao District, and Lvyuan District, totaling 65 towns (see Figure 2). Changchun’s economic development and aging population are representative of many Chinese cities. In 2021, Changchun’s gross domestic product (GDP) growth rate reached 6.2%, with a GDP per capita of CNY 78,000. According to the seventh national census, in 2020, there were 611,700 individuals over 60 years of age in Changchun’s downtown area, accounting for 19.25% of the total population [3,49]. With its population continuing to age, Changchun will face ongoing challenges related to the aging population. In response, Jilin Province issued “Implementation Opinions on the Full Liberalization of the Senior Care Service Market to Improve the Quality of Senior Care Services,” mandating comprehensive care facility development, 100% community care facility coverage, and an increase in care facility beds to 50,000 [50]. The downtown areas exhibit a higher population concentration and a more pronounced conflict between the supply of and demand for care facilities. Simultaneously, the construction of mobile phone base stations in rural areas is sparser, resulting in less suitable mobile phone signaling data being collected. Therefore, the downtown area of Changchun is both a representative and relevant research subject.
Figure 2. Location map of the downtown area of Changchun, China. Source: Ministry of Natural Resources and Gaode Maps.

2.2. Data

2.2.1. Spatial Unit

In this paper, we draw on the research method of Chen et al. (2022) [51] and use the homogeneous grid division method to divide the main urban area of Changchun into 1 km × 1 km homogeneous grids to meet the needs of fine urban management. After this division, we obtain a total of 704 grids, and each grid represents an analysis unit. The map data and road network data are sourced from Gaode Maps.

2.2.2. Mobile Phone Signaling Data

According to data published by the Ministry of Industry and Information Technology of the People’s Republic of China, there are currently 274 million mobile phone users aged over 60 in China, with a mobile phone penetration rate of 103.79% among the elderly [52]. Consequently, mobile phone signaling data can provide an accurate representation of the older population’s distribution. Mobile phone signaling data are comprehensive, real-time, continuous, and fine-grained, meaning that they meet the requirements for spatial and temporal studies of population activities [53]. Mobile phone signaling data can be used to determine users’ spatial locations through an information exchange between mobile phone users at base stations. This study utilized desensitized mobile phone signaling data from Jilin Unicom on 14 May 2021, which includes the user’s age and gender, the recording time, the recording base station ID, the arrival base station ID, and the base station latitude and longitude.
We define the elderly as the population aged 60 years and over. We were able to identify data on the distribution of older individuals aged 60–75 years using the age information in the mobile phone signaling data and the length of time the grid was parked (i.e., stopped on the grid for more than 6 h between midnight and 7 am). We identified a total of 245,700 individuals in the downtown area. Due to data limitations, it was difficult to obtain mobile phone signaling data for the elderly population over the age of 75. In 2020, the elderly population in Jilin province, aged over 75, accounted for 27.73% of the population aged over 60. Therefore, we expanded the sample proportionally based on the Seventh National Census data to cover the overall sample of elderly individuals.

2.2.3. Point-of-Interest Data

We used Python to obtain Gaode’s POI data, from which we extracted the spatial geographic location information of care institutions. We also collected information on the number of beds in residential care facilities from the Changchun Civil Affairs Bureau [54]. Our research targets residential care facilities (including nursing homes, homes for the elderly, and welfare homes) and community care facilities (including community activity centers, daycare centers, and meal helpers). In total, we selected 439 care facilities, comprising 293 community care facilities and 146 residential care facilities.

2.3. Methodologies

2.3.1. Method for Evaluating Spatial Accessibility

Spatial accessibility is measured in a number of ways, including via density analysis and nearest neighbor distance [55]. Density analysis is the ratio of supply to demand in a region. This method is widely used to make rough assessments of regional accessibility but has been criticized for failing to take into account distance attenuation and residents seeking services across borders. The nearest neighbor method calculates the distance of a demand point from the nearest service facility. However, as it does not take into account the interaction between supply and demand, its practical application is increasingly limited. Based on this, Hansen (1952) proposed a potential model that takes into account the interaction between supply and demand, as well as spatial resistance [56]. Salze et al. (2011) showed how to use the potential model to assess the spatial accessibility of facilities in the Bas-Rhin department [57]. However, this method does not impose restrictions on the search radius and may underestimate spatial variability. Researchers have improved the 2SFCA model to take account of both search radius limitations and distance attenuation [58]. As a result, this method has been widely used in urban planning [7]. We use 2SFCA to measure the spatial accessibility of care facilities.

We assume that the care resource diffusion scenario is influenced solely by transport distance, analyze the extent to which seniors in each grid are affected by the location of care facilities, and calculate the likelihood of seniors in the grid accessing care services. To achieve this, we use the improved 2SFCA method, which analyzes the supply capacity and actual demand for service facilities by moving the exploration area twice successively and introduces distance or time thresholds that fully consider supply [59], demand, and time costs (see Figure 3).

Step 1: We calculate the ratio of supply to demand for care facilities within the search radius.

\[ R^n_j = \frac{S^n_j}{\sum_{k \in \{d_{kj} < d^0_j\}} P_{kj} \left( d_{kj} \right)} \]  

(1)

Here, \( n \) is the type of care facility and \( R^n_j \) is the ratio of supply to demand for the \( j \)-th care facility of type \( n \) in the sphere of influence, that is, the ratio of the supply capacity of care facilities in the range to the demand for care facilities by seniors. \( S^n_j \) is the \( j \)-th level of supply of care facilities of type \( n \). The level of supply of RCFs uses the number of beds in the CCFs. As CCFs mainly provide services such as daycare, the number of beds does not measure their level of provision. The Code of Practice for the Construction and Service Management
We set the weight of the spatial accessibility of RCFs to 150 m. Therefore, we set the supply capacity of CCFs to 150. \( P_k \) is the number of elderly people in grid \( k \), and \( d_{kj} \) is the distance from the elderly in grid \( k \) to the care facility. \( d_0^n \) is the search radius of the \( n \)th care facilities, representing the area of influence of these care facilities. Each type of care facility has its own service radius definition based on the size and function of the care facility, reflecting the overall service capacity of the facility.

We set different weights for different care facilities. The formula is as follows:

\[
A_i^n = \frac{1}{\sum_{j\in\{d_{ij}<d_0^n\}} R^n_j f(d_{kj})}
\]  

Figure 3. Schematic diagram of the 2SFCA method. (1) is 2SFCA’s step 1 and (2) is step 2.

\( f(d_{ij}) \) is the distance decay function. Elderly people’s travel characteristics indicate their stronger willingness to travel short distances, while long-distance travel causes physical discomfort, meaning that their willingness to travel decreases rapidly. This change is similar to the kernel-density-type decay function, so we choose the kernel-density-type decay function for our \( f(d_{ij}) \):

\[
f(d_{kj}) = \begin{cases} 
\frac{3}{4} & d_{kj} < d_0^n \\
0 & d_{kj} \geq d_0^n
\end{cases}
\]  

Step 2: We calculate the spatial accessibility of the \( i \)th grid at the demand point for the \( n \)-type care facility.

After calculating the spatial accessibility of each type of care facility, the National Health Commission of the People’s Republic of China published a report stating that 70% of older Chinese people choose CCFs and 30% choose RCFs in the formal care group [61]. We set different weights for different care facilities. The formula is as follows:

\[
TA_i = \alpha A_i^{ag} + \beta A_i^{ch}
\]  

where \( TA_i \) is the spatial accessibility of integrated care facilities (ICFs), \( TA_i \in [0,1] \). \( A_i^{ag} \) is the spatial accessibility of the standardized RCFs, \( A_i^{ch} \) is the spatial accessibility of the standardized CCFs, and the standardization method uses the extreme difference method. We set the weight of the spatial accessibility of RCFs to \( \alpha = 0.3 \) and the weight of the spatial accessibility of CCFs to \( \beta = 0.7 \).
2.3.2. Parameter Setting

Based on the spatial accessibility of the 2SFCA, the setting of the search radius has a significant impact on the results. If the search radius is too large, the differences in accessibility within the region will be underestimated; conversely, the differences in regional accessibility will be overestimated. The proximity of older individuals to elderly care services is a crucial factor in measuring spatial accessibility. On the one hand, different services have varying influence ranges. On the other hand, older people exhibit different travel behaviors when faced with distinct care facilities. The primary function of RCFs is to provide comprehensive care, living, and nursing services for older individuals, and their sphere of influence is more extensive. More seniors rely heavily on car travel when choosing this type of care facility. The service radius of the RCFs was measured using the travel distance. Borrowing the idea of setting different service radiiuses for different organizations from existing studies [33, 62] and drawing on Yin’s findings [63], we set different service radiiuses for different types of care facilities for the elderly (see Table 1). Speeds of 60 km/h, 40 km/h, 30 km/h, and 20 km/h were set for the expressways, trunk roads, secondary roads, and side roads in the city, respectively.

Table 1. Service radius of care facilities.

<table>
<thead>
<tr>
<th>Types of Care Facilities</th>
<th>Beds</th>
<th>Service Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential Care Facilities</td>
<td>Micro Facility, 0–60</td>
<td>0.5 h</td>
</tr>
<tr>
<td></td>
<td>Small Facility, 60–120</td>
<td>0.9 h</td>
</tr>
<tr>
<td></td>
<td>Medium Facility, 120–220</td>
<td>1.2 h</td>
</tr>
<tr>
<td></td>
<td>Large Facility, &gt;220</td>
<td>1.5 h</td>
</tr>
<tr>
<td>Community Care Facilities</td>
<td>--</td>
<td>600 m/800 m</td>
</tr>
</tbody>
</table>

Note: The scale classification is derived from the Guide to the Construction of the Standard System for Elderly Services (2017); The service radius of residential care facilities is measured in terms of the distance traveled by car; The service radius of community care facilities is measured in terms of walking distance.

The primary function of CCFs is to provide living services, health care, rehabilitation, and cultural and entertainment services for the elderly [64], and their sphere of influence should consider the physical capabilities of older individuals. Thus, CCFs are generally located closer to where the elderly live. To assess the impact range of CCFs, we use a 15-min walking distance. Some studies have shown that the walking speed of older people is about 0.8–0.91 m/s [65]. Liu et al. (2020) based their analysis on the behavioral trajectories of a sample of 30 older people in Xi’an, and the results showed that the travel distance of older individuals was approximately 600–800 m [66]. Therefore, we set the distance thresholds for the CCFs at 600 m and 800 m.

2.3.3. Method for Evaluating Spatial Equality

We use the Lorenz curve to describe the cumulative percentage of population and the cumulative percentage curve of spatial accessibility. It reflects the degree of inequality in spatial accessibility: the greater the curve, the more uneven it is [13]. The Gini coefficient is the ratio of the area between the actual spatial accessibility distribution curve and the absolute equality curve to the area below the absolute income curve. It is calculated using the following formula:

\[ G_i = 1 - \sum_{j=1}^{n} (M_i - M_{i-1})(A_i + A_{i+1}) \] (5)

where \( G_i \) is the Gini coefficient, which ranges from 0 to 1, with smaller values representing more equal spatial accessibility in the region. \( G \in [0, 0.2] \) is considered absolute equality, \( G \in [0.2, 0.3] \) is considered comparative equality, \( G \in [0.3, 0.4] \) is considered relative rationality, \( G \in [0.4, 0.6] \) indicates poor equality, and \( G \in [0.6, 1.0] \) indicates a great disparity [67]. \( M_i \) is the cumulative proportion of the population in increasing order, and \( A_i \) is the corresponding cumulative proportion of accessibility.
3. Study Results

3.1. Spatial Characteristics of the Elderly Population and Care Facilities

The kernel density method can be used to show the overall distribution of the data and discover extreme points. We set a bandwidth of 1000 m and a cell size of 100 m, and used the kernel density method to characterize the spatial distribution of the elderly; the results are reported in Figure 4. The elderly population in Changchun is distributed eccentrically, with the main concentration center at point A, where Xinchun, Quan’an, Zijiang, and Minkang intersect. The secondary concentration center is point B, the junction between Hongqi and Chuncheng. For the purposes of this study, we draw a circle around points A and B, which are defined as the core area. This area has the highest concentration of seniors. By analogy, we define the area outside the circle up to the second tier of elderly population density as the transition area, or hexagon. This area has a medium level of elderly population density. The area outside the transition area is called the peripheral area, which has a smaller elderly population. Seniors are predominantly concentrated in the core area. This area is characterized by densely populated buildings, elevated land rents, and accessible transportation. As the distance expands, the concentration of the elderly population decreases, following a pattern of “core concentration–peripheral diffusion”.

![Distribution of the elderly in Changchun](image)

Figure 4. Distribution of the elderly in Changchun.

Figure 5 shows the distribution of care facilities in Changchun. Care facilities in Changchun are most densely distributed in the core area and more dispersed in the peripheral area. Care facilities are more concentrated in Dongzhan and Rongguang. In terms of profiles, the density of care facilities in the western part of Changchun is higher than that in the eastern part of the city. The number and distribution of different types of care facilities are markedly different. The number of RCFs is much lower than the number of CCFs. This is because the proportion of elderly people choosing residential care is much lower than the number choosing community care, and CCFs are an important place to meet the needs of most elderly people. Regarding their type, CCFs are primarily located in the core area and the transition area. The sub-districts with the highest number of CCFs are in Qingnian. RCFs are more commonly distributed in the transition area and are sparser.
in the peripheral area. However, taking into consideration land rent and environmental factors, larger RCFs have mostly been established in the peripheral area. Additionally, the supply capacity of both CCFs and RCFs is low in the southern part of Changchun from a north–south perspective, and the local space is in need of optimization.

Figure 5. Spatial distribution of care facilities.

3.2. Spatial Accessibility of Care Facilities

Spatial accessibility distribution characteristics may reveal the level of spatial equality of urban care facilities. An improved 2SFCA was used to calculate the spatial accessibility of the RCFs in Changchun. We classify spatial accessibility according to four natural breakpoints, with each color representing a different category. The color scale ranges from light to dark and is defined as ranging from poor to moderate, to good, to excellent.

3.2.1. Spatial Accessibility of Residential Care Facilities

Figure 6 shows the spatial accessibility of the RCFs. RCFs’ spatial accessibility emanates in a rippling pattern. The 2SFCA can be regarded as a specific ratio between the elderly population and the resources available to the elderly, quantified in terms of the number of resources for the elderly per person. From this standpoint, the downtown area has approximately 24.5 beds for every 1000 elderly people. This is above the national average but falls short of the government’s planning target. Regional differences exist in the spatial accessibility of RCFs. Of these, spatial accessibility to core areas and transition areas is more homogeneous, and both are at an excellent level. However, the peripheral area has the least spatial accessibility. Additionally, RCFs in the core area and transition area offer more services.

The factors affecting the spatial accessibility of RCFs vary between the north and the south. The north benefits from increased spatial accessibility due to the presence of nursing homes, richer residential resources, and a higher concentration of resources per elderly person. The accessibility of the south has improved due to the presence of a larger number of newly developed settlements and fewer seniors in comparison to the northern RCFs, resulting in fewer competitors for resources related to senior living. In addition, new
transport routes have been planned, making RCFs more accessible than in the core area, with a wider radius providing more residential resource options to the elderly.

Figure 6. Spatial accessibility of residential care facilities.

3.2.2. Spatial Accessibility of Community Care Facilities

The spatial locations of CCFs should meet the daily needs of the elderly, taking into account their neighborhoods. Consequently, we assume that the area of influence for CCFs should be aligned with a 15-min residential circle, with a service radius typically between 600 and 800 m due to the declining physical fitness of the elderly. In this paper, two results are reported in Figure 7A,B for service radii of 600 m (Figure 7A) and 800 m (Figure 7B), respectively. The spatial accessibility of CCFs does not show significant differences when using service radii of 600 m and 800 m.

Figure 7. Spatial accessibility of community care facilities (CCFs). (A) Spatial accessibility of community care facilities—600 m; (B) spatial accessibility of community care facilities—800 m.
CCFs exhibit a spatial accessibility that is polycentric and contiguous in nature. The core area’s spatial accessibility is distributed uniformly, whereas that of the peripheral area varies significantly. The core area’s accessibility varies less and is at a medium level. The spatial accessibility of CCFs is affected by transportation conditions. Elderly individuals have a restricted range of activities due to their physical limitations compared to younger age cohorts. Furthermore, seniors are inhibited by travel times in their choice of care facilities. The road network density in the core area is higher than that in the periphery, and the elderly can reach CCFs in less time, further improving the region’s spatial accessibility. Nevertheless, since the elderly population in Changchun is significantly concentrated in the core area with a higher demand, this also reduces spatial accessibility, resulting in a low level of spatial accessibility in the area.

High-value areas with spatial accessibility exceeding 0.136 are located in the peripheral area of the main urban area, namely, Xinglong, Xinxin, Yutan, and Fufeng, all of which are situated at a considerable distance from the distribution center. This is because the peripheral area is a newly developed sector in Changchun, and the number of CCFs in the area has increased. Additionally, the newly developed neighborhoods in the peripheral area have a higher proportion of young people and fewer elderly residents, which results in a lower demand for CCFs and a partial concentration of high values in this area. The distribution of resources between CCFs and RCFs is somewhat complementary. In certain regions where RCFs have limited spatial accessibility, the spatial accessibility of CCFs is higher. Based on the distribution pattern, the areas with high spatial accessibility values extend from northeast to southwest.

3.2.3. Spatial Accessibility of Integrated Care Facilities

The results, as presented in Figure 8, suggest that RCFs complement CCFs well. The ICFs’ spatial accessibility has a mean value of 0.277 and a standard deviation of 0.112, with a high frequency of cells at medium and low levels. The spatial accessibility distribution of ICFs in Changchun decreases from “center to periphery”, with the core area having the highest average accessibility and ICFs in the peripheral area having lower levels of spatial accessibility than the transition area. Nanling has the highest spatial accessibility value for ICFs, as RCFs and CCFs are concentrated there, along with well-supplied care facilities. Compared to analyzing an individual care facility, it is more instructive for planners to comprehensively consider the spatial parity of urban care facilities while rationally allocating spatial resources.

![Figure 8. Spatial accessibility of integrated care facilities.](image-url)
3.2.4. Spatial Accessibility Differences on the Sub-Districts Scale

The sub-districts/town is the smallest administrative unit in China and serves as the smallest unit in urban planning. There is considerable variation in the sizes of sub-districts in Changchun. The smallest sub-district in the downtown is Xinfa, with an area of 0.7 km\(^2\), while the largest sub-district is Yingjun, with an area of 54.38 km\(^2\), resulting in a significant difference of 53.68 km\(^2\). We considered whether this discrepancy affected spatial accessibility at the sub-district level. To verify the robustness of the research findings on a 1 km \( \times \) 1 km grid, we utilized QGIS 3.16 software to generate the center of mass with various sub-districts and measured the area-based spatial accessibility of care facilities in terms of sub-districts. The results are presented in Figure 8.

The degree of spatial equality at the sub-district scale deviates significantly from the results at smaller scales. Overall, the geographic variation in spatial accessibility at the sub-district scale is lower than that indicated by the results at the grid scale.

Spatial accessibility at the sub-district scale makes it difficult to identify the true spatial accessibility distribution characteristics of care facilities. Combining residential care facilities and community care facilities, the spatial accessibility of integrated care facilities at the sub-district scale also differs significantly from the results at smaller scales. As illustrated in Figure 9A, care facilities at the sub-district scale display a higher concentration of sub-districts with better spatial accessibility compared to transition areas.

**Figure 9.** Spatial accessibility of elderly care facilities at the sub-district level. (A) Spatial accessibility of integrated care facilities (ICFs); (B) spatial accessibility of residential care facilities (RCFs); (C) spatial accessibility of community care facilities (CCFs) at a 600 m radius; (D) spatial accessibility of community care facilities at an 800 m radius.
Additionally, the spatial accessibility of care facilities at the sub-district scale, in comparison to the grid, overlooks individual high-value areas. For instance, the spatial accessibility of care facilities at the grid level has a very high value in Yongxing. Nevertheless, the spatial accessibility of ICFs in Yongxing is of an inferior standard, likely due to the considerable fluctuations in accessibility at the sub-district level. As a result, this mode of analysis neglects extreme value points in the region. Similar situations are observed in Xinglongshan and Yutan. The internal variability of larger sub-district areas is higher, while spatial accessibility is averaged out, resulting in a reduced urban spatial accessibility gap. The north–south gap in the distribution of ICFs’ spatial accessibility is more noticeable, and the southern region has significantly lower spatial accessibility than the northern region.

At the sub-district level, the primary determinant of spatial accessibility by the service capacity of care facilities is different. The service range of RCFs increased, and the service area of large RCFs almost covered the study area, which was relatively unaffected by the scaling effect. Consequently, the spatial accessibility of RCFs at the sub-district level displayed a cascading fall, resembling the outcomes at small scales (see Figure 9B). Care facilities with a limited service radius cannot cover an entire sub-district. As a result, service capacity, which is important on a small scale, is not a significant factor influencing spatial accessibility at the sub-district level. The number of facilities is a key indicator of spatial accessibility. This is evident in Figure 9C,D, where regions with improved spatial accessibility of CCFs at the sub-district level largely correspond to the number of CCFs per person on that sub-district. CCFs are the primary social care facilities for the elderly, who, due to their physical functioning and other reasons, have a restricted range of movement. Hence, there is a pressing need to investigate CCFs on a micro-level when the government devises the blueprint for city-based care facilities.

3.3. Spatial Equality of Residential Care Facilities

We plotted Lorenz curves based on the data of the cumulative composition ratio of the population to spatial accessibility. Figure 10 shows the Lorenz curves for the three types of spatial accessibility, for ICFs, CCFs, and RCFs, which are used to explain the degree of spatial inequality in care facilities. Figure 9 illustrates that residential care facilities (RCFs) exhibit the highest spatial equality. Following RCFs, intermediate care facilities (ICFs) rank second. On the other hand, continuing-care facilities (CCFs) are found to be less spatially balanced, with less than 20% of them accessible to 40% of the elderly population.

![Figure 10. Lorenz curve.](image-url)
Alongside the Lorenz curve, we utilized the Gini coefficient to determine the spatial equality of the ICFs. Figure 11 illustrates the relative uniformity of ICFs in the downtown area, indicating a somewhat appropriate spatial arrangement of care facilities. Regarding the subtypes, the spatial arrangement of CCFs is in a relatively efficient state, and there is ample room for improvement. The Gini coefficient for the RCFs is 0.0838, which represents absolute equality. This suggests that the spatial arrangement of RCFs in Changchun is excellent, meeting the needs of the elderly in each area. Consequently, to raise the per capita allocation of resources among the elderly, the government should focus on enhancing the service capacity of existing facilities instead of unilaterally increasing the number of RCFs. In terms of area, the core area has the best spatial balance of care facilities, followed by the transition area, and the peripheral area has the most uneven distribution. Spatial balance varies among care facilities. For instance, RCFs are evenly distributed across all areas, while ICFs have a relatively balanced distribution in the peripheral area. Adjusting the CCFs located in the peripheral area would significantly enhance the spatial distribution of elderly care resources. The spatial accessibility of CCFs is relatively good in the transition area and core area, but there is a significant disparity in the peripheral area, which is a newly constructed district of Changchun City. As the population continues to move toward the peripheral area, existing elderly facilities, especially CCFs, will become insufficient, and optimization is urgently required.

![Gini Coefficient of Care Facilities](image)

**Figure 11.** The Gini coefficient of care facilities.

### 4. Discussion and Future Directions

#### 4.1. Discussion

Compared to developed countries, middle-income countries face more serious challenges from an aging population. The social demand for elderly care is growing, yet the material basis for such needs being met is relatively weak. Simultaneously, there are significant regional differences in terms of access to care facilities, and this spatial equality affects the quality of life of the elderly. Therefore, it is essential to evaluate the spatial equality of access to elderly care facilities for urban seniors in middle-income countries. We divide...
socially provided care facilities into residential care facilities and community care facilities,
with the two types of care facilities meeting different care needs. We use mobile phone
signaling data and POI, combined with an improved 2SFCA model, to explore the equality
of the spatial allocation of care facilities.

Using empirical data, we set different weights for the spatial accessibility of residential
and community care facilities to measure the equality of formal care facilities in the city.
Cultural traditions have a profound influence on the choice of elderly care models, as
has repeatedly been shown in East Asia. East Asia is influenced by Confucianism, where
children have an obligation to support their parents. Family care is the main form of care,
and community care facilities are an important type of formal care facility that complements
family care. Institutional elderly care facilities, as complementary facilities for other elderly
care services, are the least in demand in East Asian countries. In contrast, Europe, North
America, and other regions consider the government the main provider of support for
the elderly [68], and there are differences in the demand for community and residential
care facilities. Our weights can be adjusted according to the actual care needs of different
countries and regions.

In comparison to global metropolises, Changchun’s resources for the elderly are scarce. Higgs et al. (2020) highlighted that Wales’s intermediate level of elderly resources was around 40–55 beds per 1000 individuals [55]. By comparison, the RCFs in Changchun exhibit an aggregate shortfall. Furthermore, our research revealed that RCFs located in suburban areas of the city have low levels of spatial accessibility, which contrasts with the discoveries made by Yang et al. (2012) [69]. This is because the distribution of RCFs varies depending on the study area. RCFs in Changchun were mainly located in the transition area downtown, with only a few found in the periphery of the region. In contrast, Yang et al. (2012) discovered a higher distribution of RCFs in the suburban area of Beijing [69].

According to the Gini coefficient, urban peripheral areas have characteristics that
distinguish them from core areas. The core area has a relatively concentrated population,
and care facilities are densely packed and evenly distributed. In contrast, the periphery
area has a more dispersed population and a growing demand for elderly care. However,
the construction of facilities in the area is behind schedule, and the supply capacity is inade-
quate, increasing the spatial inequality of care facilities. The unequal spatial distribution
of infrastructure in peripheral areas is apparent not only in the provision of care but also
in the allocation of urban resources, such as transportation, healthcare, and education.
Policymakers and planners should consider this.

We discovered that varying research scales significantly influence the assessment of
spatial accessibility and equality in service facilities, as was the case in studies conducted
by Cheng et al. (2022) and Moturi et al. (2022) [51,70]. The results suggest that smaller
study scales allow for a more precise identification of supply and demand, which is more
favorable to the results of measuring the spatial accessibility of community care facilities
with a smaller search radius. At the same time, spatial equality measured on a large scale
may miss some extremes and misrepresent the spatial equality of care facilities [71]. The
research approach to spatial equality refined in this paper could enhance urban resource
allocation in high-resolution cities and provide theoretical backing for the planning of
15-min living circles.

4.2. Future Directions

Our study has some limitations. First, data availability constraints led us to use the
table of minimum service standards as prescribed by the Code of Practice for the Con-
struction and Service Management of Community Day Care Centers for the Elderly in Jilin
Province, which does not account for the variability of community care facilities for the
elderly. Through field research, we constructed a comprehensive index of care facilities that
measures the supply capacity of community care facilities, considering service diversifica-
tion, professionalism, scale, and other factors. This method offers a more comprehensive
analysis of care facilities’ spatial equality. Second, mobile phone signaling data make it
challenging to identify elderly individuals’ unique characteristics. Factors such as health level, race, number of children, and income may influence their preferences [72,73]. For instance, disabled elderly people may require more residential care facilities, while healthy elderly individuals might need more community care facilities to maintain social activities and a healthy lifestyle [74]. Future research can incorporate the demand-side perspective into the research framework.

5. Conclusions and Policy Implications

5.1. Conclusions

This study focuses on the spatial equality of elderly people’s access to care facilities in urban areas, which affects their quality of life. A research framework is developed to assess the spatial equality of care facilities from the viewpoint of refined urban management. Big data sources, such as mobile phone signaling and POIs, are selected and subjected to high-resolution analyses, providing policy recommendations for the allocation of urban resources. The primary findings are summarized as follows.

The distribution of the elderly population in Changchun’s downtown area indicates two centers of agglomeration, with an overall pattern of “core concentration–peripheral diffusion”. Similar to the population distribution, elderly facilities are most highly concentrated in the core area and spread more thinly in the periphery area.

Care facilities in the downtown area of Changchun have lower accessibility compared to those seen in economically developed cities.

Variations exist in the spatial accessibility of care facilities in urban areas. These disparities are mirrored by the outward-spreading ripple pattern of the RCFs, as opposed to the relatively poor accessibility of the peripheral area. Moreover, CCFs are more accessible in the core area than in the transition area, and the peripheral area’s accessibility needs improvement. Additionally, a certain degree of complementarity exists between RCFs and CCFs. The use of the Lorenz curve and the Gini coefficient reveals that the spatial distribution of intermediate care facilities in Changchun shows an absolute state of equality, while regional variations exist. In the core area, there is a good spatial balance of care facilities; however, there is a need for improved spatial balance of care facilities in the peripheral area.

5.2. Policy Implications

The elderly population in some middle-income countries is experiencing rapid growth, resulting in a demand for care facilities that is increasing year after year. Care services are a crucial aspect of government work. First, the government can optimize the supply of care services by expanding community care services, encouraging more enterprises to enter the elderly care market, and broadening investment and financing channels. Enhancing the scale of existing residential care facilities for the elderly, improving their service capacity, and promoting a spatial balance of care facilities are also essential.

Second, the spatial allocation of care facilities directly impacts the extent to which elderly individuals are satisfied with these facilities. Effective planning within the 15-min living circle, or 1 km × 1 km grid, ensures equitable access to care facilities.

Finally, optimizing walking paths within the living circle is vital. As elderly individuals often walk to community care facilities, the sensible layout of walking paths significantly influences their travel choices. Ensuring that paths are well designed and accessible can enhance the overall experience for the elderly when utilizing care facilities.

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