

Spatial Accessibility of Community Elderly Care Services for the Elderly in Beijing, China

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Abstract. Since China entered an aging society in 2000, the population has been gradually becoming older and aging faster. The accelerating and deepening of population aging poses a severe challenge to elderly care resources. This study addresses the challenges of an aging population and the uneven distribution of elderly care resources in Beijing by integrating data on the city's road network, elderly population, and care centers. Utilized QGIS software and the 2SFCA method to assess spatial accessibility and social equity of elderly care centers in Beijing at the township and street levels. There is a roughly consistent spatial density layout between the elderly care centers in Beijing and the elderly population. A spatial distribution pattern of elderly care centers in Beijing shows an uneven spatial accessibility level. A small number of northeastern and southwestern regions and the central urban area have high accessibility. In general, the spatial equity of spatial accessibility to elderly care centers in Beijing is very good, and the Gini coefficient of spatial accessibility is only 0.17. The results can provide theoretical support for the Beijing government to further improve the layout of elderly care resources in the future.

Keywords: Spatial accessibility, elderly care services, Beijing.

1. Introduction

Over the past few years, China has experienced a rapidly increasing rate of demographic aging. According to the latest census data, the demographic survey indicates that individuals aged 60 and above now constitute over 18.7% of the total population in China, signaling the country's transition into a period characterized by advanced aging [1, 2]. The subsequent increase in demand for services catering to the elderly is notable. Beijing, serving as China's capital city, is grappling with significant challenges related to an aging population. The equilibrium of elderly care service provision is under considerable strain.

To tackle the challenge of an aging population, Beijing has rolled out a dedicated strategy for senior care, aiming to speed up the development of a comprehensive elderly care system and enhance the infrastructure for senior services progressively [3]. Elderly care centers, a crucial component of public service infrastructure, are vital in ensuring the well-being of senior citizens, but their construction level lags far behind the speed of population aging, mainly facing problems such as insufficient resources, incomplete construction, and mismatch between supply and demand [4, 5]. Beijing government has significantly expanded community health services and elderly care centers as part of its strategy to support the aging population, demonstrating a commitment to "integrating healthcare and social services to enhance the well-being of older adults" [6]. A specialized investigation is required to determine if the spatial arrangement of elderly care centers within communities aligns perfectly with the distribution of the elderly demographic. This study would also need to assess the proximity of elderly care services to the elderly. Such research would uncover whether the elderly can conveniently access these services in their vicinity. The findings from this spatial accessibility analysis of elderly care centers would then offer a theoretical foundation for the strategic and equitable distribution of elderly care resources across different areas.

The spatial accessibility of community elderly care centers refers to the degree of difficulty for the elderly to reach the elderly care center from their residences. It is affected by various factors, such as

traffic conditions, geographical distance, road network and so on. After the spatial accessibility to the community elderly care centers is analyzed, the convenience for the elderly to access elderly care services can be better understood, and existing problems and deficiencies can be identified, which will provide a basis for optimizing the layout of elderly care service centers. In addition, it can also promote the rational allocation of community elderly care service resources, improve the efficiency and quality of elderly care services to meet the growing needs of elderly care services.

Accessibility to elderly care centers within communities is a critical measure of the standard of senior care services. It directly affects whether the elderly can access elderly care services conveniently. Therefore, it is of great practical significance to analyze the spatial accessibility to community elderly care centers in Beijing.

This study uses GIS and other technical means, field investigation, and data analysis to conduct in-depth research on the spatial accessibility to community elderly care centers in Beijing. This research endeavors to assess the spatial reach of senior care facilities across Beijing, with the goal of uncovering patterns in their geographic distribution and the elements that shape them. It seeks to offer a data-driven framework to enhance the strategic placement of community-based senior care services and to elevate the standards of care for the elderly. The value of this investigation is underscored by:

(1) Providing a reference for the government to formulate policies on elderly care services, helping to rationally plan the layout of elderly care service facilities and improve the supply efficiency of elderly care services.

(2) Assisting seniors in selecting community-based senior care facilities enables them to gain a clearer insight into the availability of nearby senior care services, thereby allowing them to make more informed decisions about the care options that best meet their individual needs.

(3) Enriching and improving the research theories and methods of the spatial accessibility to community elderly care centers, and providing references for research in related fields.

2. Background of Study Area

Beijing, located in the northern part of China, is the capital of the country. Beijing is surrounded by Hebei Province on its northern, western, and southern sides, while Tianjin lies to its southeast. As a major political, cultural, and economic hub, it spans roughly 16,410 km² in land area. The city's unique geographical position places it at the intersection of Northern China's plains and mountain ranges, making it an ideal strategic center throughout Chinese history.

In 2022, Beijing's total population has exceeded 21 million people, with 4.651 million aged 60 and above, making up 21.3% of the city's population [7]. The city is divided into 16 districts, each vary in population density, infrastructure, and other features. The trend of the aging population has been most prominent in the city's central districts, where the elderly population density is highest. Urban districts, such as Dongcheng, Xicheng, and Chaoyang, are among the most densely populated areas with a high concentration of elderly individuals, while the peripheral and suburban areas, like Miyun and Yanqing, have comparatively lower densities of elderly residents [8].

According to the Report on the Aging Development in Beijing in 2022 [2], the number of elderly people in Beijing shows an increasing trend year by year. In 2022, the permanent population aged 60 and above in Beijing was 4.651 million, accounting for 21.3% of the total population. It increased by 235,000 people compared with 2021, with an increase rate of 5.3%. Currently, the demographic of senior citizens in Beijing predominantly resides in the central urban areas and certain neighborhoods characterized by advanced aging. The surge in the aging demographic has exerted significant strain on services catering to the elderly, while also necessitating enhanced standards for the accessibility and spatial distribution of community-based senior care facilities.

3. Data and methods

3.1. Data

Demographic data on the elderly in Beijing (Table 1) was retrieved from the Statistics Bureau of Beijing at the district level [8]. Since the smallest administrative unit in China is the street, this study should also adopt this smallest administrative unit if it is detailed enough. However, there is no elderly population at the street level in the Statistics Bureau of Beijing, only the elderly population of its superior administrative unit, the district. To determine the number of seniors in each street, we used the ratio of the elderly population within each district relative to the overall population of each street.

The data of the community elderly care center in Beijing (Table 1) was obtained from the Statistics Bureau of China [7]. The transportation network data (Figure 1) was retrieved from Open street map [9].

Table 1. The number of the elderly and elderly care centers of every district in Beijing in 2022

District	Elderly Population [8]	Percentage of the elderly in the total population (%) [8]	Number of community elderly care centers [8]
Beijing city	4,140,000	29.0	1429
Dongcheng District	332,000	33.3	108
Xicheng District	473,000	31.0	112
Chaoyang District	698,000	31.9	210
Fengtai District	423,000	35.4	125
Shijingshan District	136,000	34.6	68
Haidian District	605,000	24.6	201
Mentougou District	83,000	32.0	38
Fangshan District	225,000	26.4	93
Tongzhou District	226,000	26.6	89
Shunwen District	179,000	26.6	85
Changping District	180,000	26.3	104
Daxing District	190,000	24.5	98
Huairou District	80,000	27.8	42
Pinggu District	111,000	27.2	33
Miyun District	121,000	27.4	16
Yanqing District	79,000	27.2	7

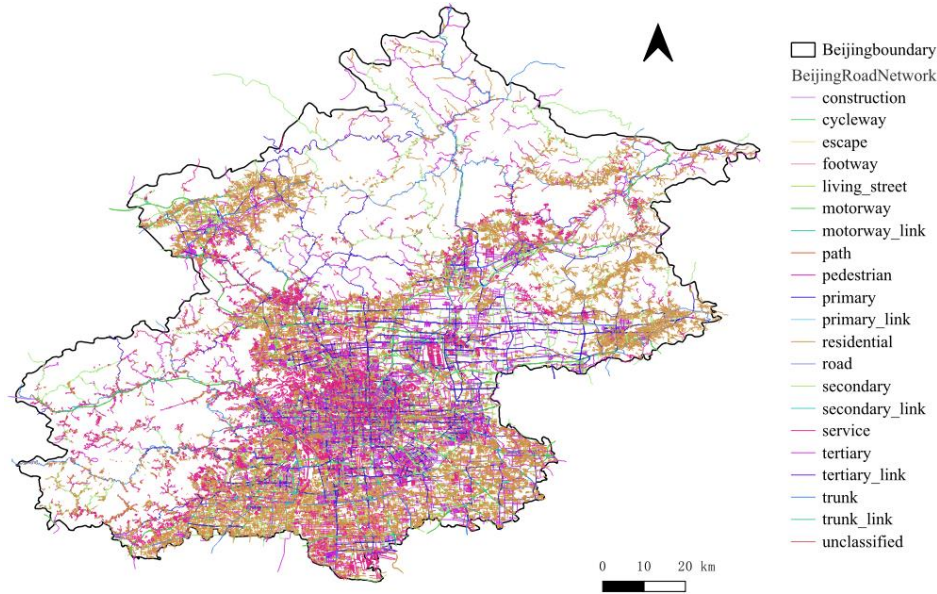


Figure 1. Road network in Beijing in 2022 (Original figure)

3.2. Methods

A large body of literature has discussed methods used for measuring spatial accessibility of public facilities. The widely recognized method of the two-step floating catchment area (2SFCA) stands out among various approaches. [10]. The research employed this technique to assess the ease of access to local senior care facilities for Beijing's senior population. The 2SFCA method is operated in two steps:

First, we selected a thresholds of travel distances to define the catchment of an elderly care center j based on the below rationale. The chosen cutoff was set at 20 kilometers, taking into account that seniors typically prefer to access senior care services within close proximity. For each elderly care center location j , we identify every senior citizen's location within a reachable distance from each elder care facility's site, known as the service area, and then determine the proportion of elder care facilities to the senior citizenry within that service area. Then we searched all elerly population locations (k) within the travel zone of D_0 from a elderly care center j to compute the supply-to-demand ratio (R_j) as follows:

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

Where P_k denotes the elderly population of the census unit k that falls within the catchment j ($d_{kj} \leq d_0$); S_j denotes the service capability of an elderly care center j (e.g. the number of beds and physicians); d_{kj} denotes the travel distance between k and j . We applied the same service capability of each elderly care center, 3/10000.

Second, we searched all elderly care centers j which were within a certain travel distance zone from each elderly population location i , and summarized the supply-to-demand ratios, R_j at all elderly population locations as follows:

$$A_i = \sum_{j \in (d_{ij} \leq d_0)} R_j \quad (2)$$

Where A_i denotes the elderly care accessibility index of elderly population at a population location i ; R_j denotes the supply-to-demand ratio at an elderly care center j within the area catered at an elderly population location i ($d_{ij} \leq d_0$). Beijing has totally 360 origins (census blocks as population locations) and 1429 destinations (elderly care centers), generating a network matrix that contains 514,440

origin-destination pairs. This matrix was used in the network analysis which was conducted using arcpy.na package in Python 3.10; the analytical results were mapped in Arc-GIS Pro 3.34.9.

Subsequently, we utilized the Lorenz curve and the Gini coefficient to assess the spatial justice concerning the accessibility of elderly care facilities for the aged population across Beijing. Lorenz curve represents a standard approach in economics [10, 11], which is employed to measure the level of equity based on its relative distribution among a population. To generate the Lorenz curve, we first ranked the average A_i of each street in an ascending order, and then plot the cumulative portion of the elderly in each street on the horizontal axis, and the cumulative portion of the average A_i on the vertical axis (Figure 2).

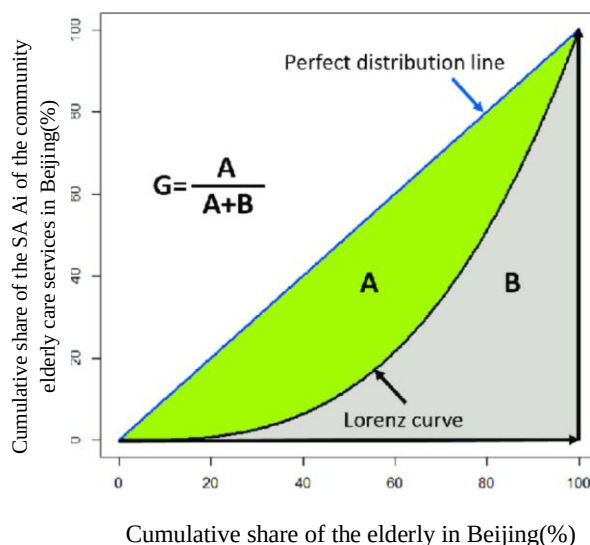


Figure 2. The Lorenz curve and Gini coefficient (Original figure)

If the spatial accessibility of each street is equal, then this will produce a straight line (Perfect distribution line) illustrating the linear relationship between the two variables in the two axes. In practice, the Lorenz Curve deviates from the Perfect distribution line (Figure 2). The Gini coefficient was calculated as the proportion of the area between the Lorenz Curve and the Perfect distribution line (Area A in Figure 2) over the area below the Lorenz Curve (Area B in Figure 2), shown as [12]:

$$G = 1 - \sum_{i=1}^n (x_i - x_{i-1})(y_i + y_{i-1}) \quad (3)$$

Where G represents the Gini coefficient; n is the total number of streets; i is an accumulative counter that counts up by 1 from 0 to n . x_i represents the cumulative percentage of the population over 60 in each street in Beijing, the cumulative percentage of the average value of A_i for each street is denoted by y_i . The Lorenz curve is the continuous curve connecting all points (x_i, y_i) , starting at $(x_0, y_0) = (0, 0)$ and ending at $(x_n, y_n) = (1, 1)$. The value of Gini coefficient falls between 0 (representing total equity) and 1 (representing total inequity). The evaluation of equity based on Gini coefficient is shown in Table 2 [12].

Table 2. Equity evaluation on Gini coefficient

Gini coefficient	equity evaluation
$G < 0.2$	too equity
$0.20 \leq G < 0.3$	relatively equity
$0.30 \leq G < 0.4$	relatively reasonable
$0.40 \leq G < 0.6$	too large
$G \geq 0.6$	with a significant gap

4. Results and Discussion

4.1. The geographical layout of senior citizens and their corresponding care facilities across Beijing

The elderly population density data of Beijing is summarized and summed by township and street scale through the QGIS software. The population distribution data is classified according to the natural breaks method (Figure 3Figure 3.). On the whole, the elderly population in Beijing shows a spatial distribution pattern of dense in the center and sparse around. From the street scale, the units of Sijiqing Street, Lugouqiao Street, Xincun Street, Jiugong Town, Huilongguan Street and Beiqijia Town have a large permanent population, up to 8,000 people, while the Xinzheng Street in Fangshan District and the Tanying Township in Miyun District have a smaller permanent elderly population.

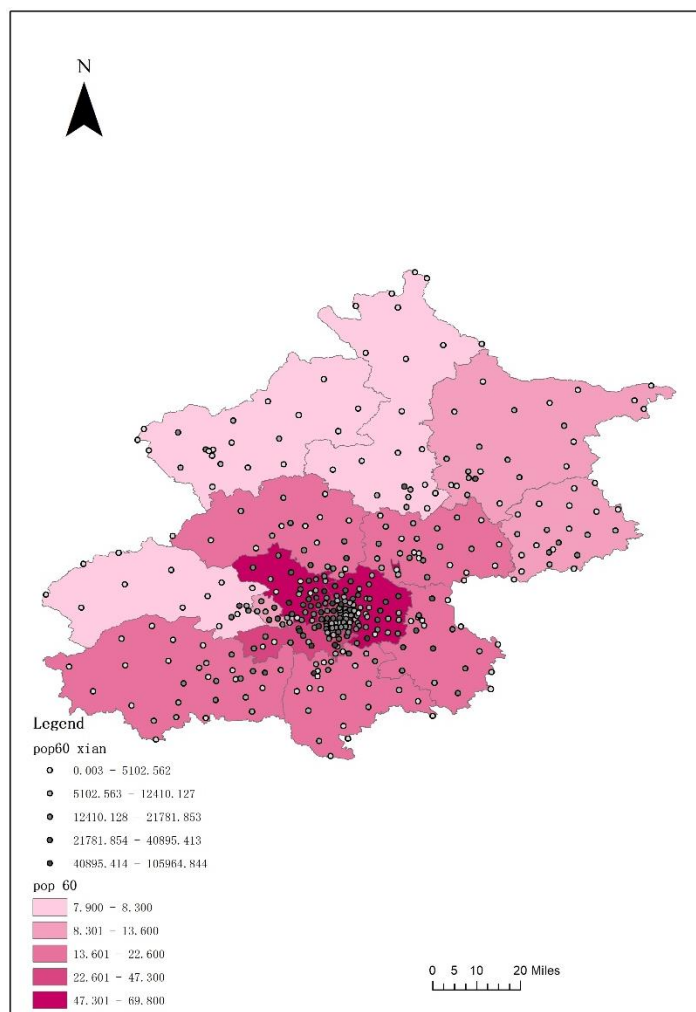


Figure 3. Spatial distribution of the elderly in Beijing (Original figure)

In Beijing, there is a total of 1,429 facilities dedicated to the care of the elderly. As shown in Figure 4, the density of elderly care centers as a whole shows an uneven distribution, with the density value in the central urban area higher than in other areas, such as Anzhen Street, Beixiaguan Street, and Yungang Street, etc. On the periphery, there are hot spots centered around township and street such as Yanqing Town, Miyun Town, Xinhua Street, Qingyuan Street, and Sujiatuo Town.

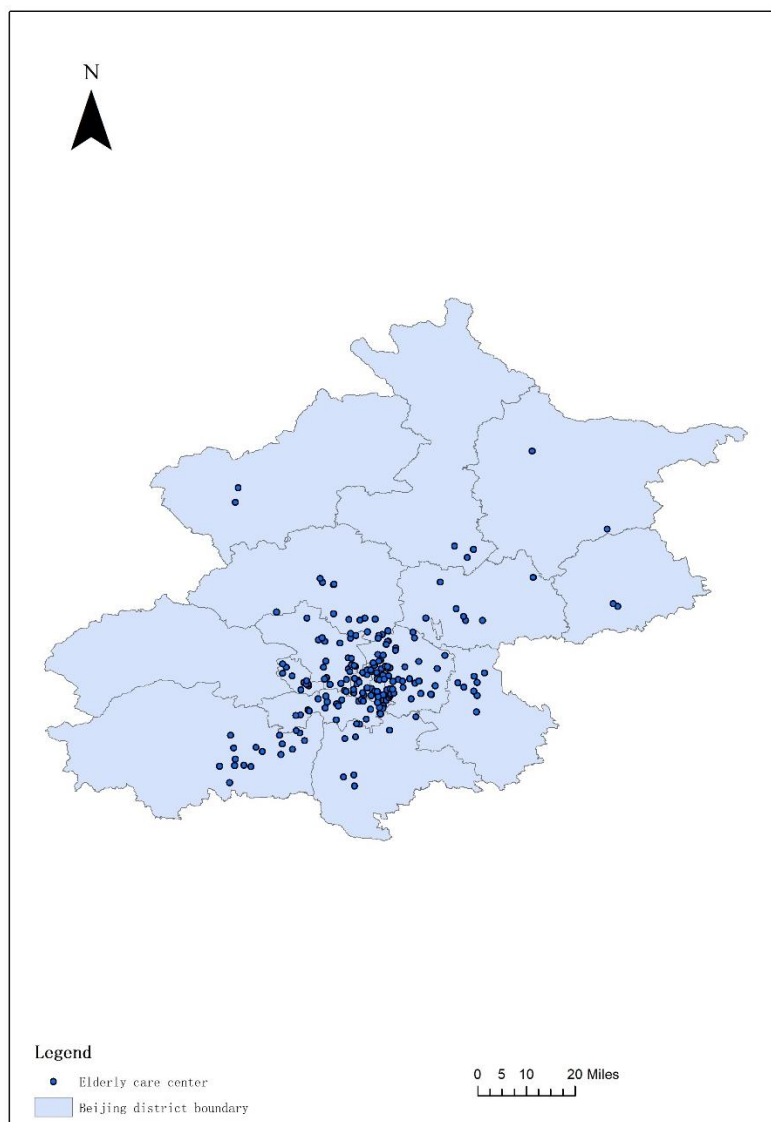


Figure 4. Spatila distribution of the locations of the elderly care centers in Beijing (Original figure)

4.2. Spatial Accessibility to Elderly Care Centers for the Elderly in Beijing

The spatial pattern of the spatial accessibility to elderly care centers for elderly people in Beijing within 20km is revealed in Figure 5. According to this graph, the spatial accessibility to elderly care centers for elderly people in the northeast and southwest of Beijing are the highest, up to 0.133, but the lowest value is in the northwest and southeast of Beijing, only between 0 and 0.012, the value in central Beijing ranges from 0.012 to 0.078. The analysis shows that the Northeast's excellent geographic accessibility can be attributed to a balanced distribution of senior care facilities, which is made possible by the region's limited number of senior care facilities and senior population. Because there are few senior care facilities and a high concentration of older residents, the central region has a low spatial accessibility. Then, the adjacent regions, like the west, are primarily mountainous and have very few senior care facilities; as a result, their spatial accessibility is zero.

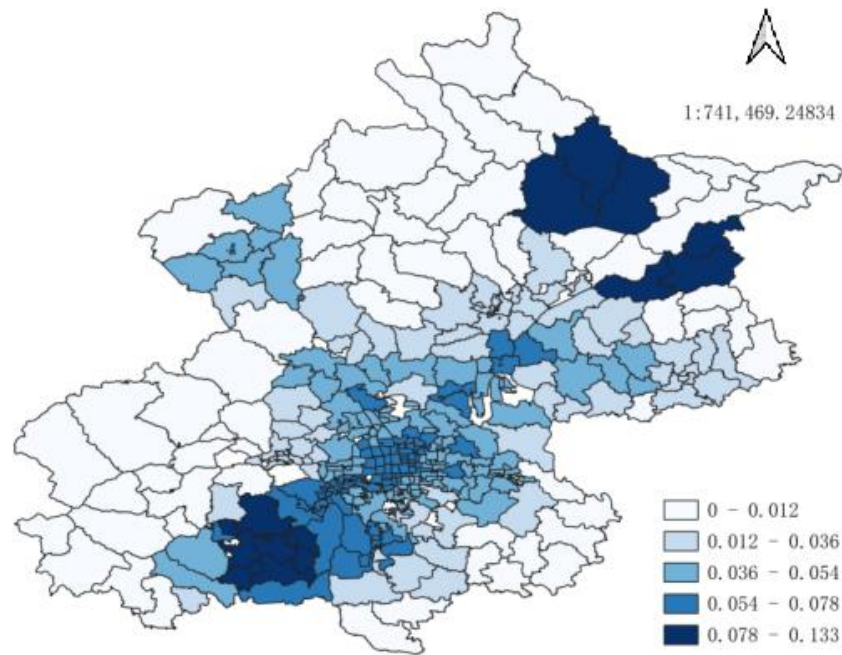


Figure 5. Spatial patterns of Spatial accessibility to Elderly Care Centers (Original figure)

According to this graph, the northeast and southwest of Beijing have the highest accessibility to community elderly care centers for people over 60, with the highest value of 0.133. However, most of the northwest and southwest regions have a range of 0 to 0.012, or even 0. The central region has a range of 0.012 to 0.078. The analysis reveals that the high accessibility in the Northeast is due to the fact that there is a balanced distribution of elderly services available to the elderly because of the small number of community-based elderly services and the number of elderly people there. Because there are fewer community senior care facilities than there are elderly individuals, accessibility is poor in the central region. The accessibility is zero because the adjacent areas, like the west, are primarily mountainous and have very few community senior care facilities.

4.3. Spatial Equity of Spatial Accessibility to Elderly Care Centers for the Elderly

The Lorenz curve of the spatial accessibility to elderly care centers is shown in Figure 6. The Gini coefficient of 0.17 indicates a high level of equality in the spatial distribution of elderly care services across Beijing's streets. This very low Gini value suggests that there is minimal disparity in how elderly individuals across different districts can access these services. In essence, the distribution of services is fairly balanced relative to the elderly population in each area.

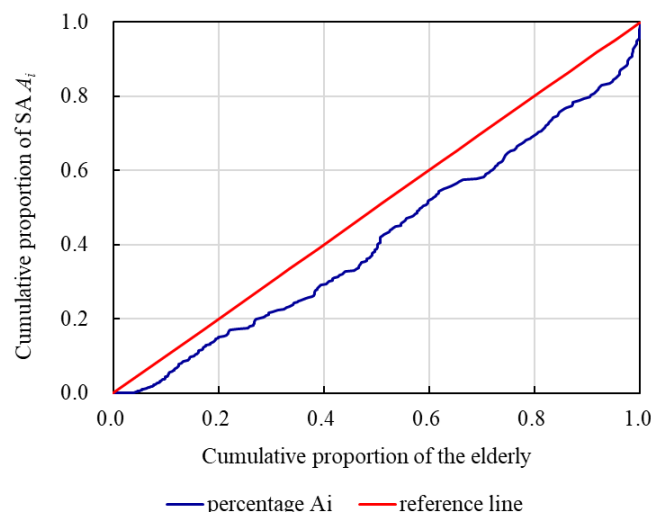


Figure 6. The Lorenz curve of spatial accessibility to elderly care centers (Original figure)

This low Gini coefficient implies that Beijing has effectively implemented policies and strategies that ensure equitable access to elderly care services across its districts. This achievement could be attributed to meticulous urban planning and strategic investment in infrastructure, particularly in areas identified as having greater current needs or potential future demands.

Even though some districts may have larger elderly populations or higher AI values, the low Gini coefficient suggests that these differences do not result in significant disparities in access. Essentially, the system in place ensures that accessibility remains balanced across the board, regardless of these variations.

The Gini coefficient serves as a compelling evidence that Beijing has achieved a commendable level of fairness in the spatial distribution of elderly care services. It reflects a well-planned and effectively executed approach to urban and social planning, ensuring that the elderly population across different districts can access the care they need with minimal disparity.

When analyzing the spatial distribution of elderly care services in Beijing, the overall results indicate that Beijing has performed relatively well in providing equitable access to these services. However, there are notable variations in the distribution of elderly populations across different districts. For example, districts such as Haidian and Chaoyang have the highest concentrations of elderly residents. Despite these large elderly populations, the Gini coefficient for the Accessibility Index (AI) in these districts falls within the 0.4-0.5 range, which is close to the baseline. A relatively high degree of fairness can be observed in the distribution of services despite the demographic pressures; these regions provide equitable and accessible elderly care services for a large portion of the elderly population.

On the other hand, districts like Yanqing exhibit a different trend. In spite of the fact that this district does not have a particularly high elderly population, the provision of elderly care facilities has exceeded the baseline, indicating that the district is well-served relative to its elderly population. This could reflect proactive planning and investment in elderly care infrastructure, potentially in anticipation of future demographic shifts or as a strategy to address potential disparities in service provision early on.

From a spatial distribution perspective, the uneven distribution of the elderly population across Beijing's districts is evident. While some districts manage to maintain a good level of service equity despite having large elderly populations, others with fewer elderly residents still perform well above the baseline in terms of service provision. This overall trend suggests that while Beijing is performing well in some areas, there remain disparities that need to be addressed to ensure that all districts provide fair and equitable access to elderly care services.

4.4. Limitations

The elderly population statistical data in this study is not a direct measure of the population. It is calculated according to the proportion of elderly people in the country based on the total population data. It is indirect data, and there is bound to be a certain gap with the direct statistical data. This gap will affect the accuracy of the study's results.

A unified service index for all community elderly care services is used in this study, and different service indices are not assigned according to their capabilities. This can lead to overestimation of the accessibility results of community elderly care services.

5. Conclusion

This study evaluates the spatial accessibility to elderly care centers for the elderly in Beijing and its social equity. Its findings are summarized as below.

(1) The allocation of community elderly care services aligns with the demographic distribution of the elderly population.

(2) As a whole, elderly care centers in Beijing have an uneven spatial accessibility level. The central urban area is mostly home to units with high accessibility, such as Xichanganjie Street,

Shichahai Street, Dongzhimen Street, and in the northeastern part of the region, such as Fengjiayu Town, Bulaotun Town, and in the southwestern part of the region.

(3) The Gini coefficient of the spatial accessibility to elderly care centers is very small, only 0.17. It indicates that the social equity of spatial accessibility to elderly care centers is very good as a whole. This shows that Beijing's special plan for elderly care services is successful.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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