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Density, Diversity, and Design: Evaluating the Equity of the Elderly Communities in Three Measures of the Built Environment

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Abstract: Building an aging-friendly city is necessary, considering the unprecedented demographic shift of the aging population. It is necessary to study the built environment conditions surrounding the elderly's residential areas. This study examines the density, diversity, and design (3D) features around the two typical elderly communities, which are community-based care and the nursing home. Then, the equity analysis is conducted from the social and spatial perspective. We use the 3D framework to measure the built environment around elderly communities. The essential features of an aging-friendly community are used to assess the built environment around the elderly communities. Moreover, we analyze the social and spatial equity of the elderly communities from the facility level and the town level. From the facility level, the 3D features of the elderly communities and the whole communities are compared to identify the social disparity among groups. From the town level, the average values of the 3D features are aggregated to each town, and then the attribute values of the towns are compared to reveal the spatial gaps and spatial mismatch areas. Results found that the spatial distributions of the 3D features around elderly communities present the center-periphery patterns. This study also found that a social disparity exists between the elderly communities and the whole communities. Moreover, there is a spatial mismatch between the diversity of facilities, road connections, and the number of elderly. Towns located in the fringe area are with a high number of elderly, but with a low diversity and road connections. The findings of this study can help planners and decision-makers to optimize the living facilities for old people and inform the gap in planning an aging-friendly city.

Keywords: elderly community; built environment; 3Ds; social equity; spatial equity

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1. Introduction

The elderly population is a growing number of groups in the world. According to the United Nations 2022 report, the total number of people aged 65 years or over is 771 million in 2022, which means that 10 percent of people are aged 65 years or over [1]. In this context of ageing, the Sustainable Development Goals (SDGs) proposed several strategies to increase the quality life of the elderly, such as enhancing the equity of accessing urban environments, promoting health [2]. As the elderly would spend more time in their neighborhoods, the neighborhood conditions and the surrounding built environment are important factors associated with their quality of life [3,4]. In this context, the built environment design for neighborhoods housing elderly individuals and active aging has gained an increasing amount of attention [5–7].

Many studies have shown that the environment of places influences the elderly outcomes, such as health status, the quality of life, and mental well-being [8,9]. Home and communities, as two typical environments, would enable the elderly to live independently and participate in social activities. However, aging well in place needs more support to sustain a high quality of life [10]. Neighborhoods with a greater density, mixed land uses, high road connectivity, and greater population density, are more attractive to people and promote more physical activities [11,12]. Those neighborhood characteristics are also correlated with elderly outcomes (e.g., life satisfaction, physical activity, travel behavior) [13,14]. The age-friendly cities and communities guide from the WHO highlights eight domains of communities that would improve the life quality of the elderly. Of which, community support, built environment, and transport connectivity are essential factors [15]. Studies found that aging well is associated with public amenities, such as healthcare services [16], transit services [17], green space services [18], daily life services [19], and recreational services [20]. Worse access to public amenities generates a resource deprivation for the elderly [21].

With regard to the influence of amenities, studies examined the effects of the density, diversity, and accessibility of the amenities among the elderly [22–24]. Since the elderly have specific demands of daily living (e.g., healthcare, shopping, recreational), the amenity density in a neighborhood is an important factor affecting their residence choice [23,25]. Mobility and social participation are two important factors influencing the health and quality of life among the elderly [26]. A neighborhood with a high diversity of amenities may promote the mobility of the elderly, because of the possibility to access facilities within walking distance and in safe walking circumstances [24]. Moreover, neighborhood design is found to be a promising strategy to enhance the walking trips of the elderly population and promote their social participation in the neighborhood [22].

The equity of access to public amenities, as other social groups, is a fundamental right for the elderly population [27]. However, older people are found to be disadvantaged in access to essential public services, compared with younger people [28]. Moreover, the disparity does not exist among age groups but also existed geographically among elderly communities. The accessibility to public facilities decreases from the urban central area outwards [29,30]. As the uneven distribution of amenities, the elderly population is found to be deprived of accessing high-quality amenities (e.g., upper-tier hospitals) [31]. In this context, the ability to access public amenities, for the elderly population, should account for the social and spatial perspectives.

Various methods have been applied to assess the equity for the elderly, which includes statistical methods, economic indices, and geographic models [31–33]. The economic models (e.g., Lorenz curves, Gini index, Theil index) are the most widespread methods to assess the spatial disparity and the social disparity between the elderly and other groups [31,34]. To capture the geographic characteristics of the disparity of equity for the elderly, studies applied the hot-spot analysis [32], and the spatial autocorrelation analysis [33]. Spatial and social are the two features to evaluate equity [35]. Studies have examined spatial and aspatial equities and used both the economic and geographic models to identify whether the disparity of equity exists and where the uneven areas are located [36–38]. However, studies of the built environment for the elderly have seldom examined the social and spatial equities, simultaneously.

In summary, the current research has rarely examined the built environment around the elderly community and limited research assessed the disparity of equity for the elderly community from the social and spatial perspectives, simultaneously. The conceptual framework is shown as Figure 1. We adopted the 3Ds framework (density, diversity, design features), developed by Cervero and Kockelman [39], to examine the characteristics of the built environments around the different elderly communities (the community-based care and nursing home). Then, the Lorenz curve and the Gini coefficient are used to identify the disparity of the 3D features between the elderly communities and the other communities to analyze the social equity. At last, the global Moran' I and the local spatial association indicator (LISA) models are applied to identify the spatial patterns of disparity for the elderly communities, and the Mann–Whitney U test is used to compare the spatial equity among towns.

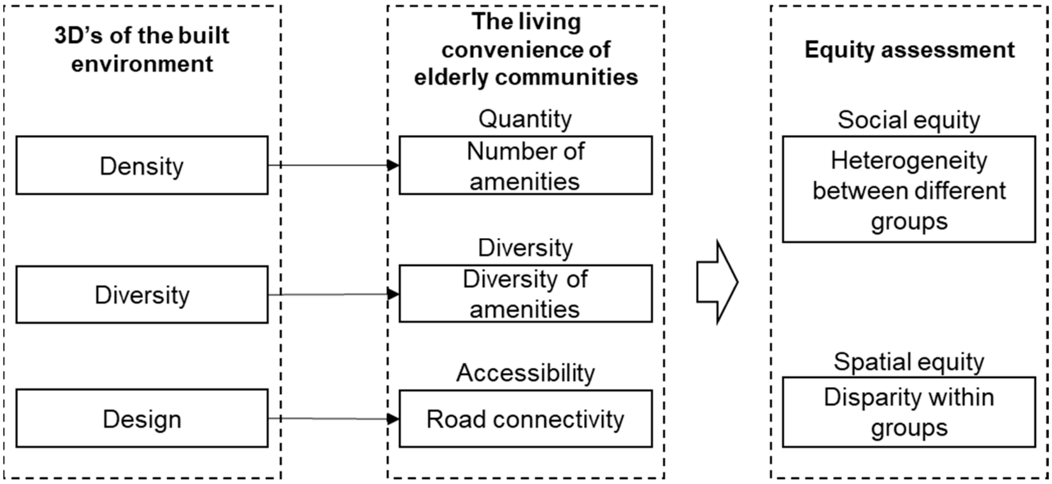


Figure 1. The conceptual framework of this study.

2. Materials and Methods

2.1. Study Area

China is experiencing the issue of ageing. According to the 2020 National Old-age Development Bulletin, the number of people aged 65 and over is 190.64 million, accounting for 13.50% of the total population [40]. Given the one-child policy forming the new family structure in China, the traditional elderly care mode, in which the next generations take care of older relatives, brings a lot of pressure on families [41]. Moreover, the rapid economic growth and globalization have carried out a new emerging culture in China, which has changed the lifestyles and attitudes to life of Chinese people [42]. Elderly people require a high-quality elderly care. The limited elderly care resources and the expanding demand of the elderly make the government shift the role from taking all duties of the elderly care to the leaders and designers of the elderly care system [43]. Multiple subjects (e.g., communities, private enterprises, and social volunteers) are invited to develop the elderly care system, and diversified elderly care modes have emerged in China.

We chose a typical city in China, which adopted diversified elderly care modes, to examine the built environments around the elderly care communities. The study area is the city of Nanjing, which is located in the core area of the Yangtze River delta and Yangtze River urban agglomeration. There are 11 municipal districts in the city of Nanjing with a total area of 6587 square kilometers (Figure 2). According to the Seventh National Population Census survey, the permanent population in Nanjing is about 9.31 million. Of which, the number of elderly people over 65 years old is 1.28 million, accounting for 13.70% [44]. In the past decade, the proportion of the aging population in Nanjing increased by 4.50% (9.20% in 2010). In response to the aging the population issue, the government of Nanjing has carried out numerous policies to create an environment for active aging, such as building an elderly care service system combining medical care with nursing care. In this context, the city of Nanjing is a typical study area to examine the equity of the elderly communities.

2.2. Data

This study uses the elderly community data, the POI data, the road data, and the census data to conduct the equity analysis. Of which, the elderly communities' data is collected from the Nanjing Civil Affairs Bureau [45]. We collected the information of 768 elderly communities, including 493 community-based care and 275 nursing home facilities. The information includes the addresses and types of the elderly communities. The addresses are transformed to the spatial coordinates and imported to the ArcGIS for further analysis. We used Baidu API to collect the POI data, which covers the most frequent public amenities that the elderly use. To facilitate the analysis, the POI data is classified into five categories, which are healthcare, shopping, transit, park, and life service facilities (Table 1). The road data is derived from Open Street Map and converted to a road network for the road connectivity analysis. The census data is based on the 6th national census of the population dataset, and the number of elderly is aggregated to each town in Nanjing.

Figure 2. The boundary of the City of Nanjing.

Table 1. The data description.

Category		**Description**
Elderly community		Community-based care and nursing home
Public amenity	Healthcare facilities	Hospital, clinic, pharmacy
	Shopping facilities	Shopping mall, supermarket
	Transit facilities	Bus station, metro station
	Park facilities	Park
	Life service facilities	Library, museum, bank, restaurant
Road data		Road network from Open Street Map
Census data		From the 6th national census of population dataset

2.3. Measures of Density, Diversity, and Design

This study assesses the built environment around the elderly neighborhood from the density, diversity, and design features. The 3D features are important factors to describe the built environment in urban settings and they may affect people's activities and travel patterns [39,46].

The density index is calculated using the number of POIs divided by the total areas of the 1 km walking catchment area around the elderly care facilities. Each category and the whole POIs' density are calculated, respectively. According to previous studies, the average walking distance for the elderly is around 1 km, so this study assumes that the activities area around the elderly communities is within 1 km [47]. The formula for calculating the density index is shown, as follows:

$$H_{density} = \frac{n_i}{A_{buffer}} \tag{1}$$

where $H_{density}$ denotes the density of amenities around elderly communities for amenity i. n_i is the number of amenity i in the 1 km walking catchment area, and A_{buffer} is the total area of the walking catchment.

The diversity index is calculated by the mix of public amenities around the 1 km walking catchment area of the elderly communities. The formula is shown as follows in Equation (2).

$$H_{diversity} = \sum_i^n L_i^2 \tag{2}$$

where $H_{diversity}$ is the diversity of amenities around elderly communities. L refers to the proportion of the amenity i out of n types.

The design index is calculated using a gravity analysis to measure the road network connectivity around elderly communities. The gravity index is developed to measure the reachable index within a certain searching radius [48]. First, the nodes of the street segments are chosen as the origins and destinations. Then the urban network analysis (UNA) tool is used to calculate the gravity index. The average values of the gravity index for the road nodes within the 1 km distance to the elderly community are aggregated to each elderly community.

$$H_{design} = \sum_{j \in G-(i);\, d(i,j) \leq r} \frac{w_j}{e^{\beta * d(i,j)}} \tag{3}$$

where H_{design} is the road network connection around the elderly communities. β is the coefficient that controls the distance decay of the shortest path from node i to j. w_j is the weight function to destination j. $d(i,j)$ is the distance between node i to j. r is the searching radius.

2.4. Assessing Social and Spatial Equities

This study evaluates the social equity and spatial equity of the built environment around elderly communities. The one-way ANOVA test, Lorenz curve, and Gini coefficient methods are applied to assess the disparity of the social equity between the elderly and other groups. The global Moran's I, LISA models, and Mann–Whitney test are used to identify the spatial patterns of equity.

The one-way ANOVA test is used to compare the means of the explanatory variable of the different groups to examine whether there is a significant difference between different groups [49]. In this study, we applied the one-way ANOVA test to identify whether there is a significant difference between the elderly communities and the whole communities, in relation to the 3D features.

The Lorenz curve and the Gini index were originally used to present the distribution of wealth across the population [50]. Of which, the Lorenz curve shows the graphic distribution of the research variables, while the Gini index presents the mathematical function of the Lorenz curve. It is calculated by a ratio of the area between the Lorenz curve and the line of equality divided by the total area under the line of equality [51]. Numerous studies have used the Lorenz curve and the Gini index to evaluate the degree of social equity [52–55].

$$G = 1 - \frac{1}{n} \sum_1^n \left(\frac{\sum_1^{i-1} Y_i + \sum_1^i Y_i}{\sum_1^n Y_i} \right) \tag{4}$$

where G denotes the Gini index, n is the total number of elderly care facilities, $\sum_1^i Y_i$ is the cumulative attribute values from group 1 to group i, and $\sum_1^n Y_i$ denotes the total values of the attribute index.

To capture the spatial equity patterns of the built environment around the elderly communities, this study used the global Moran's I method to determine the existence of spatial association among factors. To further identify the patterns of clusters, this study used the LISA. LISA is developed by Anselin (1995) [56], which is suited to examine the cluster patterns of hot spots and spatial outliers. The high-high patterns represent the clustering of towns with high values; low-low patterns represent the clustering of towns with low values; low-high patterns represent the clustering of towns with low values surrounded by those with high values; high-low patterns represent the clustering of towns with high values surrounded by those with low values; and other areas indicate that there is no spatial autocorrelation. The formulas are given as follows:

$$I = \frac{n \sum_{1=1}^{n} \sum_{j=1}^{n} W_{ij}(x_i - \overline{x})(y_j - \overline{y})}{\sum_{1=1}^{n} \sum_{j=1}^{n} W_{ij} \sum_{j=1}^{n} (x_i - \overline{x})^2} \tag{5}$$

$$I_i = \frac{(x_i - \overline{x}) \sum_{j=1}^{n} W_{ij}(x_j - \overline{x})}{\left(\frac{1}{n} \sum_{i=1}^{n} (x_i - \overline{x}\right))^2} \tag{6}$$

where I is the global Moran's I index, I_i is the LISA index, x_i and x_j denote the attribute values for features i and j; W_{ij} is the spatial weight; and n is the total number of features.

The Mann–Whitney U test is a non-parametric test developed by Mann and Whitney. It is widely used for the comparison of the distributions for two or more groups to examine whether there are any differences between groups. This method does not require the data to be normally distributed [57]. We applied this method to compare the number of elderly in towns with higher values and low values to identify the demand and supply condition of the elderly care.

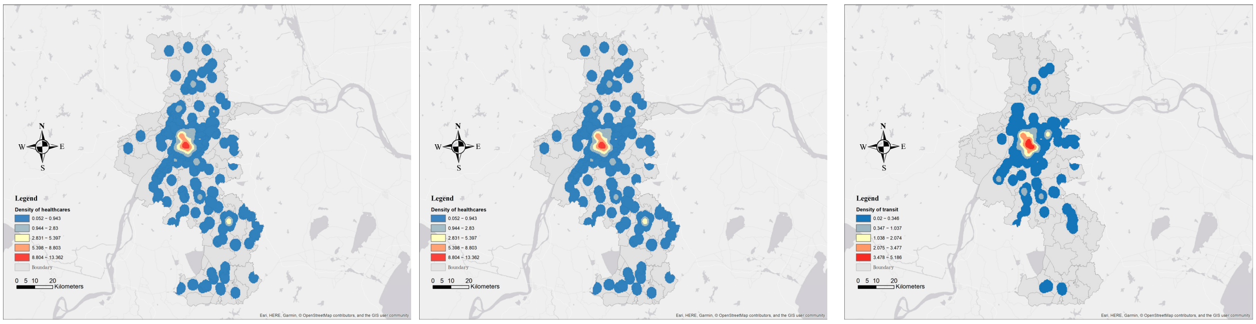
3. Results

3.1. Measurements of Density, Diversity, and Design

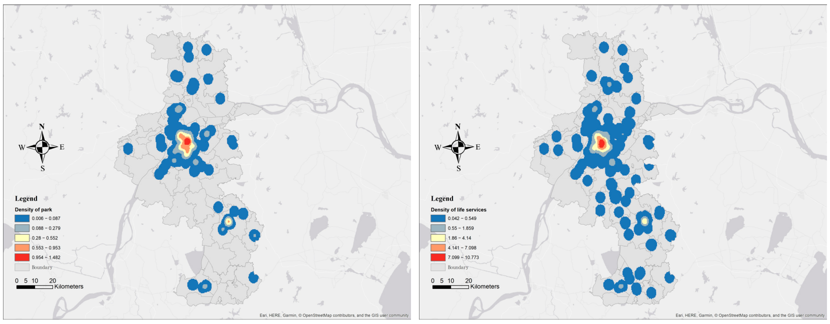
Figures 3–8 show the maps of density, diversity, and design measurements surrounding elderly communities. We used the natural breaks (Jenks) method to classify each level of density, diversity, or design. Red patterns show higher values of density, diversity, or design, whereas blue patterns indicate lower values.

3.1.1. Density

Through the density analysis, we found that the general distribution of the density for public facilities performed a core-edge spatial pattern, whereby the public facilities are densely distributed in the urban core and dispersedly distributed in the rural area (see Figure 3). This density index indicates the level of vitality in a place, as we can see from these five figures, they all showed similar spatial patterns. Specifically, the distribution of shopping facilities, healthcare facilities, and life services covered more land areas than that of parks and transit stations. In other words, parks and transit stations are more clustered in our study. The box plot map displays the average density values of public facilities around the elderly care facilities (Figure 4). It shows that the average density value of shopping facilities is the highest, and the values of healthcare, life services, and transit facilities are lower. The value of park facilities is the lowest. These results indicate the necessary facilities for the elderly are well distributed around elderly communities. Moreover, elderly communities in the urban core are well served with recreational and transit facilities. However, there are some spatial mismatches between elderly communities and recreation and transit facilities in the suburban area.



(**a**) Density of healthcare (**b**) Density of shopping (**c**) Density of transit



(**d**) Density of park (**e**) Density of life services

Figure 3. Density of public facilities surrounding the elderly communities.

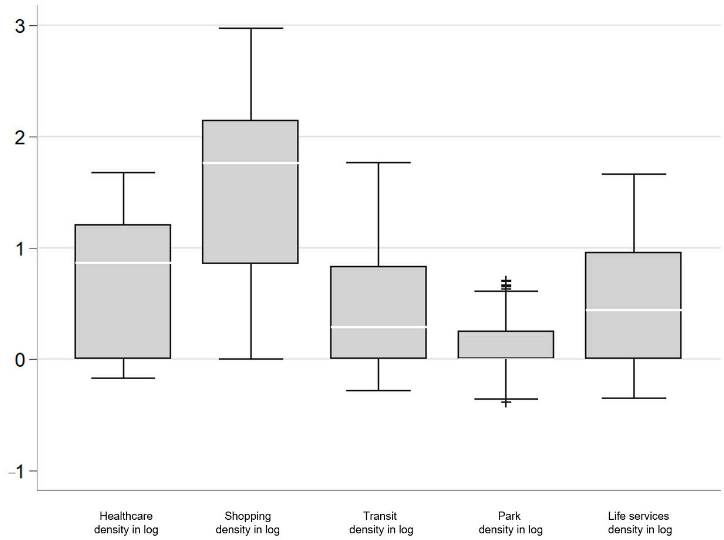
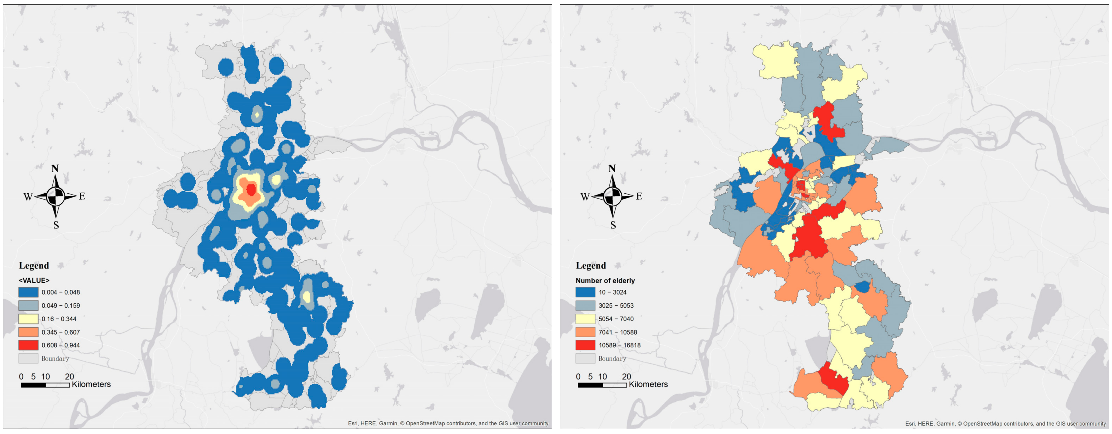
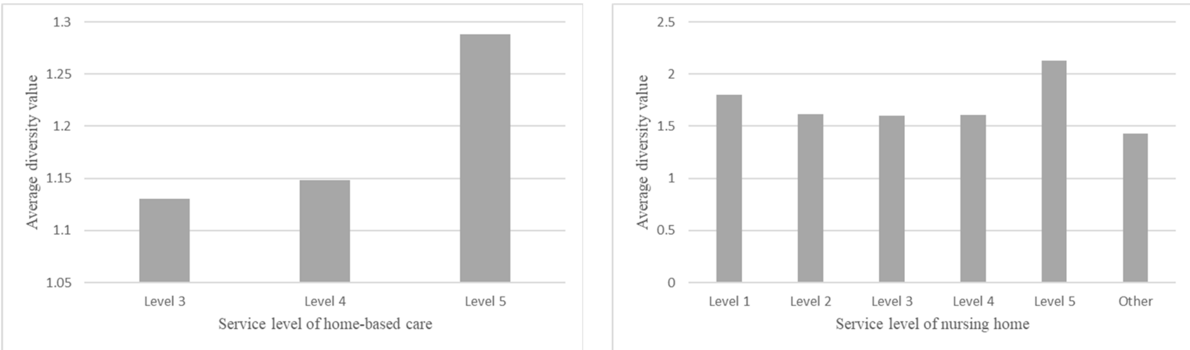


Figure 4. Boxplot distribution of the density of public facilities (log) surrounding the elderly communities.



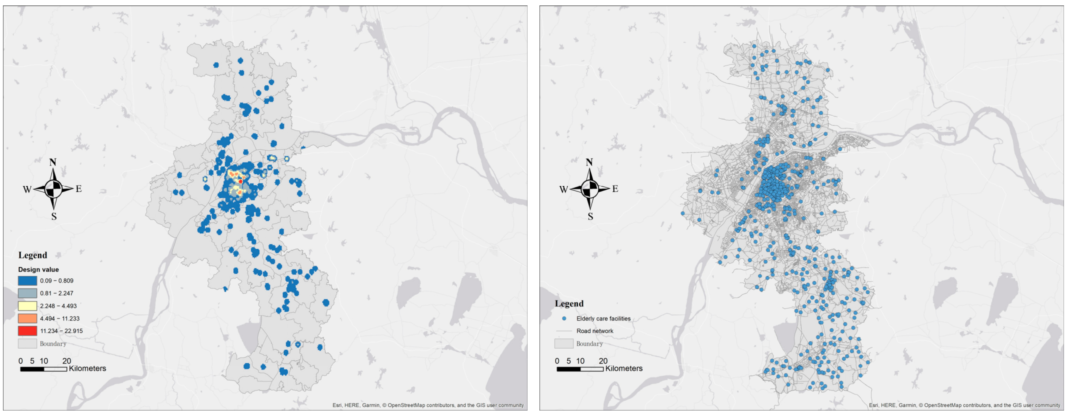
(**a**) (**b**)

Figure 5. Diversity of the public facilities surrounding the elderly communities (**a**), the distribution of the elderly (**b**).



(**a**) (**b**)

Figure 6. Average diversity value for the different level of elderly communities. (**a**) average diversity value for the service level of home–based care (level 3–level 5: service level from low to high). (**b**) average diversity value for the service level of nursing home (level 1–level 5: service level from low to high).



(**a**) (**b**)

Figure 7. Design of the road networks surrounding the elderly communities (**a**), road networks and the distribution of the elderly communities (**b**).

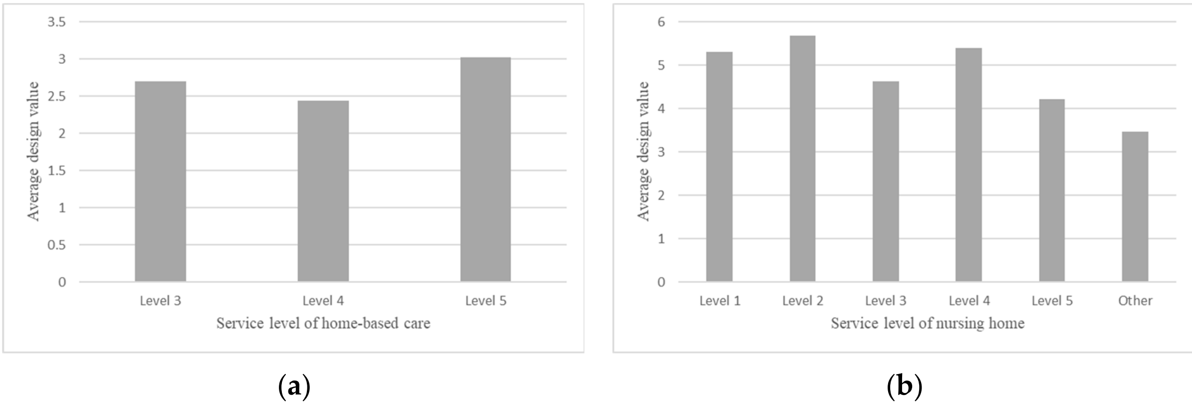


Figure 8. Average design value for the different levels of elderly communities. (**a**) average design value for the service level of home–based care (level 3–level 5: service level from low to high). (November) (**b**) average design value for the service level of nursing home (level 1–level 5: service level from low to high).

3.1.2. Diversity

The diversity index represents the level of land use mix around the elderly communities. A site surrounding with highly mixed land use would attract more people to visit and improve its vitality. Moreover, diverse land use would provide more types of services for the elderly to meet their demands [58]. We found that elderly communities surrounding high mixed land use are clustered in the urban core. Figure 5 compares the diversity map and the distribution of the elderly in the unit of Jiedao town. It shows that highly dense diversity patterns are mostly intersected with towns where a large number of the elderly live. We also compare the diversity values among the different levels of elderly care facilities (Figure 6). For community-based healthcare, the land use around the higher service level of facilities is more diverse than that of the lower level. For nursing homes, the relationship between the service level of facilities and the land use diversity is a "U-shape", which means Level 1 and Level 5 nursing homes have more diverse land use types than the middle level. The surrounding land use of the Level 5 nursing home is the most diverse.

3.1.3. Design

Unlike the larger-clustered distribution in the density and diversity map, the patterns are dispersed in the design map (Figure 7). Except for the urban core, the elderly communities in the rest areas usually have a weaker road network connection. The average design value is also varied by the level of elderly communities (Figure 8). For community-based care, the road network connection values for all levels of facilities are similar, and the Level-5 community-based care has the best road connections. For nursing homes, the result does not show a spatial association between the levels of facilities and the road connections. The level-2 nursing homes have the best road network connections, whereas the level-5 nursing homes have the worst road connections which is beyond our expectations.

3.2. Social and Spatial Equity Analysis

The equity analysis is conducted to analyze the social equity and spatial equity of the built environment around the elderly communities from the perspective of density, diversity, and design. The social equity is analyzed using the Lorenz curve and Gini coefficient method to compare the difference in the built environment between the elderly communities and the whole communities. The spatial equity is analyzed using the global Moran' I and LISA to identify the disparity patterns of towns with a lower density, diversity, and design index.

3.2.1. Social Equity Analysis

Table 2 shows the significant heterogeneity in the values of density, diversity, and design between the elderly communities and the whole community ($p < 0.001$). The average values of those three factors for the elderly community are all lower than those for the whole community. The average difference in density values between the elderly communities and the whole community is larger than the difference in the diversity and design values. Among the public facilities, the average difference value in life service facilities between those two groups is the largest, while the value of park facilities is the smallest. Moreover, Figure 9 shows the Lorenz curve maps between the elderly communities and the whole community, the results also indicate that all of the built environment features around the whole community is better than those around the specifically elderly communities.

Table 2. One-way ANOVA test results.

3Ds Features		Average Value	Mean Difference to Value of the Whole Community (%)	F
Density	Healthcare facility	10.587	−21.810	36.14 ***
	Shopping facility	107.281	−18.871	13.34 ***
	Transit facility	4.279	−20.355	24.35 ***
	Park facility	1.026	−12.866	8.88 ***
	Life service facility	5.971	−29.493	27.55 ***
	All facilities	120.204	−27.577	31.6 ***
Diversity		1.296	−21.373	246.65 ***
Design		3.346	−22.534	14.01 ***

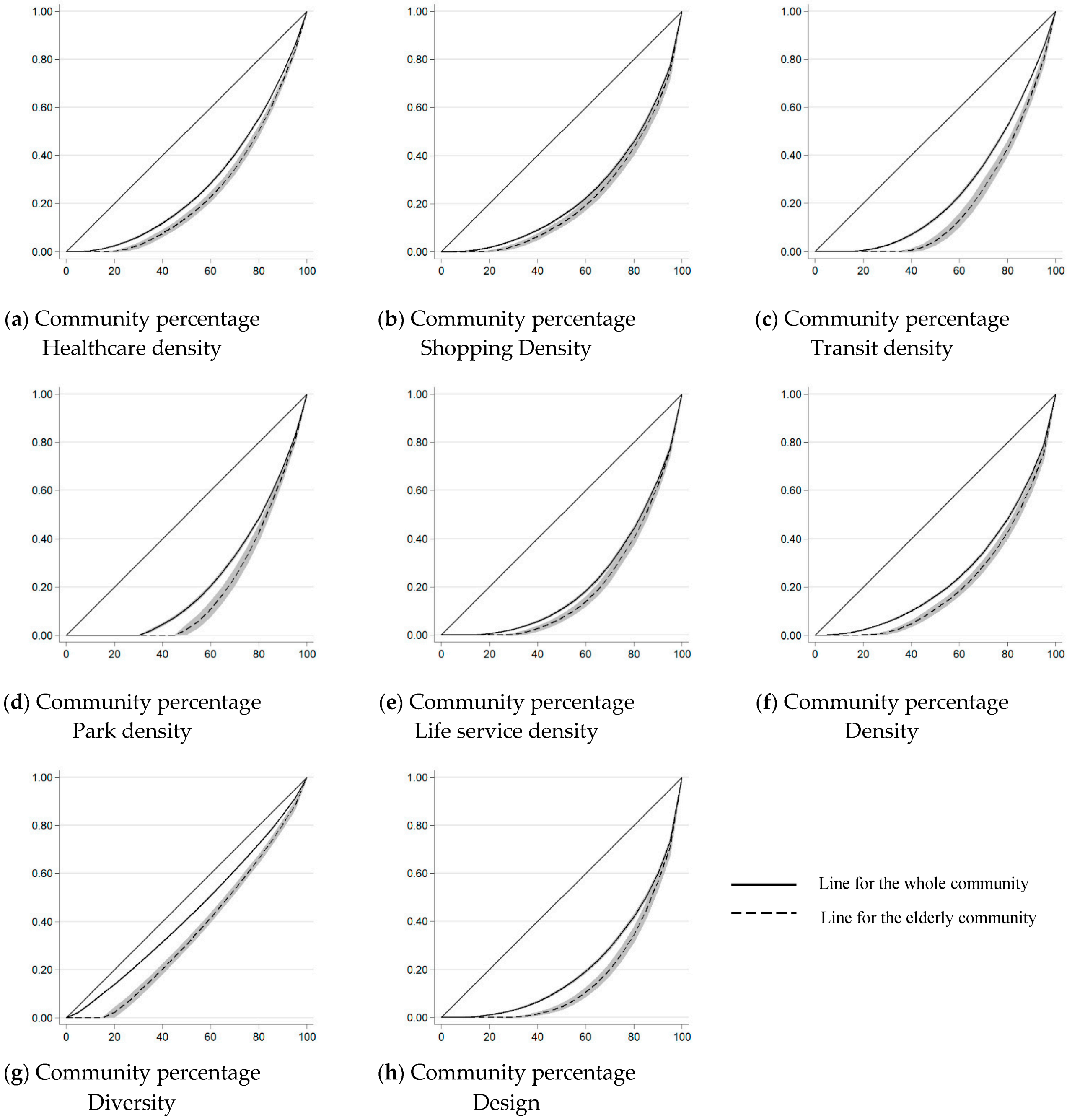
Note: *** it means that the significance test result is less than 0.01.

We also analyzed the equity of the density, diversity, and design among elderly communities by measuring the Gini index. The range of the Gini index is between 0 and 1. The lower the Gini index is, the more equal the elderly communities' access to the surrounding public facilities. The Gini index for density, diversity, and design are 0.574, 0.295, and 0.660, respectively. The diversity of public facilities around elderly communities is more equal in the city of Nanjing, while the road network connections among the elderly communities are more unequal. The Gini index of density is in the middle among those three values. With regards to specific facilities, the Gini index of the healthcare, shopping, transit, park, and life services are 0.536, 0. 593, 0.631, 0.641, and 0.635, respectively. They are all higher than 0.5, which indicates that there exists unequal patterns in the surroundings of the elderly communities in Nanjing.

3.2.2. Spatial Equity Analysis

We aggregate the density, diversity, and design index of elderly communities to towns. The global Moran's I analysis is used to examine whether there is a spatial autocorrelation for the towns by the measurements of density, diversity, and design. The results of the global Moran's I index for density, diversity, and design are 0.552, 0.254, and 0.316, respectively. They are all indicating a significant positive spatial autocorrelation ($p < 0.001$). These results indicate that elderly communities with a similar built environment are spatially clustered across the City of Nanjing.

The LISA model is used to identify the cluster towns or spatial outliers for the elderly communities with a similar built environment. As Figure 10 shows, the high-high pattern for density and design index appears to be concentrated in the urban core, while low-low patterns are clustered at the periphery of the city. Shifting the focus to the diversity index reveals a greater number of towns with more diverse facilities around the elderly care facilities, primarily distributed not only in the urban core but also in some new towns on the east side of Nanjing. We conducted the Mann–Whitney U test to identify the spatial association between the number of elderly and the cluster of high attribute values and low attribute values (Table 3). The number of elderly in towns with higher density values is significantly different from those with lower density values. Specifically, cluster towns with higher density values tend to have a higher number of elderly. In contrast, there is not a significant association between the number of elderly in the cluster of high-value towns and that in the cluster of low-value towns. With regard to specific public amenities, the difference in the number of elderly for transit facilities is relatively smaller than for other amenities. The results indicate that an appropriate number of amenities have been implemented in the highly-dense elderly towns, but the more diverse amenities and more connections around the elderly communities need improvement in towns with a large number of elderly.



(**a**) Community percentage Healthcare density

(**b**) Community percentage Shopping Density

(**c**) Community percentage Transit density

(**d**) Community percentage Park density

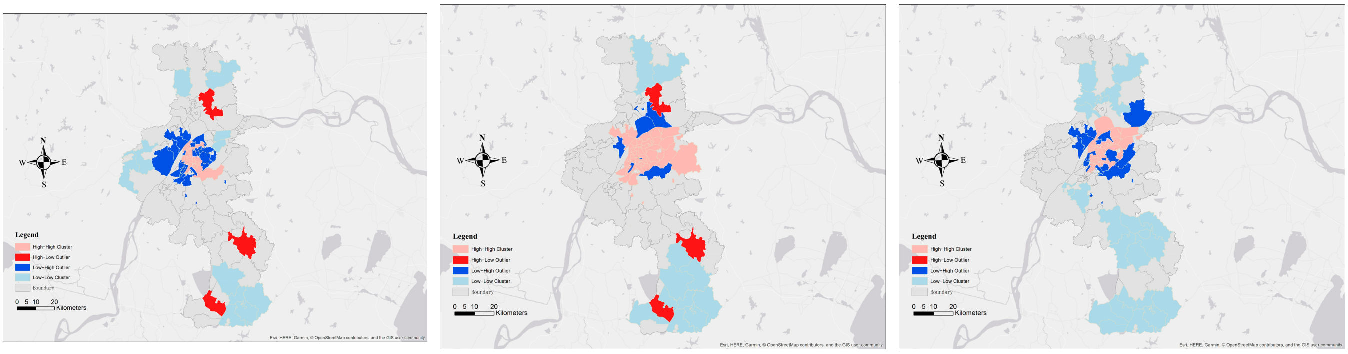
(**e**) Community percentage Life service density

(**f**) Community percentage Density

(**g**) Community percentage Diversity

(**h**) Community percentage Design

Figure 9. Comparison of the Lorenz curve between the elderly communities and the whole community.



(**a**) Density index (**b**) Diversity index (**c**) Design index

Figure 10. LISA analysis for the density, diversity, and design index.

Table 3. Mann–Whitney U test results.

Variable	Number of Elderly		Mann–Whitney U Test	
	Cluster of High Value	Cluster of Low Value	Z	*p* Value
Density	9194.813	4244.158	−5.358	0.000 ***
Diversity	6702.758	5065.315	−1.626	0.104
Design	6774.462	5827.619	−1.315	0.189
Healthcare facilities	8419.658	4386.378	−4.655	0.000 ***
Shopping facilities	9257.871	4484.030	−5.046	0.000 ***
Transit facilities	7048.465	5473.257	−1.945	0.052 **
Park facilities	7832.108	4787.793	−3.052	0.002 ***
Life service facilities	8418.313	4834.683	−3.983	0.000 ***

Note: ** $p < 0.1$, *** $p < 0.01$.

4. Discussion

Through the analysis aforementioned, we found that the 3D features around elderly communities spatially performed a urban-suburban disparity. The patterns for the elderly communities with a high density, diversity, and design index are generally concentrated in the urban core. However, we also find that the spatial patterns of the diversity index, density of healthcare, shopping, park, and life services present multi core layouts. These findings are consistent with previous studies [59,60]. The built environments around the elderly communities may be affected by various factors (e.g., geographic location, economy, policy). Therefore, it is reasonable to examine the disparities in the built environments around elderly communities from social and spatial perspectives.

With regard to the distribution of a specific public amenity, the essential facilities for living (healthcare, shopping, life services) are better served than the commuting and recreational facilities. The elderly's physical activities together with their health are critical factors influencing aging well [61]. The proximity to the park would generate more active park use. However, there is an imbalance between the elderly proportion (more than 20%) and the usage of parks (less than 5%) in many countries [62]. Limited access to public transportation may make the elderly less social [63]. It is recommended that some social sustainable strategies can be taken to help the elderly integrate into the community [64]. Secondly, the diversity and design values vary by different levels of the elderly communities. The level of the elderly community is not in line with the diversity or design value. Currently, the rating of elderly communities is based on internal features (e.g., scale, area, aging-care service). However, neglecting/underestimating the influences of the external environment on the elderly's daily activities (accessing to services, visiting others) may reduce the life qualities of the elderly [65]. Community design is supportive of healthy aging [66]. Therefore, the rating of elderly communities may account for the design of the surrounding physical environments.

With regard to social equity, we find that the values of built environment features around elderly communities are all more deficient than those of the whole community. Neighborhood characteristics are proven to be associated with health and well-being [24]. As a vulnerable group, the elderly need additional support from society to achieve aging well in the community. Essential physical environments, such as hospitals, recreational facilities, walking-friendly environments, and other related resources, are important to support their aging life [2]. Accounting for the increasing number of elderly, the equity of their residential environment should also be considered in urban planning. Improving the physical environment around the elderly communities would enhance the place attachment of the elderly and thus build an age-friendly community.

The spatial equity results indicate that the elderly communities located in suburban areas are usually with low density, diversity, and design values. The disparity of the 3D features around the elderly communities exists among urban and suburban areas. A previous study assumed that the elderly would move from suburban to urban areas for seeking better access to services. However, numerous empirical studies have the opposite finding. They reveal that there is a decreasing propensity for the elderly to move from the suburban to the urban core area, and many of the elderly prefer to live in suburban areas for a better environment [67,68]. Therefore, it is necessary to improve the built environments of the suburban areas and create better services for the elderly. The LISA analysis shows that the high clusters of density index and a large number of the elderly population are spatial matching. However, the results also show that towns with a low-low cluster of diversity and design index, still have a large number of the elderly population. The government may further optimize the built environment around the elderly communities in the area by improving the diversity of essential facilities and the connectivity of the road network.

There are several policy recommendations to create a sustainable society for the elderly, according to the findings of this study. Urban development should involve humanistic care for the elderly population. Formulating special plans for elderly care facilities to ensure the construction of elderly care facilities is standardized, effective, and consistent with the demands. Moreover, the Goal 11 of the SDGs is to construct sustainable cities and communities for all-age populations. It is necessary to promote the elderly population participating in the planning or policy improvement of the elderly communities. More elderly participation in the process of the community design will create a more suitable aging-friendly environment, based on the elderly's real demands. Lastly, the SDGs also encourage good health and well-being. The decline of the physiological function makes healthcare more important to the elderly. It is advisable to expand the universal health service coverage for the elderly population and improve their accessibility to healthcare services.

5. Conclusions

In the context of building an aging-friendly community, the built environment around the elderly community is critical to influencing the quality of life for the elderly. To identify the characteristics of the built environment around the elderly community, this study imported the 3Ds framework to measure the spatial patterns of the density, diversity, and design features. Then we examined the social and spatial disparities of the 3D features between elderly communities and the whole community. The Lorenz curve and Gini coefficient are used to conduct the social equity and the global Moran' I and the LISA model are applied to identify the spatial equity among towns. The key findings are summarized below.

(1) The spatial patterns of the 3D features around elderly communities follow the "center-periphery" rules. The built environments of the elderly communities in the urban center are better than those in the periphery areas.

(2) The social disparity exists between the elderly communities and the whole community. The built environments of the elderly communities are significantly different from those of the whole community, and the density, diversity, and design index are lower.
(3) There is a spatial mismatch between the diversity of facilities, road connections, and the number of elderly. Towns located in the fringe area are with a high number of elderly, but with a low diversity and road connections.

The contribution of this study is that the 3D framework is imported to measure the built environment around elderly communities. The essential features of an aging-friendly community are used to assess the built environment around the elderly communities. Moreover, we analyzed the social and spatial equities of the elderly communities from the facility level and the town level. From the facility level, the 3D features of the elderly communities and the whole communities are compared to identify the social disparity among groups. From the town level, the average values of 3D features are aggregated to each town, and then the attribute values of the towns are compared to reveal the spatial gaps and spatial mismatch areas. Through the comprehensive analysis including the social-spatial perspective and multi-level, it contributes to the studies of neighborhood design and active aging.

There are several limitations in this study. This study used cross-sectional data which was unable to capture the temporal characteristics of elderly communities over time. The use of panel data would depict the spatial and temporal patterns of the built environments around the elderly communities. Moreover, the city of Nanjing in China was chosen as the study area. The elderly care system and implemented policies in Asian countries are different from Western countries. A comparative study between the different countries may provide more generalized conclusions for the built environment around elderly communities.

In addition to the physical factors, future research needs to focus on assessing the elderly care facilities from the perspectives of social, economical, and environmentally sustainable factors, which are also important in assessing the quality of life for the aging populations. Social sustainable factors can be evaluated by the elderly's social participation in activities, the elderly's social feelings, and the elderly's social integration to the society, etc. The economical sustainable factors include the local GDP, government financial support, and the supporting elderly care industry, etc. The environment sustainable factors can be assessed by the green space density, the air quality, and the risk of exposure, etc.

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