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The Spatial Equity Assessment of Community-Based Elderly Care Facilities in Old Neighborhood of Chongqing

Jiayue Zhao, Hongjuan Wu, Guiwen Liu

***Abstract*—**Old neighborhoods with a large elderly population depend on community-based elderly care facilities (community-based ECFs) for aging-in-place. Yet, due to scarce and scattered land, the facilities face inequitable distribution. This research uses spatial equity theory for measuring the spatial equity of community-based ECFs in old neighborhoods. Field surveys gather granular data and methods including coverage rate, Gini coefficient, Lorenz curve and *G2SFCA*. The findings showed that coverage is substantial but does not indicate supply is matching to demand, nor does it imply superior accessibility. The key contributions are that structuring spatial equity framework considering elderly residents' travel behavior. This study dedicated to the international literature on spatial equity from the perspective of travel behavior and could provide valuable suggestions for the urban planning of old neighborhoods.

***Keywords*—**Community-based ECFs, elderly residents' travel behavior, old neighborhoods, spatial equity.

I. Introduction

POPULATION aging is set to become a considerable global concern by 2030. China is entering a deep aging phase with its rapidly aging population, and by 2050, it will be among the worlds most aged countries. The geographical distribution of community-based ECFs fails to meet elderly residents demands. Community-based ECFs offer a variety of services including home help, medical care, and leisure activities. However, the spatial distribution in old neighborhoods is not optimal. This is partly due to the government not foreseeing the rapid rise in the elderly population when allocated these facilities. The other reason is that the equitable elderly resource allocation becomes problematic due to limited spatial land.

Facing an aging population and limited resources, its vital to optimize resources distribution for spatial equity [1]. Spatial equity stresses equity resources distribution at unit spatial levels [2]. Spatial equity uses minimum standards and equal choice as metrics, both focusing on equal resource allocation [3]. However, travel behavior, crucial for spatial equity was ignored.

Spatial equity in public facilities is an extensively studied issue with area-driven analyses using census or computed data, focusing chiefly on single categories [4]. Most studies consider quantity and quality of facilities against elderly needs, notable research gaps persist [5]. This research concentrates on spatial equity in old neighborhoods and diversity it offers elderly residents, extending beyond single type community-based ECFs [6]. It aims to use spatial equity theory to explore spatial equity in old neighborhoods. This paper aims to answer three main questions: (1) analyzing the minimum equity of community-based ECFs; (2) examining the supply-demand equity of community-based ECFs and elderly residents; (3) evaluating the accessibility equity on elderly residents' travel behavior.

II. Literature Review

Spatial equity in public facilities can be approached from two perspectives. The first perspective focuses on absolute spatial equity [7]. Some studies analyze facility scales' impacts whereas others incorporate transportation modes but neither sufficiently consider travel behavior [8]. The second perspective underscores spatial equity in light of social factors and supply-demand dynamics [9]. Comprehensive models have been developed to quantify spatial equity, including population demand, dispersion, and social deprivation [10]. Most contemporary studies construct demand difference indexes for urban or rural zones, accounting for population and social demand or using demand intensity measurements to devise a facility distribution priority framework.

The Gini coefficient and Lorenz curve are another key spatial equity metrics. Introduced by Corrado Gini in 1912, the Gini coefficient initially measures regional income distribution disparities [11]. The Lorenz curve visually represents the Gini coefficient, depicting regional equity or inequity. Accessibility analysis is also a spatial equity measurement method [12]. Its evolution has undergone four stages. The first phase includes buffer [13], kernel density estimation [14] and network analysis [15]. These methods ignored travel costs. The second phase comprised minimum distance and cost-weighted distance approaches which, overlooked supply characteristics [16] and cost-weighted distance [17]. The third phase integrated the gravity model, circumventing the nearest distance assumption without service radius limitations [18]. The fourth phase introduced the two-step floating catchment area (2SFCA), addressing previous shortcomings [19].

Current research exhibits some shortcomings. First, most studies overlook the needs of the elderly in old neighborhoods.

Jiayue Zhao and Guiwen Liu are with the School of Management Science & Real Estate, Chongqing University 400000 Chongqing China (e-mail: 201801021003@cqu.edu.cn, gwliu@cqu.edu.cn).

Hongjuan Wu is with the School of Management Science & Real Estate, Chongqing University 400000 Chongqing, China (corresponding author, e-mail: hongjuanwu@cqu.edu.cn).

Second, previous studies typically focus on a single type of community-based ECF. Given the growing diverse demand, this approach appears insufficient.

III. Methodology

A. The Coverage for Minimum Equity

Coverage refers to the minimum standards for minimum equity. The coverage rate of community-based ECFs refers to the proportion of old neighborhoods that can obtain elderly care services within the walking living circle. By adopting the community committee of old neighborhoods as reference, coverage is deemed established when community-based ECFs such as a community care stations, community health centers, elderly activity centers, and elderly activity spaces are encompassed within community living circle. Evaluate the coverage is represented by (1) to (3):

$$N_{i,s,j} = \begin{cases} 1, \exists M_j \in M_{i,s} \\ 0, others \end{cases} \quad (1)$$

$$NR_{i,s,j} = \frac{\sum_{s=1}^{m_i} N_{i,s,j}}{m_i} \quad (2)$$

$$TNR_{i,s,j} = \frac{\sum_{i=1}^{4}\sum_{s=1}^{m_i} N_{i,s,j}}{\sum_{i=1}^{4} m_i} \quad (3)$$

In (1), $N_{i,s,j}$ is "1" represents coverage, whereas "0" means non-coverage; i is Chongqing's functional zone; s is old neighborhood, and $N_{i,s}$ is the old neighborhood s in functional zones i; M_j denotes the *j-type* of community-based ECFs; in (2), $NR_{i,s,j}$ signifies the coverage rate in Chongqing; m_i is the number of old neighborhood in each functional zones; in (3), $TNR_{i,s,j}$ signifies the coverage F_j in the overall functional zones.

B. The Gini Coefficient and Lorenz Curve for Supply-Demand Equity

Using the Gini coefficient and Lorenz curve to examine supply-demand equity. The Gini coefficient is as a quantitative indicator to measure spatial equity. 0.4 is often as the alert line; 0.3-0.39 is as relatively reasonable, whereas 0.4-0.59 is a large gap. The Gini coefficient formula is in (4):

$$GINI = 1 - \sum_{s=1}^{n}(P_i + P_{i-1})(C_i - C_{i-1}) \quad (4)$$

In (4), P_i represents the cumulative percentage of elderly population; and C_i denotes the cumulative percentage of community-based ECFs capacity.

The Lorenz curve visually illustrates the Gini coefficient, portraying the supply-demand matching among different regions. As an intuitive expression of spatial equity, which is plotted by the cumulative percentage of elderly population and the corresponding cumulative percentage of service capacity, can be used to compare the spatial equity of the distribution of different types of community-based ECFs.

C. The G2SFCA Method for Accessibility Equity

Accessibility equity serves as a crucial criterion for evaluating the spatial equity [21]. This study used *G2SFCA* to measure the accessibility of community-based ECFs at the community level. *G2SFCA* is an integrated method of 2SFCA and Gaussian function, which is often used to achieve more realistic accessibility. This method not only takes the supply of community-based ECFs, elderly residents' travel behavior (travel time and travel mode) but also takes continued distance decay into consideration.

Step 1. For each supply location of a community-based ECFs j, demand locations of neighborhood i, which are within a threshold distance d_0 from the catchment of the community-based ECFs. The supply-demand ratio, which denotes the ratio of the area of community-based ECFs to the demand of elderly residents, is in (5):

$$R_j = \frac{S_j}{\sum_{i\in\{t_{ij}\le t_0\}}^{k} P_i \times G(D_{ij})} \quad (5)$$

In (5), R_j denotes the supply-demand ratio; S_j is the total area of community-based ECFs at location j; P_i signifies the population at location i; $t_{ij}$is the walking time; $G(D_{ij})$ is Gaussian function; t_0 is the walking time threshold.

Step 2. The Gaussian-of-function is calculated in (6):

$$G(t_{ij}) = \begin{cases} \frac{e^{-(1/2)\times\left(t_{ij}/t_0\right)^2} - e^{-(1/2)}}{1-e^{-(1/2)}} & t_{ij} < t_0 \\ 0, \quad if, t_{ij} > t_0 \end{cases} \quad (6)$$

In (6),$G(t_{ij})$ representing the distance impedance coefficient.

Step 3. The accessibility of A_i is computed from the sums of the supply to demand ratios R_j multiplied by the friction-of-distance in (7):

$$A_i = \sum_{y\in\{t_{ij}\le t_0\}} R_j G(t_{ij}) \quad (7)$$

In (7), A_i denotes accessibility.

IV. Materials

A. Study Area

Chongqing's four functional zones is selected as the study area, which accommodate approximately one-third of the total population. There are four functional zones encompassing commercial zone, educational zone, financial zone, and industrial zone. These functional zones collectively showcase a typical functional distribution in China, embodying a representative microcosm.

B. Data Sourcing

To quantify spatial equity thoroughly and reliably, data from three important components (old neighborhoods, community-based ECFs, and elderly residents) are collected.

1. Data of Old Neighborhoods

Data of 90 old neighborhoods were selected as the study sample including basic information (names) and geographical information (locations and boundaries).

2. Data of Elderly Residents

Data of elderly residents include elderly population, travel mode, and travel time. Travel mode and time represent elderly residents travel behavior.

3. Data of Community-Based ECFs

Data of community-based ECFs encompasses basic information (names), geographical information (locations), and characteristic information (number of employees and construction area).

V. Results

A. Minimum Equity of Community-Based ECFs

Evaluation of minimum equity used the coverage analysis in Fig. 1.

1. The financial zone has been the highest proportion (89%) covered, whereas the educational zone has been the lowest proportion (78%) covered among the four functional zones.
2. Although the coverage rate of the overall community-based ECFs is relative equality, the coverage rate of different types of facilities is markedly different. For example, the elderly activity space reached full coverage in each functional zone. However, the coverage rate of the elderly activity center was at the lowest value no matter which functional zones.

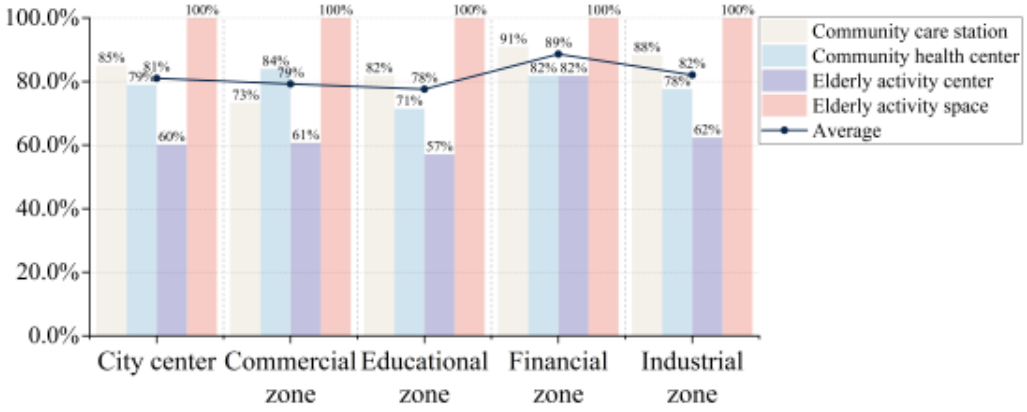


Fig. 1 The coverage rate of community-based ECFs

B. Supply-Demand Equity between Community-Based ECFs and Elderly Residents

The supply-demand equity between community-based ECFs and elderly residents is evaluated through Gini coefficient and Lorenz curve. There is obvious different supply-demand equity of community-based ECFs in functional zones when consider elderly population. The results are as follows:

1) The supply-demand inequity is more serious for community health center (0.433) than the community care station (0.347), elderly activity center (0.341), and elderly activity space (0.332) as shown in Fig.2.
2) The supply-demand equity of community care station and elderly activity space in all four functional zones are slightly equity (0.201<Gini coefficient<0.400) in Figs. 3 (a), (b), (c) and (d). Such as 70% of all the elderly have obtained about 50% and 55% of the services provided by community care station and elderly activity space (refer to Fig. 3 (b)). However, 40% of all the elderly have only access to less than 15% of the services in other three functional zones (refer to Fig. 3 (a) to Fig. 5 (d)).

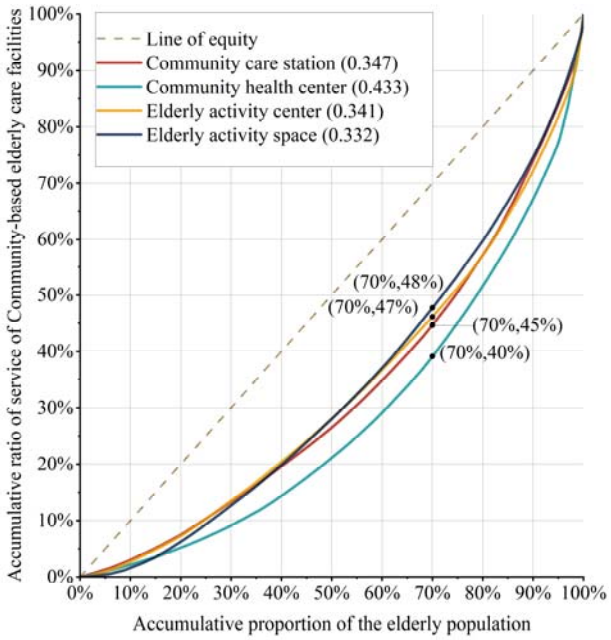
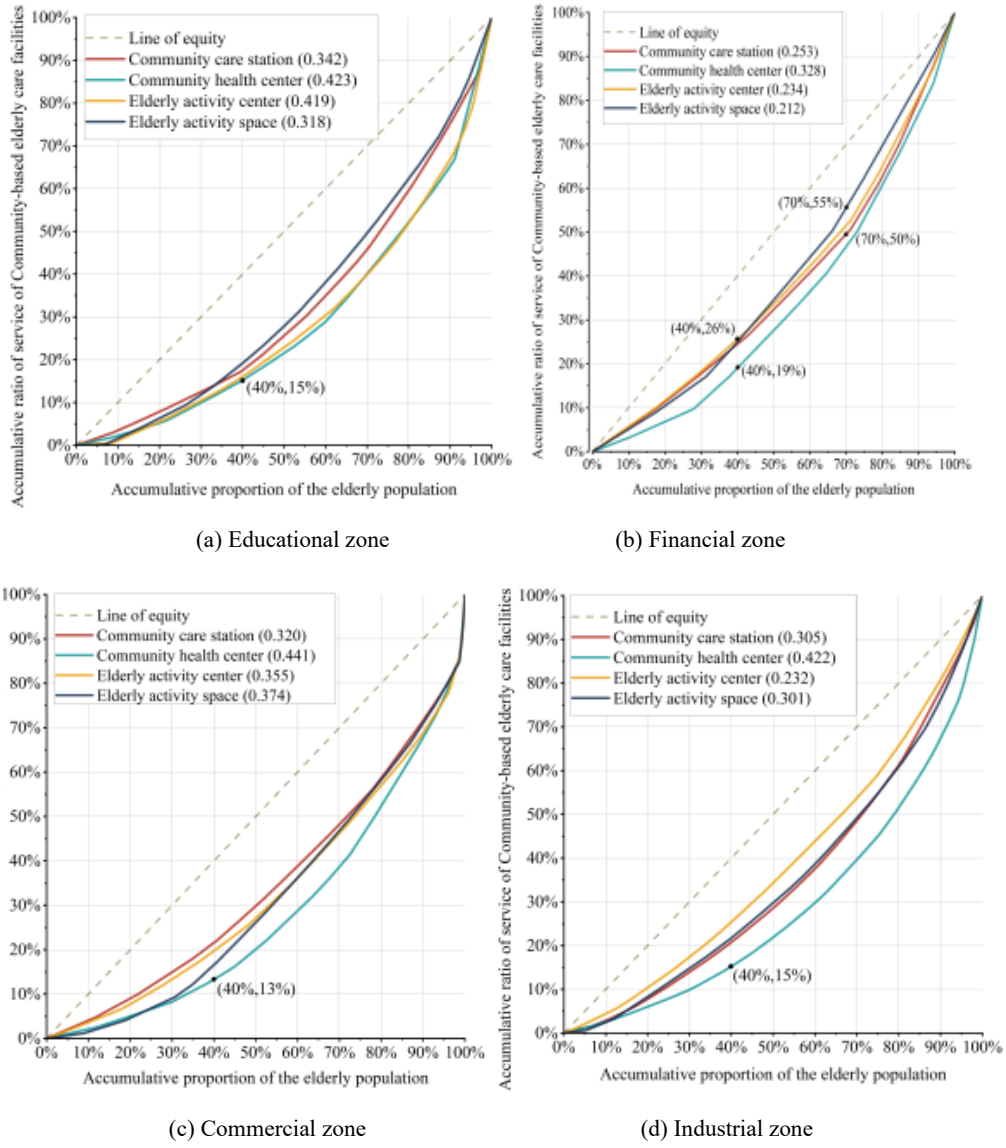


Fig. 2 Lorenz curve of four types of community-based ECFs



(a) Educational zone (b) Financial zone

(c) Commercial zone (d) Industrial zone

Fig. 3 Lorenz curve of community-based ECFs in the four functional zones

C. Accessibility Equity on Elderly Residents' Travel Behavior

Accessibility is a vital way for measuring zones where are inadequate resources. The results of walking accessibility show:

1) The accessibility of overall community-based ECFs varies dramatically in the four functional zones (refer to Fig. 4). The accessibility in the educational and industrial zones is significantly higher than the other zones.
2) Among the four types of community-based ECFs, the accessibility varies greatly in functional zones (see Figs. 5 (a) to (d)). First, the accessibility of community care station in the educational, financial and industrial zones is higher than the commercial zone (refer to Fig. 5 (a)). Second, compared to financial and commercial zones, the accessibility of community health center in the educational and industrial zones also higher (refer to Fig. 5 (b)) than the other zones. Third, a high accessibility to elderly activity center and elderly activity space are in a scattered distribution of four functional zones (refer to Figs. 5 (c) and (d)).

TABLE I
GINI COEFFICIENTS OF ACCESSIBILITY

	ECFs	CCS	CHC	EAC	EAS
Educational zone	0.624	0.551	0.618	0.476	0.642
Financial zone	0.402	0.453	0.322	0.568	0.290
Commercial zone	0.788	0.812	0.371	0.656	0.622
Industrial zone	0.437	0.392	0.358	0.493	0.537
City center	0.628	0.639	0.509	0.406	0.583

Note: ECFs represents community-based ECFs; CCS represents community care station; EAC represents elderly activity center; EAS represents elderly activity space.

Table I displays the Gini coefficient of accessibility. 1) Overall, the Gini coefficient of accessibility to overall community-based ECFs in all functional zones exceed 0.4, representing varying degree of inequity. 2) Community care

station (0.639), community health center (0.509), and elderly activity center (0.406) also show significant inequity. 3) It is worth noting that only community care station (0.392) in industrial zone, community health center in financial (0.322), commercial (0.371), and industrial (0.358) zones are smaller than 0.4, representing slightly equity.

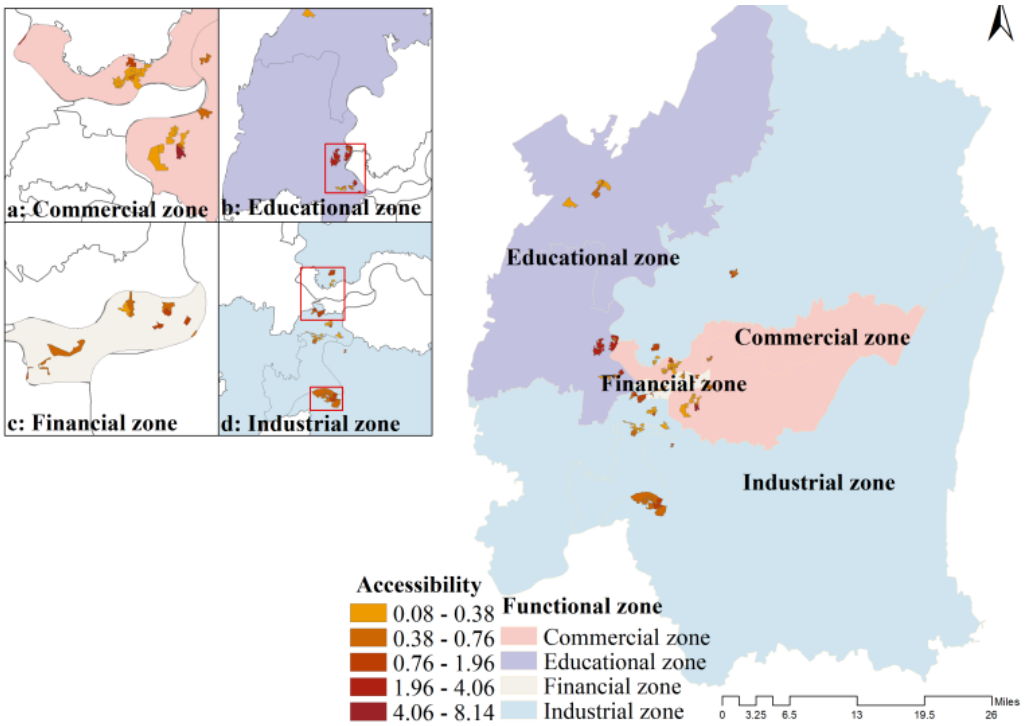
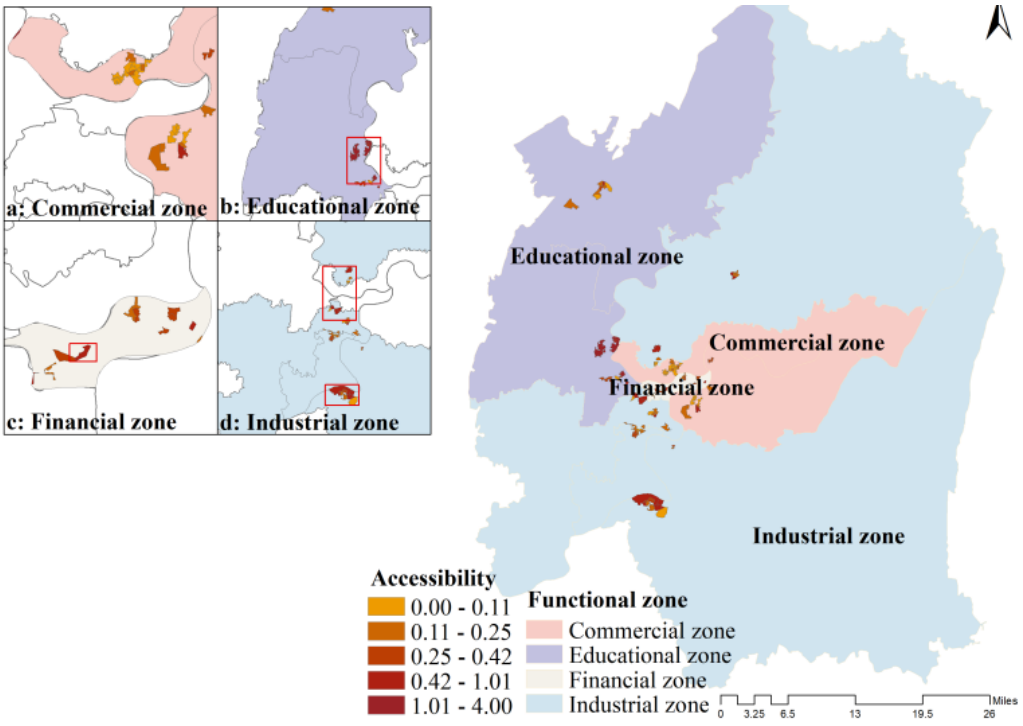
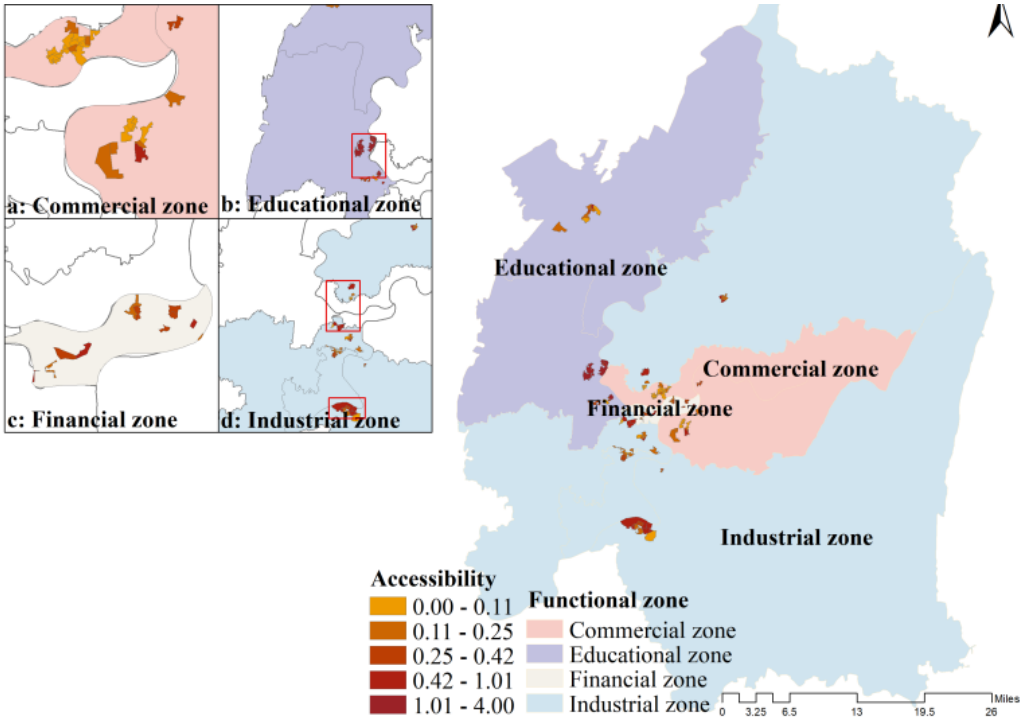


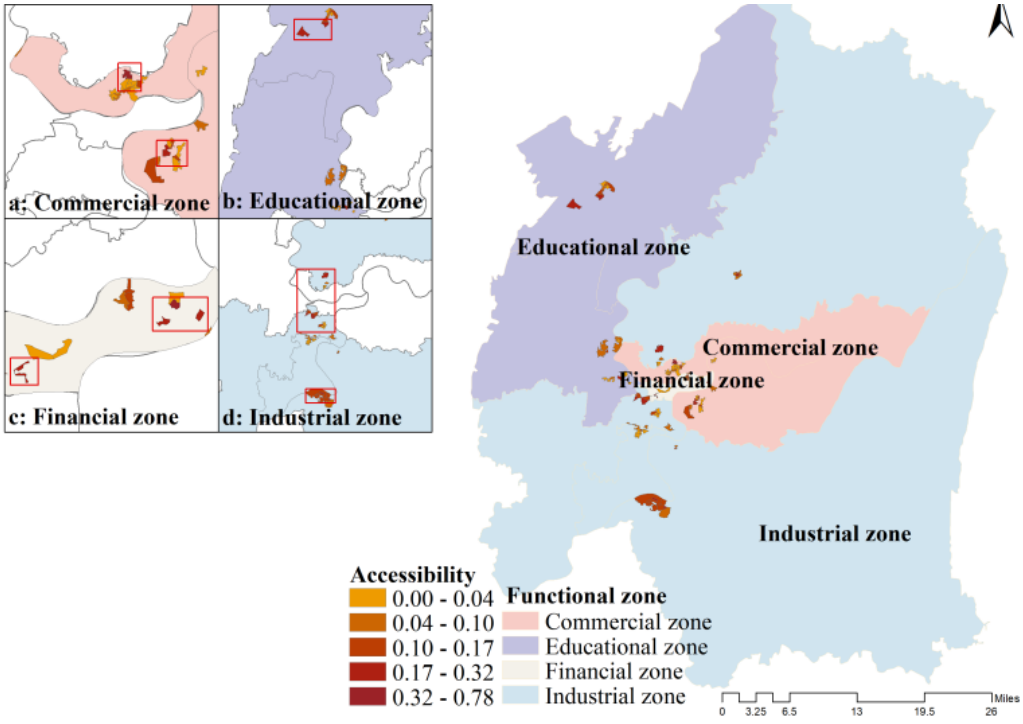
Fig. 4 Accessibility for overall community-based ECFs



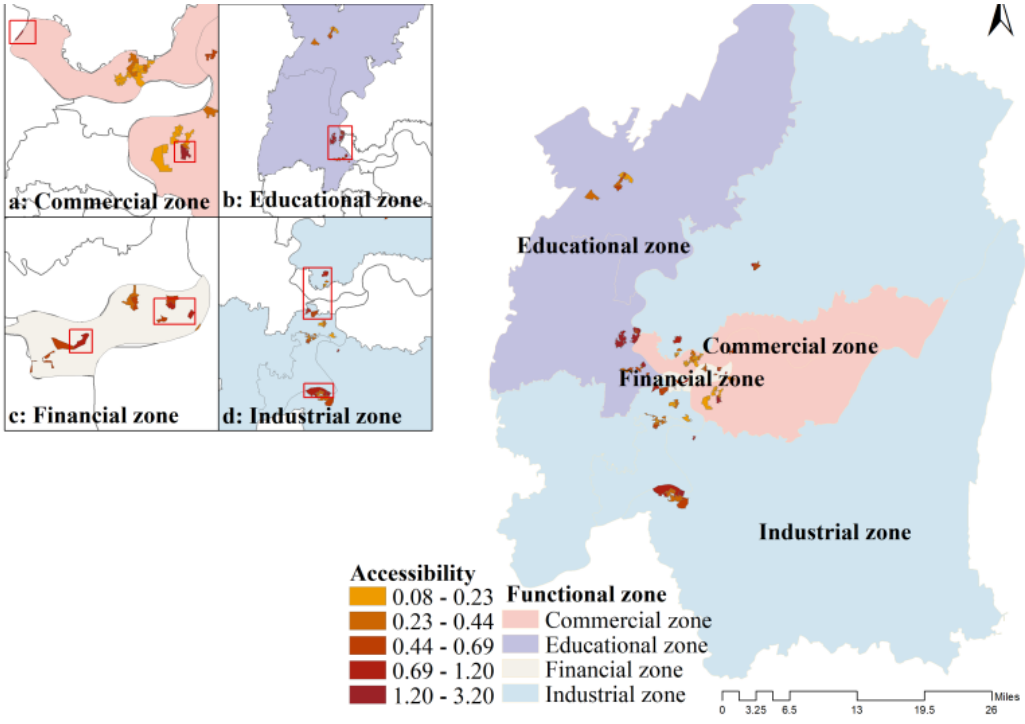
(a) Community care station



(b) Community health center



(c) Elderly activity center



(d) Elderly activity space

Fig. 5 Accessibility for community-based ECFs

TABLE II
DIFFERENT DEGREE OF SPATIAL EQUITY OF OVERALL COMMUNITY-BASED ECFS IN THE FUNCTIONAL ZONES

	Educational zone	Commercial zone	Financial zone	Industrial zone
Minimum	No.4		No.1	
Supply-demand		No.4	No.1	
Accessibility		No.4	No.1	

Note: "No.1" indicates highest degree of spatial equity, whereas "No.4" indicates lowest degree of spatial equity.

VI. DISCUSSION

A. A Framework to Redefine the Spatial Equity

A spatial equity framework of "minimum equity - supply-demand equity - accessibility equity" was proposed to redefine spatial equity based on spatial equity theory. Spatial equity theory emphasizes minimum standards and equal choice, which both underlining the importance of sufficient facilities and equal proximity. However, they can not adequately explain the reasonableness of community-based ECFs distribution. A key shortfall is the disparity between the equality applied to the inputs and outputs in elderly service provision, largely driven by the variability in the residents' behavior. More importantly, the variation in travel behavior shed light on whether urban planning is meeting the actual demands of the residents. Incorporating elderly residents travel behavior to allocate elderly resources should be put on the agenda. If the majority of residents prefer commuting by walking or cycling, whereas the city's infrastructure largely caters to vehicles, it might result in issues of spatial equity. These behaviors, therefore, do not only influence spatial equity but also reflect whether or not urban planning meets the demands of residents. The exploration of minimum equity and supply-demand equity must be complemented with a travel behavior based on accessibility equity.

B. Variation of Spatial Equity across Different Functional Zones

An intriguing discovery reveals that the financial zone enjoys far superior access to elderly resources when compared with other functional zones possessing higher aging rate (Table II). This way of regional division is very different from previous studies, but a similar conclusion is drawn, that is, the level of aging rate and the spatial equity of community-based ECFs change in the opposite direction [20]. Several studies conclusively establish the spatial disparity of equity existing between urban and rural regions [17]. However, the focus has predominantly landed on this categorical disparity, with a marked paucity of attention towards internal urban variations, especially the aging zones. The spatial inequity could be caused by the policies and socio-economic factors. First, a potential shortcoming in governmental strategies could be the insufficient recognition of the distinct demands associated with zones facing accelerated aging rates. The tendency to generalize based on urban and rural areas, which inadvertent oversight led to a skewed allocation of elderly resources. Second, zones disparities in elderly care can be further compounded by socio-economic factors. Zones with a lower aging rate such as financial zone might be economically more advanced and invest more resources into community-based ECFs, ensuring a more equitable distribution. Conversely, in zones with higher aging rates (educational and commercial zones), there might be

a lack of investment of elderly resources, leading to an inadequate number of community-based ECFs and hence lower spatial equity in service distribution.

C. Policy Inspiration of Community-Based ECFs Spatial Planning

A key aspect of this planning process is the central value of neighborhood living circle planning.

1) Adjust configuration considering elderly residents travel behavior: an important finding is that the measurement of spatial equity is not just considering minimum equity and supply-demand equity but also should consider the accessibility equity based on elderly residents' travel behavior.
2) Regional collaboration for demand first: another finding showed that regions with high aging populations demonstrate a lower degree of spatial equity. It is essential to tailor distinct strategies to cater for the unique characteristics of various aging regions. These strategies should be steadfastly grounded in critical factors such as the density of the elderly population, the demands and their travel behavior, to ensure efficacious spatial planning. For instance, in regions with high levels of aging demographics, the priority should be to increase the provision of community-based ECFs.

VII. Conclusion

This study proposes a spatial equity framework - "minimum equity - supply-demand equity - accessibility equity" to access the spatial equity of community-based ECFs within old communities. Making a fine-data of community for exploring the spatial equity could provide valuable suggestions for the spatial planning of old neighborhoods. Although this study provides a new perspective on the spatial equity of community-based ECFs, it is still necessary to add some new indicators to further explore the robustness further. In the follow-up study, bus mode, bicycle mode, and private car mode could be added to the travel modes for robustness test due to the diversity of travel mode.

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