Equity in essential services accessibility among the elderly: a comparison of community resilience during and after the COVID-19 pandemic

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Abstract

The COVID-19 has caused heavy damage across the globe. Lockdown measures implemented during the pandemic have affected residents' normal daily lives. During the stay-at-home orders, the elderly faced greater challenges in accessing essential services due to their physical limitations. Reducing inequities in access to essential service facilities is crucial for enhancing community resilience. In this research, three indexes were developed to measure community resilience in accessing essential services. Specifically, we have considered the differences in walking ability between the elderly and healthy adults, as well as the unique needs of the elderly. The Lorenz curve and the Gini coefficient were employed to measure spatial equity. Shanghai was selected as our case study. We utilized datasets from 2020 and 2023 to compare changes in equity during and after the COVID-19 pandemic. The results indicate that the Diversity Index exhibits the highest equity, followed by the Demand Accessibility Index, while the equity of the Per Capita Quantity Index is the lowest. The distribution of essential service facilities post-pandemic is moving in a direction unfavourable to the needs of the elderly. These findings provide valuable scientific insights for policymakers to strengthen community resilience and reduce inequities in essential facility access.

Keywords

equity; the elderly; essential services; accessibility; community resilience

1. Introduction

The COVID-19 has been a serious global pandemic in the past four years, claiming millions of lives and causing significant damage worldwide. During the most severe periods of the pandemic, many countries implemented various restrictions on travel and activities(Abdullah et al., 2020), collectively known as 'lockdowns'. These measures included school closures, remote work, limitations on public gatherings, curfews, the suspension of international flights, and the enforcement of social distancing guidelines, etc.

During the lockdown, only essential services remain open, and residents are permitted to leave their homes only to collect essential items, such as food and medicine.

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Lockdowns are considered the most effective means of controlling the spread of the virus(Kabiraj et al., 2020), but they also inevitably result in the decline of urban functions and disrupt citizens' normal daily lives. Additionally, the lockdowns have exacerbated many inequities, with vulnerable groups facing greater difficulties such as accessing essential services and working from home, etc. Various viruses may continue to emerge in the future, we need to learn from past lockdown periods and focus on reducing the inequities they cause, thereby enhancing community resilience in the face of infectious diseases.

Recent studies have highlighted that the vulnerability of the population and the built environment are two key factors affecting the resilience of communities impacted by COVID-19(Xu et al., 2021). In this paper, our main focus is on the equity of community resilience concerning residents' accessibility to essential service facilities, particularly for senior citizens. We have found that the elderly suffered more unfairness due to the COVID-19. They are at a higher risk of contracting the virus and developing severe symptoms(Sasson, 2021). Due to limitations in physical condition and mobility, they encounter more difficulties in accessing essential services, especially for those who are not living with their children. Moreover, they have unique needs for essential services, such as a higher demand for healthcare resources. Therefore, we aim to explore whether the elderly experience more inequalities in accessing essential service facilities compared to the general population.

Additionally, with the economic downturn post-pandemic, we have observed changes in the distribution of many facilities, including service facilities and shops. Many facilities in urban areas have closed down or relocated to the suburbs. The redistribution of facilities inevitably affects people's access to essential services. Hence, it is also essential to examine whether the equity of essential service facility distribution after the pandemic is improving or deteriorating.

While some previous studies have focused on the accessibility of essential services(Corso et al., 2000, Manning, 2010, Mayer, 1979), most have only considered spatial accessibility in normal daily life. In fact, there are several differences in accessing essential services during the pandemic. Firstly, public transportation may be suspended or routes adjusted, leading most people to rely on walking to access essential services. Secondly, people's needs for facilities differ from usual during the pandemic. Outings are primarily for obtaining essential services to sustain life, such as for groceries and seeking medical care. Additionally, the needs of the elderly for essential services differ from those of the general population. Thirdly, due to social distancing requirements, essential service facilities often have capacity restrictions or require advance appointments during a pandemic. Therefore, the per capita quantity of facilities is also an aspect that needs to be measured.

Based on these considerations, we created three indexes. Using Shanghai as a case, we calculated these three indexes separately for the general population and the elderly.

Subsequently, we utilized Lorenz curves and Gini coefficients to assess the equity performance of these three indexes. Finally, we compared the data from 2020 and 2023 to illustrate how these three indexes changed in terms of equity performance during and after the pandemic.

The significance of this study lies in examining whether elderly individuals faced inequities in accessing essential service facilities. It explores changes in equity during and after the pandemic and provides recommendations to policymakers, thereby contributing to enhancing community resilience and reducing inequities in essential facility access.

This paper is organized into sections. Section 2 reviews relevant work involving community resilience and equity. Section 3 briefly introduces our study area and data. Section 4 describes the methodology. Section 5 presents the results and discussions. Section 6 concludes the main findings and discusses future research.

2. Literature review

2.1 Community resilience

Resilience was initially introduced in ecology by Holling(Holling and S, 1973), which originally meant "a measure of a system's ability to absorb shocks while still maintaining its previous resistance". Since then, the concept of resilience has been gradually applied to various fields including engineering, environmental sciences, business, disaster management, and urban studies(Hollnagel et al., 2006, Manyena, 2006, Masnavi et al., 2019).

Affected by the COVID-19, improving urban resilience and community resilience has received widespread attention(Yip et al., 2021, Fransen et al., 2022, Bento and Couto, 2021). Cities, especially as dense centres of the mobile population, are more prone to pandemics than rural areas. Intercity and intra-city transporting systems and dense transactions pose more threats to urban areas and make them more vulnerable to pandemics (Mollalo et al., 2020).

Many studies conclude that the pandemic has taught policymakers valuable lessons for planning more resilient communities(Elcheroth and Drury, 2020). The mainstream view is that resilience relies on qualities that enable a community to prepare for, respond to, recover from, and improve after hazards(Zautra et al., 2008). Resilient communities can absorb the impacts of the pandemic more effectively and recover rapidly.

According to previous research(Suleimany et al., 2022), community resilience to pandemics includes institutional, social, economic, built environment and infrastructural, and demographic dimensions. Among these dimensions, built environment and infrastructural resilience reflects the physical infrastructural capacity of a city(Keenan, 2020, Programme, 2021), and it is the most relevant dimension for urban planning.

In terms of built environment and infrastructure resilience, previous researchers have mainly focused on critical infrastructure networks, such as electricity, transportation, and communications, with the goal of quickly recovering from disasters, such as earthquakes and floods(Bruneau et al., 2003, Barker et al., 2013). However, community resilience during the pandemic differs from that during disasters. Infrastructure has not been physically damaged during lockdown(Chang et al., 2022); rather, urban functions have weakened due to limited activities. Therefore, the primary criterion of this dimension of community resilience is the availability of services, including various services such as health and hygiene services, retail, and commercial services, etc.

Therefore, we can explore community resilience from another perspective. Firstly, it's important to understand which essential services people need the most during lockdown. Many studies have highlighted the importance of accessibility to services such as education, healthcare, food, and cultural amenities for a community's vitality and cohesion(Contreras et al., 2017, Dempsey et al., 2011, Talen, 2003). Those services are important in normal times, but the situation is different during the pandemic lockdown. In this paper, we focus on the essential services that need to be obtained by reaching a physical facility. The distribution of these essential facilities is a key determinant of community resilience (Valinejad et al., 2022).

In this paper, these essential services are divided into four categories: food and daily necessities services, health care services, express delivery services, and financial services. These categories were selected based on a comprehensive review of existing research(Foli and Ohemeng, 2022, Figliozzi and Unnikrishnan, 2021, Giebel et al., 2022) and consideration of people's basic living needs during lockdown. Food and daily necessities services are crucial for maintaining physical fitness and daily life. Health care services enable people to receive treatment when sick. Express delivery services also play an essential role, especially with the increasing reliance on e-shopping. During lockdown, e-shopping can reduce people's travel and minimize the risk of cross-infection. Therefore, the distribution of delivery terminals is critical to ensure that people can collect their purchased goods even if the number of couriers is reduced during lockdown. Financial services are also essential as obtaining the aforementioned services usually requires payment. However, other needs such as education and recreation were not included in our research as we focused only on basic needs for maintaining life.

Based on the classification of essential service facilities in China and residents' frequency and preferences in accessing these facilities, these four types of essential services are further subdivided into eight facilities. These include four kinds of facilities related to food and daily necessities services: supermarkets, convenience stores, food markets, and greengroceries. Two kinds of facilities related to health care services: hospitals and pharmacies. One facility related to express delivery services: delivery terminals, and one facility related to financial services: bank ATMs.

Many scholars have conducted research on essential services during the pandemic, but their focus varies. For example, some studies have focused on food access, including food security(Béné et al., 2021, Laborde et al., 2020), food purchase behaviour(Ellison et al., 2021), and food supply chain(Rejeb et al., 2022), while less attention has been given to the spatial distribution and accessibility of food stores. Additionally, although there have been some studies on the accessibility of certain types of services(Logan and Guikema, 2020, Mayaud et al., 2019, Feng et al., 2017), research on equity in these essential service facilities is still insufficient, especially for vulnerable groups such as the elderly. Therefore, this study aims to fill these research gaps.

2.2 Equity

Litman(Litman, 2002) presented two categories of equity: horizontal equity and vertical equity. Horizontal equity concerns the distribution of impacts between individuals and groups considered equal in abilities and needs, whereas vertical equity concerns the distribution of impacts between individuals and groups that differ in abilities and needs.

Undoubtedly, vulnerable groups face more inequity from the impact of the pandemic, as evidenced by the fact that adults over 65 years of age represent 80% of hospitalizations due to the COVID-19 and have a 23-fold greater risk of death than those under 65(Mueller et al., 2020). Therefore, the elderly are more affected by the pandemic(Sam, 2020). Elderly people are typically less inclined to cover long distances on foot(Somenahalli and Shipton, 2013). Therefore, specific considerations to improve services should adopt an equity-focused approach to address the pandemic needs of vulnerable groups (Sam, 2020).

This is why we emphasize vertical equity. Vertical equity means essential services are accessible to populations with the greatest potential need. Vertical equity in the distribution of resources plays a crucial role in coping with pandemics(Suleimany et al., 2022). Under these considerations, it is imperative to investigate whether the elderly have equal access to essential service facilities.

3. Study area and data

3.1 Study Area

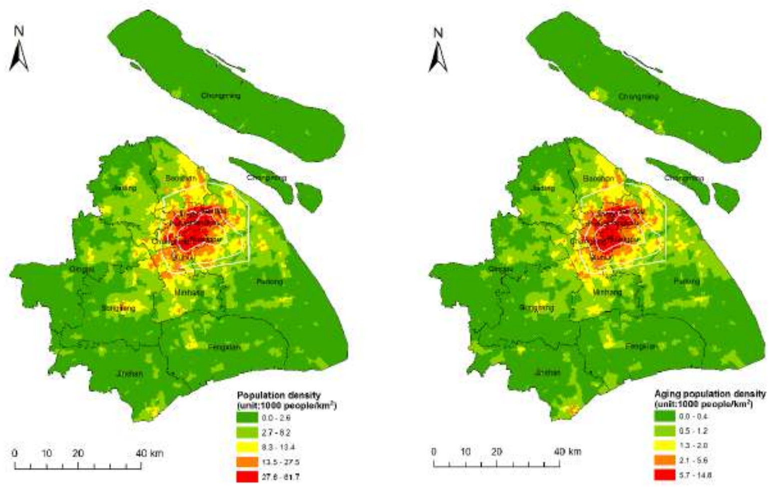
Shanghai, located in the east of China, is the most rapidly urbanizing and developed megacity in the country, encompassing a total area of 6340.5 square kilometres and a population of 24.87 million in 2020(Bureau, 2021). Shanghai is divided into 16 districts (Fig.1). There are three Ring Roads in Shanghai: the Inner Ring Road, the Middle Ring Road and the Outer Ring Road. The area within the Outer Ring Road is defined as the urban area, including the city centre, several sub-centres, and other densely populated areas. Meanwhile, the area outside the Outer Ring Road consists mainly of suburbs, including some new towns and rural areas. Fig.2 shows the distribution of total population density and elderly population (aged 65+) density in Shanghai. It can be observed that the population density is higher in the urban areas and some suburban new towns, while it is lower in other areas.

Fig.1. Study area

Furthermore, Shanghai has entered an aging society. Table 1 shows the total population and aging rate in Shanghai from 2010 to 2022, indicating a continuous deepening of aging in Shanghai. Considering the vast elderly population, Shanghai was chosen as the case city for our research. Investigating the equitable distribution of essential service facilities and offering insights into community resilience within such a megacity holds significant importance.

Table 1 The total population and aging rate in Shanghai from 2010 to 2022

	2010	2020	2021	2022
Total population(million)	23.01	24.87	24.89	24.75
Aging rate (60 years and above) (%)	15.1	23.4	24.0	25.0
Aging rate (65 years and above) (%)	10.1	16.3	17.4	18.7



(a) (b)

Fig.2. (a) Population density distribution in Shanghai, (b) Population density distribution of the elderly over 65 years old in Shanghai (The values are presented as quantile ranges)

3.2 Data

Population data was sourced from the WorldPop-Constrained-individual-countries-2020-UN-adjusted dataset (https://www.worldpop.org/), published in 2020. Moreover, population data for individuals aged 65+ were extracted to represent the elderly population for comparison with the overall population in this study. The selection of the age threshold of 65+ is mainly based on previous research, which suggests that individuals in this age group are more susceptible to health issues(Molarius and Janson, 2002). Additionally, it is a common age threshold in many studies related to aging(Pickering et al., 2001).

The digital geographic data, including eight types of essential service facilities, was obtained from Points of Interest (POI) sourced from Gaode Maps. We acquired Shanghai POI data for 2020 and 2023 to compare facility distribution during and after the pandemic. This data has been converted into WGS1984 coordinates for consistency and compatibility in our analysis.

4. Methodology

We divided the entire study area into 300m × 300m grids, which served as our basic research units. We set two types of buffer zones for the grids: one for the general population and another for the elderly. Considering the weaker walking ability of the elderly, the buffer zone for them is smaller than that for the general population. We developed three indicators, calculated separately for different buffer zone sizes to compare the results for the elderly and the general population. Since each grid produces calculation results, we visualize these results on the map. Finally, we use the Gini coefficient and Lorenz curves to reveal the equity of these three indicators. The following will introduce the specific methods and details of each step.

4.1 The walking buffer area for the elderly and the general population

Due to reduced physical strength in the elderly, their acceptable walking range is smaller than that of the general population. We assume that the maximum acceptable walking time is 15 minutes (Guzman et al., 2021). Given a walking speed of 1.4 m/s for the general population (Bohannon, 1997) and 1.1 m/s for the elderly(Duim et al., 2017), the corresponding walking distances for 15 minutes are 1260 meters and 990 meters, respectively. To establish buffer zones, we determine the maximum walking distance of vertices at the edge of each grid (Fig.3). For the general population, the buffer zone distance is set at 600 meters (Fig.3(a)), while for the elderly, it is 400 meters (Fig.3(b)). Within these buffer ranges, we assume that all essential service facilities are reachable. The following three indexes for measuring the ability to access essential service facilities are calculated within these two buffer ranges, respectively.

(a) (b)

Fig.3. Buffer area for each grid: (a) for general population, (b)for the elderly.

4.2 Demand Accessibility Index

The first index is the Demand Accessibility Index(DAI). It’s important to consider that people have different needs and preferences for service facilities. To capture these differences, we conducted an online questionnaire survey in March 2020 to characterize the travel demands and frequencies of different groups in Shanghai during the lockdown. The survey included 1540 respondents, of which 9.4% were over 65 years old. Respondents were asked about the purposes of essential travel, their purchasing preferences for food and daily necessities (shopping at physical stores or online), their preferred shopping locations (supermarkets, convenience stores, wet markets, greengroceries), as well as the frequency of their outings per week.

Based on our previous survey findings, significant differences exist in the demands and preferences between the elderly and the general population. When it comes to purchasing food, senior citizens tend to favour affordable and fresh options, leading them to prefer wet markets over supermarkets and convenience stores. Additionally, due to a higher likelihood of experiencing health issues, the elderly have a greater demand for access to hospitals and pharmacies.

Moreover, with the rapid development of express delivery and smartphone payment services in China, young people show a preference for online shopping and cashless transactions. In contrast, elderly individuals often stick to traditional shopping methods in physical stores and prefer cash payments due to their limited proficiency with internet usage and smartphones. Consequently, senior citizens exhibit lower demand for express delivery services and a higher demand for bank ATMs.

In this study, we utilized weighted values to compute the DAI (see Table 2). The assignment of these weights, totalling 1, draws from our survey data and is supplemented by insights obtained from existing literature(Weng et al., 2019, Lian and Yen, 2014). The computation process for the DAI of a grid involves multiplying the count of each essential service facility within the buffer zone of each grid by its corresponding weight and subsequently aggregating these values.

Table 2 Weights in the calculation of DAI

		Weight (for general population)	Weight (for the elderly)
Food and daily necessities services	Supermarket	0.15	0.08
	Convenience store	0.13	0.04
	Wet market	0.1	0.18
	Greengrocery	0.12	0.12
Health care services	Hospital	0.1	0.2
	Pharmacy	0.1	0.2
Express delivery services	Delivery terminal	0.25	0.06
Financial services	ATM	0.05	0.12

4.3 Diversity Index

As Jacobs(Jacobs, 2016) commented, a fine-grained mixing of diverse uses creates vibrant and successful neighbourhoods. Shannon information entropy is the most widely used tool for quantifying diversity in land use distribution (Christian et al., 2011). In this study, Shannon entropy is applied to measure the Diversity Index(DI) of essential service facilities within each buffer zone, calculated using the following formula:

$$H(X) = -\sum_{x \in X} p(x) ln p(x) \tag{1}$$

where $H(X)$ represents the diversity of essential service facilities within the buffer zone of each grid. X denotes the number of essential service facility types. This study mainly includes eight facility types: supermarkets, convenience stores, food markets, greengroceries, hospitals, pharmacies, delivery terminals, and ATMs. $p(x)$ denotes the proportion of the xth type of facility in each buffer zone.

4.4 Per Capita Quantity Index

The two aforementioned indexes do not involve population quantity, whereas the Per Capita Quantity Index(PCQI) correlates with population size. As previously mentioned, given the constraints on social distancing during the lockdown, the capacity of each service facility is also limited, thus necessitating the measurement of the number of facilities per capita.

The calculation method for this index involves dividing the number of essential service facilities in the buffer zone of each grid by the grid population. Naturally, this calculation is also performed separately for all residents and the elderly population.

4.5 Min-Max Normalization of the data

As each index is measured in a different unit, we adopt a minimum-maximum normalization approach to convert the data into dimensionless values ranging between 0 and 1. Given that higher index values indicate greater community resilience, we perform minimum-maximum normalization using the following equations:

$$z' = \frac{x - x_{min}}{x_{max} - x_{min}} \quad (2)$$

where z' represents the normalized value between 0 and 1, x is the original value, x_{max} is the maximum for a specific index, and x_{min} is the minimum value for a specific index.

4.6 Equity assessment

To assess equity, we employ Lorenz curves, which enable us to visualize and quantify the fairness of the three indexes across residents in various grids. Originally used in economics to depict income or wealth inequality, the Lorenz curve illustrates the relationship between population (%) and wealth (%) (Lorenz, 1905). Now it has been applied to various fields to demonstrate the equity of resources among population(Delbosc and Currie, 2011, Rezaei and Nouri, 2015, Melkamu and Bannor, 2015).

In our study, the Lorenz curve was utilized to illustrate the relationship between the indexes and the population. Subsequently, the Gini coefficient will be computed to quantify spatial equity. The Gini coefficient is calculated using the following formula(Delbosc and Currie, 2011):

$$G = 1 - \sum_{k=1}^{n} (P_k - P_{k-1})(R_k + R_{k-1}) \quad (3)$$

where P_k is the cumulative percentage of grid population, and R_k is the cumulative percentage of the index. The Gini coefficient ranges from 0 to 1, where 0 means complete equity and 1 denotes complete inequity. A lower Gini coefficient indicates a more equal distribution of that index. A study suggested that a Gini value under 0.2 denotes satisfactory equity, whereas a value between 0.2 and 0.5 indicates medium inequity and a value above 0.5 is considered high inequity(Delbosc and Currie, 2011). In some studies, 0.4 is considered as a warning threshold of inequity(Wen et al., 2016).

5. Results and discussions

5.1 Community resilience in accessing essential service facilities

5.1.1 The results of DAI

Fig.4 shows the DAI value for all residents and the elderly. Overall, only the regions within the Inner Ring Road have a higher DAI. In the urban area, the Demand Accessibility Index for all residents is usually higher than that for the elderly. In 2020, high values of DAI were primarily concentrated in the core areas of the city, while in 2023, the distribution of high values within the urban area exhibited a trend of dispersion, with some sub-centres of the city also showing high DAI values. Additionally, in some suburban new towns, the DAI values in 2023 were higher than those in 2020. These findings indicate a trend of decentralization and dispersion in the distribution of POIs after the pandemic.

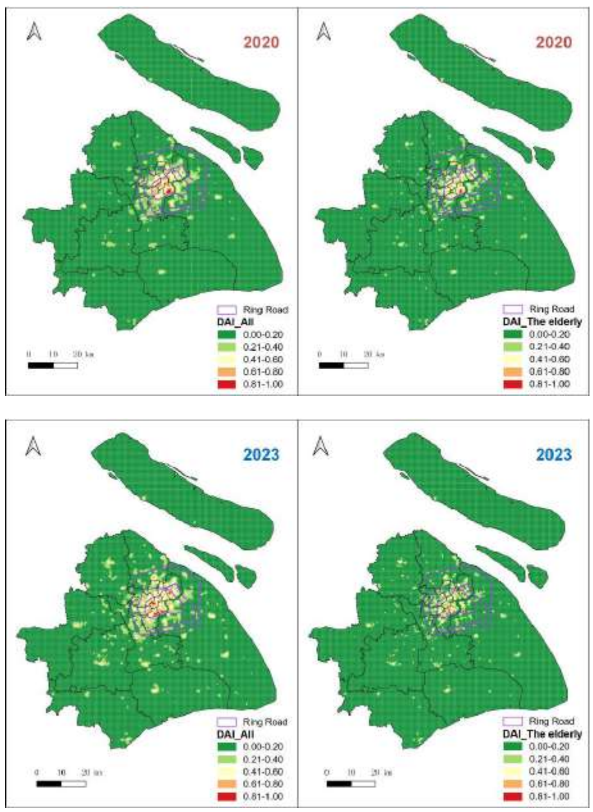


Fig.4. Demand Accessibility Index distribution.

5.1.2 The results of DI

The DI depicts the variety of essential service facility types within the buffer zone of each grid. A higher DI indicates a greater diversity of facilities. As shown in Fig.5, the distribution of DI appears relatively balanced. Apart from the high values observed in urban areas, many suburban regions also exhibit high DIs, sometimes even comparable to those in the city centre. In comparing all residents with the elderly, the DI for all residents tends to be higher, suggesting that larger buffer areas also mean a richer variety of essential service facilities.

Fig.5. Diversity Index distribution.

5.1.3 The results of PCQI

PCQI is calculated by dividing the number of facilities in each buffer by the population of the grid. Therefore, although the number of POIs in the urban area is large, considering the large population, we can find that the PCQI value in the urban area is not high(Fig.6). Conversely, in many suburban areas, this value is relatively high. Moreover, the PCQI value for the elderly is higher than that for all residents.

Due to the reduction of many POIs in the urban area and the increasing trend of POIs in the suburbs after the pandemic, the PCQI value in some suburban areas in 2023 have increased compared to 2020, while the PCQI value in some urban areas have decreased compared to 2020.

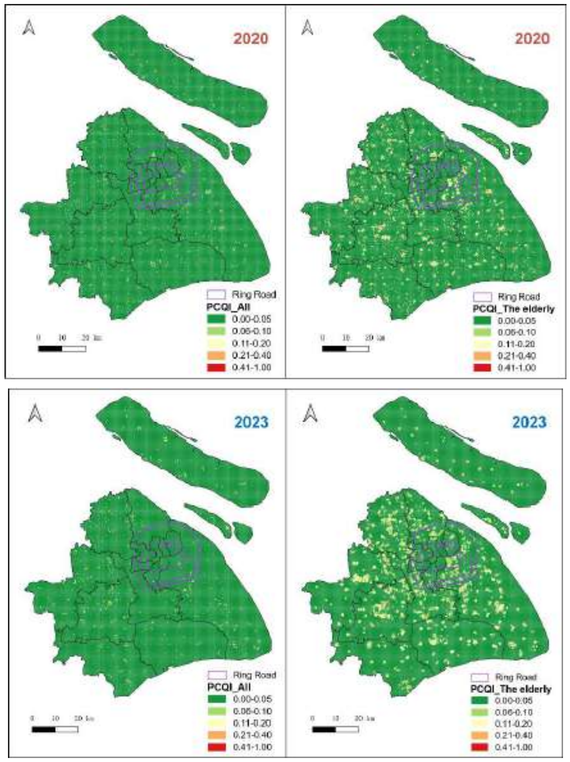
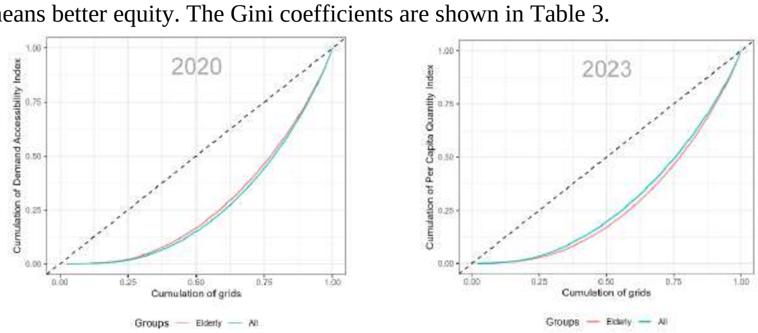


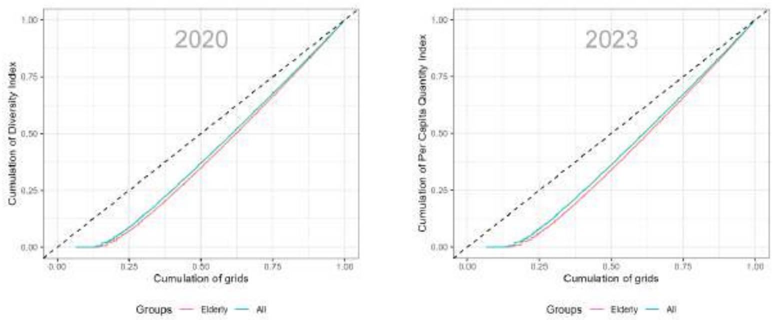
Fig.6. Per Capita Quantity Index distribution.

5.2 Spatial equity of essential service facilities' distribution

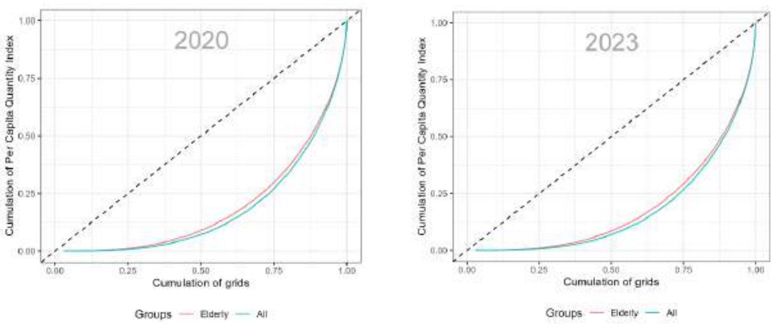
The Lorenz curves for the three indexes were drawn to show the equity of essential service facilities' distribution, and is divided into for all residents and for the elderly (Fig.7). The dash line represents perfect equity. If the curve is closer to this dash line, it means better equity. The Gini coefficients are shown in Table 3.



(a)



(b)



(c)

Fig.7. The Lorenz curves for the three indexes: (a) for DAI, (b) for DI, (c) for PCQI

The results are summarized as follows:

Firstly, The Gini coefficients of PCQI is often the largest of the three indexes, reflecting the most pronounced inequity exhibited by that index. The Gini coefficients of DI is often the smallest among the three indexes, reflecting a relatively balanced distribution of these facilities in terms of diversity. We can see that the Gini coefficients of DAI and PCQI all exceeded 0.4, which is the warning line of inequity.

Table 3 Gini coefficients

	Gini coefficients -DAI		Gini coefficients -DI		Gini coefficients -PCQI	
	All	The elderly	All	The elderly	All	The elderly
2020	0.478	0.456	0.200	0.224	0.649	0.622
2023	0.419	0.451	0.209	0.236	0.657	0.632

Then, let’s focus on the differences between all individuals and the elderly in these three indexes. The Gini coefficients of DAI values in 2023 are smaller than those in 2020, respectively. This indicates an improvement in equity in DAI after the pandemic. This phenomenon is mainly attributed to the decentralization of POIs, with many suburban areas having a richer array of POIs than before the pandemic. However, in 2020, the equity performance of DAI for the elderly was better than that for the general population, while in 2023, the situation reversed, implying a weakening of facility distribution catering to the needs of the elderly after the pandemic.

As for DI, the Gini coefficients in 2023 are a little bit larger than those in 2020, indicating a slight decrease in the equity of facility diversity after the pandemic. Whether during or after the pandemic, this index reflects better equity for the general population compared to the elderly.

For the PCQI, the Gini coefficients in 2023 are also larger than those in 2020, indicating a decrease in the equity of per capita facility quantity after the pandemic. However, when considering the comparison between the elderly and the general population, the equity is better for the elderly.

This outcome indicates a fundamental difference between the three indexes: Shanghai is a diverse and highly commercialized city, so the types of essential service facilities are relatively balanced. However, due to the different population densities between the urban and suburbs, there is a great inequity in terms of per capita quantity of essential service facilities. Among the three indexes, particular attention needs to be paid to the DAI. During the pandemic, the equity of DAI for the elderly was better than for the general population, while the opposite is true after the pandemic. This suggests that the distribution of essential service facilities post-pandemic is moving in a direction unfavourable to the needs of the elderly. This is something that the government should pay attention to, especially in areas with high elderly population density, ensuring that essential service facility distribution meets the needs of the elderly.

6. Conclusions

Strengthening community resilience in cities is urgently needed in this post-COVID era. Reducing the inequity in access to essential service facilities is considered an effective way to improve community resilience dealing with pandemics and to improve the livelihoods of all populations.

In this research, we created three indexes to measure community resilience in accessing essential services. We classified the essential services and their corresponding facilities, taking into account the varying walking capacity and needs of the elderly when measuring accessibility. The Lorenz curve and the Gini coefficient were used to assess the spatial equity of the three indexes, which represents an innovative application of interdisciplinary methods.

The results of our study suggest that the equity level is different among the three indexes. The Diversity Index exhibits the highest equity, followed by the Demand Accessibility Index, while the equity of the Per Capita Quantity Index is the lowest. These findings underscore the importance of prioritizing fairness in terms of per capita facilities and addressing the diverse demands of different groups.

Several issues need to be addressed in future studies. Firstly, in terms of equity, this paper only considers the elderly as a vulnerable group. However, there are many other vulnerable groups, such as low-income individuals, people with chronic illnesses, and homeless individuals. Future research should also consider these groups to provide a more comprehensive understanding of equity in access to essential services. Secondly, capacity restrictions in public places during the lockdown were not fully addressed in this paper. While the per capita quantity of essential service facilities was considered, the paper did not further limit the number of people allowed to enter these facilities. In the future, this approach can be combined with epidemiological research to conduct accessibility studies based on the maximum number of people allowed to enter each type of essential service facility, which could provide valuable insights for controlling the spread of the pandemic and assisting policymakers in resource allocation decisions.

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Conflicts of Interest
The authors declare no conflict of interest.

References

ABDULLAH, M., DIAS, C., MULEY, D. & SHAHIN, M. 2020. Exploring the impacts of COVID-19 on travel behavior and mode preferences. *Transportation Research Interdisciplinary Perspectives,* 8**,** 100255.

BARKER, K., RAMIREZ-MARQUEZ, J. E. & ROCCO, C. M. 2013. Resilience-based network component importance measures. *Reliability Engineering & System Safety,* 117**,** 89-97.

BéNé, C., BAKKER, D., CHAVARRO, M. J., EVEN, B., MELO, J. & SONNEVELD, A. 2021. Global assessment of the impacts of COVID-19 on food security. *Global Food Security,* 31**,** 100575.

BENTO, F. & COUTO, K. C. 2021. A behavioral perspective on community resilience during the COVID-19 pandemic: The case of Paraisópolis in São Paulo, Brazil. *Sustainability,* 13**,** 1447.

BOHANNON, R. W. 1997. Comfortable and maximum walking speed of adults aged 20—79 years: reference values and determinants. *Age and ageing,* 26**,** 15-19.

BRUNEAU, M., CHANG, S. E., EGUCHI, R. T., LEE, G. C., O'ROURKE, T. D., REINHORN, A. M., SHINOZUKA, M., TIERNEY, K., WALLACE, W. A. & VON WINTERFELDT, D. 2003. A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthquake spectra,* 19**,** 733-752.

BUREAU, S. M. S. 2021. *The Seventh National Population Census of the People's Republic of*

China [Online]. Available: https://tjj.sh.gov.cn/zdlyxxgk/20210701/64f46d9879094179993177a94dfc0f2f.html [Accessed 18 May, 2021 2021].

CHANG, S. E., BROWN, C., HANDMER, J., HELGESON, J., KAJITANI, Y., KEATING, A., NOY, I., WATSON, M., DERAKHSHAN, S. & KIM, J. 2022. Business recovery from disasters: Lessons from natural hazards and the COVID-19 pandemic. *International Journal of Disaster Risk Reduction,* 80**,** 103191.

CHRISTIAN, H. E., BULL, F. C., MIDDLETON, N. J., KNUIMAN, M. W., DIVITINI, M. L., HOOPER, P., AMARASINGHE, A. & GILES-CORTI, B. 2011. How important is the land use mix measure in understanding walking behaviour? Results from the RESIDE study. *International Journal of Behavioral Nutrition and Physical Activity,* 8**,** 1-12.

CONTRERAS, D., BLASCHKE, T. & HODGSON, M. E. 2017. Lack of spatial resilience in a recovery process: Case L'Aquila, Italy. *Technological forecasting and social change,* 121**,** 76-88.

CORSO, L. C., WIESNER, P. J., HALVERSON, P. K. & BROWN, C. K. 2000. Using the essential services as a foundation for performance measurement and assessment of local public health systems. *Journal of Public Health Management and Practice***,** 1-18.

DELBOSC, A. & CURRIE, G. 2011. Using Lorenz curves to assess public transport equity. *Journal of Transport Geography,* 19**,** 1252-1259.

DEMPSEY, N., BRAMLEY, G., POWER, S. & BROWN, C. 2011. The social dimension of sustainable development: Defining urban social sustainability. *Sustainable development,* 19**,** 289-300.

DUIM, E., LEBRãO, M. L. & ANTUNES, J. L. F. 2017. Walking speed of older people and pedestrian crossing time. *Journal of Transport & Health,* 5**,** 70-76.

ELCHEROTH, G. & DRURY, J. 2020. Collective resilience in times of crisis: Lessons from the literature for socially effective responses to the pandemic. *British Journal of Social Psychology,* 59**,** 703-713.

ELLISON, B., MCFADDEN, B., RICKARD, B. J. & WILSON, N. L. 2021. Examining food purchase behavior and food values during the COVID-19 pandemic. *Applied Economic Perspectives and Policy,* 43**,** 58-72.

FENG, X. L., MARTINEZ-ALVAREZ, M., ZHONG, J., XU, J., YUAN, B., MENG, Q. & BALABANOVA, D. 2017. Extending access to essential services against constraints: the three-tier health service delivery system in rural China (1949–1980). *International Journal for Equity in Health,* 16**,** 1-18.

FIGLIOZZI, M. & UNNIKRISHNAN, A. 2021. Home-deliveries before-during COVID-19 lockdown: Accessibility, environmental justice, equity, and policy implications. *Transportation Research Part D: Transport and Environment,* 93**,** 102760.

FOLI, R. K. & OHEMENG, F. L. 2022. "Provide our basic needs or we go out": the COVID-19 pandemic lockdown, inequality, and social policy in Ghana. *Policy and Society,* 41**,** 217-230.

FRANSEN, J., PERALTA, D. O., VANELLI, F., EDELENBOS, J. & OLVERA, B. C. 2022. The emergence of urban community resilience initiatives during the COVID-19 pandemic: An international exploratory study. *The European journal of development research***,** 1-23.

GIEBEL, C., IVAN, B., BURGER, P. & DDUMBA, I. 2022. Impact of COVID-19 public health restrictions on older people in Uganda:"hunger is really one of those problems brought by this COVID". *International psychogeriatrics,* 34**,** 805-812.

GUZMAN, L. A., ARELLANA, J., OVIEDO, D. & ARISTIZáBAL, C. A. M. 2021. COVID-19, activity and mobility patterns in Bogotá. Are we ready for a '15-minute city'? *Travel Behaviour and Society,* 24**,** 245-256.

HOLLING & S, C. 1973. Resilience and Stability of Ecological Systems. *Annual Review of Ecology & Systematics,* 4**,** 1-23.

HOLLNAGEL, E., WOODS, D. D. & LEVESON, N. 2006. *Resilience engineering: Concepts and precepts*, Ashgate Publishing, Ltd.

JACOBS, J. 2016. *The death and life of great American cities*, Vintage.

KABIRAJ, A., PAL, D., BHATTACHERJEE, P., CHATTERJEE, K., MAJUMDAR, R. & GANGULY, D. How successful is a lockdown during a pandemic? 2020 IEEE 17th India Council International conference (INDICON), 2020. IEEE, 1-6.

KEENAN, J. M. 2020. COVID, resilience, and the built environment. *Environment Systems and Decisions,* 40**,** 216-221.

LABORDE, D., MARTIN, W., SWINNEN, J. & VOS, R. 2020. COVID-19 risks to global food security. *Science,* 369**,** 500-502.

LIAN, J.-W. & YEN, D. C. 2014. Online shopping drivers and barriers for older adults: Age and gender differences. *Computers in human behavior,* 37**,** 133-143.

LITMAN, T. 2002. Evaluating transportation equity. *World Transport Policy & Practice,* 8**,** 50-65.

LOGAN, T. M. & GUIKEMA, S. D. 2020. Reframing resilience: Equitable access to essential services. *Risk Analysis,* 40**,** 1538-1553.

LORENZ, M. O. 1905. Methods of measuring the concentration of wealth. *Publications of the American statistical association,* 9**,** 209-219.

MANNING, I. 2010. Accessibility of essential services in urban and regional Australia. *National Economic Review***,** 1-14.

MANYENA, S. B. 2006. The concept of resilience revisited. *Disasters,* 30**,** 434-450.

MASNAVI, M., GHARAI, F. & HAJIBANDEH, M. 2019. Exploring urban resilience thinking for its application in urban planning: A review of literature. *International journal of environmental science and technology,* 16**,** 567-582.

MAYAUD, J. R., TRAN, M., PEREIRA, R. H. & NUTTALL, R. 2019. Future access to essential services in a growing smart city: The case of Surrey, British Columbia. *Computers, Environment and Urban Systems,* 73**,** 1-15.

MAYER, J. 1979. Spatial aspects of basic-needs strategy: the distribution of essential services. *Int'l Lab. Rev.,* 118**,** 59.

MELKAMU, M. & BANNOR, R. K. 2015. Estimation of agricultural resource inequality in India using Lorenz curve and Gini coefficient approach. *International Journal of Current Research and Academic Review,* 3**,** 174-184.

MOLARIUS, A. & JANSON, S. 2002. Self-rated health, chronic diseases, and symptoms among middle-aged and elderly men and women. *Journal of clinical epidemiology,* 55**,** 364-370.

MOLLALO, A., VAHEDI, B. & RIVERA, K. M. 2020. GIS-based spatial modeling of COVID-

19 incidence rate in the continental United States. *Science of the total environment,* 728**,** 138884.

MUELLER, A. L., MCNAMARA, M. S. & SINCLAIR, D. A. 2020. Why does COVID-19 disproportionately affect older people? *Aging (albany NY),* 12**,** 9959.

PICKERING, G., BRUNET, F., ROUSSEL, M. & PASTOR, J. 2001. Evaluation of the offer of physical activity for the elderly in a region of France. *Archives of gerontology and geriatrics,* 33**,** 1-6.

PROGRAMME, U. N. H. S. 2021. *Cities and pandemics: Towards a more just, green and healthy future*, United Nations Human Settlements Programme (UN-Habitat).

REJEB, A., REJEB, K., APPOLLONI, A., IRANMANESH, M., TREIBLMAIER, H. & JAGTAP, S. 2022. Exploring food supply chain trends in the COVID-19 era: A bibliometric review. *Sustainability,* 14**,** 12437.

REZAEI, S. & NOURI, B. 2015. Evaluation of inequalities in the distribution of health resources by Gini coefficient and Lorenz curve: a case study in Kurdistan province from 2006 to 2013. *Scientific Journal of Kurdistan University of Medical Sciences,* 20.

SAM, P. 2020. Redefining vulnerability in the era of COVID-19. *Lancet,* 395**,** 1089.

SASSON, I. 2021. Age and COVID-19 mortality. *Demographic Research,* 44**,** 379-396.

SOMENAHALLI, S. & SHIPTON, M. 2013. Examining the distribution of the elderly and accessibility to essential services. *Procedia-social and behavioral sciences,* 104**,** 942-951.

SULEIMANY, M., MOKHTARZADEH, S. & SHARIFI, A. 2022. Community resilience to pandemics: An assessment framework developed based on the review of COVID-19 literature. *International Journal of Disaster Risk Reduction***,** 103248.

TALEN, E. 2003. Neighborhoods as service providers: a methodology for evaluating pedestrian access. *Environment and Planning B: Planning and Design,* 30**,** 181-200.

VALINEJAD, J., GUO, Z., CHO, J.-H. & CHEN, R. 2022. Measuring community resilience during the COVID-19 based on community wellbeing and resource distribution. *Journal of Social Computing,* 3**,** 322-344.

WEN, J., YANG, Y., JIANG, Y., LI, L., WANG, X. & CUI, X. 2016. Analysis on equity of Ningxia's health resource allocation based on Gini coefficient and index of Dissimilarity. *Chin Health Econ,* 35**,** 61-64.

WENG, M., DING, N., LI, J., JIN, X., XIAO, H., HE, Z. & SU, S. 2019. The 15-minute walkable neighborhoods: Measurement, social inequalities and implications for building healthy communities in urban China. *Journal of Transport & Health,* 13**,** 259-273.

XU, W., XIANG, L., PROVERBS, D. & XIONG, S. 2021. The influence of COVID-19 on community disaster resilience. *International journal of environmental research and public health,* 18**,** 88.

YIP, W., GE, L., HO, A. H. Y., HENG, B. H. & TAN, W. S. 2021. Building community resilience beyond COVID-19: The Singapore way. *The Lancet Regional Health–Western Pacific,* 7.

ZAUTRA, A., HALL, J. & MURRAY, K. 2008. Community development and community resilience: An integrative approach. *Community Development,* 39**,** 130-147.