Research on the spatial equity of medical facilities based on Rawls’ theory of justice: A case study of Nanchang, China

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Research on the spatial equity of medical facilities based on Rawls’ theory of justice: A case study of Nanchang, China

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Abstract

Background: Under the impact of COVID-19, public health awareness and medical systems in various countries are facing significant changes. Such problems as unequal and unbalanced distribution of medical resources have become increasingly prominent. Therefore, building a scientific and reasonable equity evaluation system for urban public medical facilities layout optimization is of great research significance.

Methods: This paper introduces the improved potential model and uses the Baidu API navigation planning service to measure the spatial accessibility of medical care under two modes of transportation in Nanchang, and analyzes the spatial equity of medical facilities through the degree of accessibility equilibrium, accessibility adequacy and accessibility deprivation of vulnerable groups.

Results: In terms of accessibility equilibrium and adequacy, The study found a positive correlation between the accessibility of medical facilities and the level of medical services, and spatial equity was the worst in first-level hospitals. The results of the Mann-Whitney U test show that the communities with high housing prices in central city areas have better medical accessibility than those with low housing prices located on the urban fringes. In addition, owing to the high dependence of low-income people on public transport, marginalized urban communities have worse public transport than the central city, resulting in a dual deprivation of resources and location.

Conclusions: In practice, research on spatial equity of medical facilities should pay attention to the
exploitation of medical resources of vulnerable groups, prioritize the planning and construction of primary hospitals (primary hospitals), and ensure residents’ demand for basic medical facilities, and step-by-step improvement of inequities in healthcare facilities.

**Keywords:** Spatial equity. Vulnerable groups. Potential model. Rawls’ theory of justice. Accessibility

### 1. Background

Health is the foundation of human existence and social stability, a vital guarantee for the quality of life of individuals. The United Nations has included “Medicare for All” in the 2030 sustainable development agenda. Health equity refers to an equal right to health for all and ensures equity in the price and quality of health care when accessing health services. Therefore, the fairness of the spatial distribution of medical institutions has always been the focus of health reform and development(1,2).

Spatial equity emphasizes equal access to services from a supply and demand perspective for different regions or social groups(3), representing the feasibility of people reaching specific locations (4). Accessibility can be an indicator to quantify spatial fairness (5,6). Accessibility is mainly affected by three factors: the supply of facilities, the population’s demand for facilities, and the cost of travel between supply and demand points. Access to public services should be improved to reduce inequalities at the social and spatial levels (7–9).

However, while advocating for medical equity, health inequalities still exist between different regions, often among vulnerable groups(10–14). With the introduction of spatial dislocation, the unequal distribution of resources faced by socially disadvantaged groups has become a focus of attention among scholars (15). Ongarora et al. found that inadequate availability of medicine in public health facilities in low-income communities and high drug prices in private health facilities negatively impact the accessibility of medical facilities for low-income populations. Shen et al. showed that people living on the outskirts of Shanghai have less access to medical facilities (16,17). Therefore, the spatial equity of medical facilities should focus on the
deprivation effect of access to medical facilities for vulnerable groups.

1.1 Accessibility

Spatial accessibility is often described as “the complexity of getting from a place to a destination based on a certain means of transportation” (18–20). Therefore, medical facility accessibility expresses the complexity of potential users reaching a medical facility via a certain means of transportation, namely, the cost of obtaining medical services.

In recent years, quantitative research on accessibility has developed from the nearest distance of a single facility to the cumulative cost of reaching multiple facilities. The nearest distance method assumes that residents will only choose the nearest single service facility (21). This approach ignores the cumulative access of residents to medical facilities within a set travel time or distance threshold and the cumulative capacity of the facilities. Cumulative opportunities-based methods are a hot topic in computing accessibility methods (22,23), which cumulate the total opportunities from the point of demand to supply points by setting travel time or travel distance thresholds (24). Such approaches use only one catchment size for all populations, and most studies do not consider threshold times or distances for different levels of facilities (25). Spatial interaction-based methods are a further improvement of methods based on cumulative opportunities, which combine travel distance or travel time attenuation functions with the attractiveness of the facility to measure accessibility. It reflects the population’s demand for and supply of the surrounding facilities (26,27). The method based on spatial interaction mainly includes potential models, the two-step floating catchment area method (2SFCA), and various improved formulas (28,29).

Currently, most scholars use spatial interaction-based methods to quantify the accessibility of medical facilities. Tao et al. considered the size of different catchment areas, distance attenuation effects, and the cost of travel at all levels of facilities and investigated the spatial fairness of graded medical facilities through an
improved two-step floating catchment area method (30). Cheng et al. considered factors such as the transportation network, population size, medical facilities, and resistance to travel. They constructed an improved potential model to analyze the spatial accessibility of medical facilities in the Changning District of Shanghai (31).

1.2 Spatial equity theory of medical service facilities

The current mainstream topic is the research on space equity of medical service facilities based on egalitarianism theory. The core idea of egalitarianism emphasizes equality for all (32). Facilities distribution standards for different populations in different regions are unified, which is highly operable for measuring the spatial equity of medical facilities. Based on egalitarian equity theory, equity studies of medical facilities commonly use the Gini coefficient and Lorenz curve for numerical analysis. Rong et al. used population distribution and bed number distribution to map the Lorenz curve to evaluate the fairness of the distribution of medical institutions in Zhengzhou (33). Wang et al. analyzed the Lorenz curve of the accessibility of third-level hospitals in Shaanxi Province and found that the distribution of spatial accessibility of first-level hospitals is more in equilibrium than that of second-level and third-level hospitals (13). However, achieving full equitable distribution based on egalitarianism is complex, and its theoretical criteria are demanding.

Rawls’ theory of justice further corrects egalitarianism. Martens summarized two aspects: 1. the principle of maximizing the average while ensuring the bottom line, and 2. the principle of maximizing the average and limiting the gap between the highest and lowest levels (34). Therefore, when studying the issue of equity in medical facilities, we should also consider minimum standards for the population’s access to health resources, while striving for the maximum equitable distribution of conditions to guarantee the minimum demands of the community population for medical facilities.

Through the review of the literature, three main shortcomings of the existing research: 1. when calculating
the travel cost, the research usually ignores the quality level of hospitals and the diversity of transportation modes. Different levels of medical service facilities always serve different purposes, and their capacity and service scope vary greatly (35), especially when the patient’s health is critical. The time required to receive diagnosis is directly related to the survival rate (36). The accessibility of service facilities varies greatly in travel costs under different traffic modes (21,37). 2. Due to the limitations of traffic data, some papers use static travel times to quantify accessibility, ignoring the actual traffic conditions, such as traffic congestion, waiting time, walking time, etc. This may lead to conflicting conclusions (38,39). As data availability increases, travel times can be calculated from open data provided by internet mapping or navigation services (27,33,40). These studies have greatly reduced the cost of accessibility measurement by creating an internet data model that takes into account all factors affecting travel time between origin and destination. 3. In the current system of fair evaluation of medical facilities, the direct application of equalization criteria and the neglect of practical factors make the corresponding requirements of the strategy for optimizing public resources too high and difficult to implement. A high degree of equity does not mean that health institutions have adequate resources; therefore, it is necessary to guarantee the minimum demands of the communities for medical facilities.

Based on the above literature, this study has twofold: 1. assessing and describing the spatial accessibility of communities’ medical facilities; and 2. comparing the accessibility of medical facilities to different groups and analyzing whether there is space deprivation among vulnerable groups. The innovation of this research mainly has two aspects. First, based on Rawls’s theory of justice, this paper analyzes the equilibrium degree and adequacy degree of spatial equity in medical facilities. Second, the expense cost matrix of different modes of transportation and the difference in communities’ quality of life was used to classify the groups and compare their fairness.
Compared with other accessibility research methods, the potential model considers the spatial accessibility of medical facilities by considering the cumulative demands of the population, the cumulative supply of facilities, and the corresponding time threshold in different hospitals. Given this, based on the real-time route planning big data extracted from the Baidu map development platform, this paper pulled the time and expense costs under the two traffic modes. Then, the potential model was introduced to quantify hospital
accessibility, the hospital accessibility of three quality levels under the two traffic modes for different groups was calculated, and the degree of equity in medical accessibility was analyzed. Figure shows an overview of the methodology for the paper (Figure 1).

Based on Rawls’s theory of justice, the fair evaluation rule of the accessibility of medical facilities involves three aspects:

- The distribution of the accessibility value of medical facilities should be as balanced as possible (evaluation of equilibrium degree).

  Residents must have the ability to reach at least one medical facility within a time threshold; otherwise, the accessibility of medical facilities in the corresponding communities is considered inadequate (evaluation of adequacy degree).

  The equity degree of accessibility between vulnerable and nonvulnerable groups was compared, and it was judged whether vulnerable groups experience the phenomenon of medical resource deprivation (evaluation of deprivation degree).

2.1 Improved potential model

This paper quantifies the spatial accessibility of medical facilities using an improved potential model (33), using community coordinate points as starting points and measuring based on real-time road networks and walking modes. The model formula is as follows:

\[
A_i = \sum_{j=1}^{n} \frac{S_{kj}M_j}{n\beta n_j}, \quad V_j = \sum_{k=1}^{m} \frac{S_{kj}B_k}{m\beta j_k}, \quad S_{ij} = 1 - \left(\frac{D_{ij}}{D_{ij}}\right)^\beta
\]

\(A_i\) is the accessibility to health facilities in community \(i\); \(M_j\) refers to the service capacity of medical facilities (by the number of hospital beds measured); \(\beta\) represents the friction coefficient of stroke; \(n\) and \(m\) denote the number of facilities and residential areas, respectively; \(V_j\) is the population scale factor; \(P_k\) is the population of community \(k\); \(S_{ej}\) represents the scale factor of medical facility \(j\); \(D_{ij}\) is
the travel impedance between i and j (expressed in time); and $D_j$ represents the time threshold for travel to different levels of hospitals. When $S_{ij} \leq 0$, this indicates that hospital j is not attractive to people in community i, and therefore, these residents will not choose to seek care at that hospital.

In this study, the travel friction coefficient $\beta$ was set to 1.5, and the travel time threshold of hospitals at all levels was 20 minutes for first-level hospitals, 50 minutes for second-level hospitals, and $+\infty$ for third-level hospitals (31).

2.2 Evaluation of the equilibrium degree of accessibility

Based on quantitative results of the value of accessibility to medical facilities, the paper evaluates the equilibrium degree of accessibility in the region in conjunction with the coefficient of variation formula (41):

$$CV = \frac{\sigma_A}{\mu_A}$$

$CV$ is the coefficient of variation of the accessibility value of medical facilities in a particular region, and $\sigma_A$ and $\mu_A$ are the standard deviation and average of the accessibility value of medical facilities in the area, respectively. The smaller the coefficient of variation, the smaller the dispersion degree of data, and the better the spatial equilibrium degree of accessibility of medical facilities in the region.

2.3 Evaluation of the adequacy of accessibility

Criteria for assessing the adequacy of accessibility: at least one medical facility is accessible to the communities within a time threshold; if it is below this standard, the accessibility of facilities is considered inadequate. The formula is as follows:

$$CY = \frac{U_i}{U}$$

$CY$ is the adequate ratio of accessibility to community medical facilities in a particular region, $U_i$ is the number of communities with inadequate medical facilities in the region, and $U$ is the number of all
2.4 Evaluation of the degree of accessibility deprivation

2.4.1. analysis of public transport efficiency

If only considering travel time cost, private cars have an absolute cost advantage over public transport. The paper should therefore consider travel expenses under both modes of travel. Due to the low level of the social economy, travel expenses are the main reason why disadvantaged groups choose the mode of travel. They usually adopt the public transport travel mode, and the travel service provided by taxis is the opposite of public transport. It is more important for vulnerable groups to consider the time and expense costs of the two modes of travel and then analyze whether there is a gap in the accessibility of facilities between public transport and taxis.

\[ A_i = \sum_{j=1}^{n} \frac{S_{ij}^P}{C_{ij}^P}, \quad V_1 = \sum_{k=1}^{n} \frac{S_{ik}^P}{C_{ik}^P}, \quad S_{ij} = 1 - \left( \frac{C_{ij}^T}{D_{ij}} \right)^{\frac{1}{f_{tt}}}, \quad C_{ij} = T_{ij} + F_{ij}, \]

\[ RA_i = A_i^P - A_i^T \]

\( RA \) is the calculation result of the relative accessibility of community i, \( A_i^P \) and \( A_i^T \) are the calculation results of the accessibility of public transport and taxis, respectively. \( C_{ij} \) is the comprehensive cost of travel between community i and hospital j, \( T_{ij} \) is the corresponding time cost, \( F_{ij} \) is the corresponding expense cost, and \( f_{tt} \) is the cost conversion parameter (42). \( f_{tt} \) is the cost conversion parameter, estimated by dividing the annual average income of Nanchang city by the legal yearly working hours. In 2021, the average annual salary in Nanchang city was 97,800 yuan, and the legal yearly working hours were 2,000, so the value of \( f_{tt} \) was 0.815 yuan/minute. If \( RA_i < 0 \), then the accessibility efficiency of public transport is less than that of the taxi, and the medical accessibility of vulnerable groups has the phenomenon of deprivation.

2.4.2. difference analysis of community living quality
American sociologist John Kane has found that socially vulnerable groups face residential segregation (Nilsson et al., 2018). Most vulnerable groups live in price advantageous residential areas, such as suburbs and shanty towns, and the level of infrastructure around communities is low. To this end, 16 quantitative indicators were selected from four aspects: living environment, economic condition, location condition, and transportation condition. High-accessibility communities accounted for the first 25%, and low-accessibility communities for the last 25%. The Mann–Whitney U test measures the correlation between the accessibility of medical facilities and the quality of living in the communities and analyzes whether there are differences in the quality of life between low-accessibility and high-accessibility communities and whether low-accessibility communities aggregate many vulnerable groups.

2.5 Data collection and sorting

2.5.1. Community data

Through the three real estate rental-sale service platforms Anjuke, Lianjia, and Fangtianxia, the paper crawled the relevant attribute data of 19704 residential communities in Nanchang’s six districts (Figure 2) and integrated a total of 2,463 communities through data cleaning, screening, and eliminating duplication data. The data included house prices, green rates, floor area ratio, location of communities, property costs, and the number of households. Then, according to the population distribution data of each household in Nanchang city, the total population distribution data of each Nanchang city community were obtained.
2.5.2. medical facilities data

This paper obtained the grade information of hospitals in six districts of Nanchang by inquiring about the designated research institutions of the National Healthcare Security Administration and field investigation and selecting the data of 78 first-level hospitals, 16 second-level hospitals, and 19 third-level hospitals, including the address data and the number of hospital beds.

2.5.3. travel time data

The paper obtained travel time data through the Baidu API service, a web-based resource, and then used the Python scripting language to receive travel routes and time between supply and demand points in the study area. The off-peak time was selected for data collection, Aug 9, 2022, from 9:00 a.m. to 11:00 a.m. The specific process is as follows: (1) the communities coordinates crawled through the real estate rental and sales
service platform as the starting point, and the hospital address coordinates recorded by the National Healthcare Security Administration as the target point; (2) request the route planning of all communities to medical facilities in batches from Baidu API; and (3) Baidu API generally recommends multiple routes when invoking the function of route planning. This study selected Route 1 as the data source to obtain the best travel routes, travel times, and associated fares for all communities to all medical facilities.

3. Results

Figure 3. (a) Distribution of hospital beds and population; (b) Lorenz curve of hospital beds

Based on the analysis of the distribution of institutional beds and the resident population in districts (Figure 3), the equity of distribution of street medical institutions in districts was evaluated. The number of beds in medical institutions varies significantly on different streets of Nanchang. Medical resources are mainly concentrated in central urban areas, such as Yuzhang and Dongjiayao in Donghu District, Machang in Xihu District, Nangang in Qingshanhu District, and Shajing in Honggutan District. However, the population distribution of the Fenghuangzhou and Jiulonghu in Honggutan District is relatively dense. Nevertheless, medical resources are scarce, directly resulting in low intensity of medical service allocation in areas with a
high population density. In general, there are significant differences in the allocation level of medical resources on different streets in Nanchang.

According to the Lorenz curve, within the regional scope, approximately 75% of medical facilities’ beds are distributed in streets where the population accounts for 10% of total service allocation, with approximately 20% of the people of communities located in the streets where no medical facilities exist. The corresponding Gini coefficient is 0.838. There are severe inequalities in the distribution of medical institutions in street units.

![Box plot of shortest travel time](image)

**Figure 4.** Box plot of shortest travel time

To intuitively compare travel time differences between different levels of hospitals, the shortest travel time between residential areas and the nearest hospital in the two travel modes of public transport and taxi was taken as the analysis (Figure 4). As seen, travel times vary between levels of hospitals. For both methods, the average shortest travel time was 23.2 minutes and 5.6 minutes for first-level hospitals, 28.8 minutes and 9.2 minutes for second-level hospitals, and 31.1 minutes and 9.9 minutes for third-level hospitals, respectively. The phenomenon is because the number of high-level medical resources is less and more concentrated than that of low-level hospitals, which makes it challenging to provide nearby medical services. As a result, the average minimum travel time for first-level hospitals was the shortest, followed by second-level and third-level hospitals, with significant differences in travel time.
3.1 Distribution of accessibility values to medical facilities

Figure 5. (a) Accessibility distribution of first-level hospitals; (b) Accessibility distribution of second-level hospitals; (c) Accessibility distribution of third-level hospitals.
As seen from the figure (Figure 5), the accessibility degree of first-level hospitals is low in all areas, the high-value communities are sparse and distributed irregularly, and the spatial distribution of the accessibility of second-level and third-level hospitals shows a trend of central agglomeration and outward dispersion. The accessibility of the central city is better than other areas. The scale and number of medical facilities in the central urban area of the study area are much larger than those outside the central urban area, resulting in an excessive concentration of medical resources, which provides better medical services for residents in the area. However, there are few medical institutions outside the central city, and medical facilities can hardly cover the south of the Red Valley Beach area and the west of the newly built area. Their access to medical care is obviously lower than the average level of the whole area, which leads to some differences and imbalances in medical facilities and services within the districts.

Communities’ accessibility values for first-level hospitals are primarily between 0 and 0.1 and vary widely from community to community; there are many communities with a “0 value”. The community with the most significant accessibility value of first-level hospitals is the community Changzheng community in Changling of Xinjian District, corresponding to 9.803. The overall accessibility of second-level hospitals is better than that of first-level hospitals. The values of second-level hospitals’ accessibility are mainly between 0 and 0.25, with relatively small differences in community accessibility. Third-level hospitals generally tend to have access values between 0.4 and 0.9, with high accessibility values.

3.2 Evaluation of the equilibrium degree of accessibility

<table>
<thead>
<tr>
<th>Accessibility value of first-level hospitals</th>
<th>accessibility value of second-level hospitals</th>
<th>accessibility value of third-level hospitals</th>
</tr>
</thead>
</table>
As seen from Table 1, the overall equilibrium degree of spatial accessibility in third-level hospitals is the best, with a variation factor of less than 0.5 in all regions. The general equilibrium degree of spatial accessibility in second-level hospitals was good, and the spatial variability coefficient of access in all districts was less than 1.5. The overall spatial accessibility of first-level hospitals is more dispersed, and the average level of accessibility is low. There are significant differences in accessibility values among different districts.

The results showed that, because of the low level of hospital service capacity and the short travel time frame, the value of accessibility of first-level hospitals varies widely among the whole class. The districts with
enormous accessibility values are Xinjian District (9.803), but the corresponding coefficients of variation were
the lowest (4.391). Due to the high service capacity and unlimited travel time of tertiary hospitals, the
accessibility value distribution of tertiary hospitals is in relative equilibrium.

The administrative areas with good hospital accessibility at all levels are mainly Donghu District and
Xihu District. In addition to first-level hospitals, the average attendance at second-level and third-level
hospitals in the two regions is also high. Donghu District and Xihu District can provide more balanced and
higher-level medical institutions for the residents of the districts and guarantee the fundamental rights and
interests of residents of the districts to use relevant medical facilities. This phenomenon is mainly due to a
large number of first-level hospitals in the two regions, the convenience of public transport systems, and the
excellent geographical location of the two districts. Because the supply of medical service facilities in the
central city is better than in other regions, the final distribution results still show the concentration trend in
the central city.

3.3 Evaluation of the adequacy degree of accessibility

<table>
<thead>
<tr>
<th>Inadequacy degree of accessibility of first-level hospitals</th>
<th>Inadequacy degree of accessibility of second-level hospitals</th>
<th>Inadequacy degree of accessibility of third-level hospitals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Six districts in Nanchang</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Donghu District</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honggutan District</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qingshanhu District</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qingyunpu District</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Overall, the proportion of communities with inadequate degrees of the three levels of medical facilities in the six districts of Nanchang was 54.9%, 5.9%, and 0%, respectively (Table 2). The results indicate that more than 90% of the population was able to visit second-level hospitals within the prescribed time threshold. The investigation results show that residents’ ability to visit the first-level hospital in our district is greatly restricted, and the allocation intensity of the first-level hospital needs to be improved. The public transport system is perfect in central urban areas, the distribution of medical resources is relatively adequate in all regions, and the ability of residents to seek medical treatment is better than in other regions.

As shown in the figure above (Figure 6), inadequate communities are mainly distributed in Hongguutan District. There are also many communities with inadequate access to primary hospitals in Donghu District, Qingshanhu District, and Qingyunpu District. Since primary hospitals are designed to meet the essential public health needs of residents in the surrounding areas, they are primary hospitals that provide prevention, treatment, health care, and rehabilitation services to the community. Therefore, in the subsequent allocation optimization of urban medical facilities, improvements should be made step by step, following the order of

<table>
<thead>
<tr>
<th>District</th>
<th>Proportion</th>
<th>First level</th>
<th>Second level</th>
<th>Third level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xihu District</td>
<td>31.7%</td>
<td>0.0%</td>
<td>0.0%</td>
<td></td>
</tr>
<tr>
<td>Xinjian District</td>
<td>64.1%</td>
<td>12.1%</td>
<td>0.0%</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6. Inadequacy communities of hospitals
areas where secondary hospitals are insufficient, areas where primary hospitals are inadequate, and areas
where both levels of hospitals are inadequate.

3.4 Evaluation of the deprivation degree of vulnerable groups

3.4.1. evaluation of public transport efficiency
Figure 7. (a) Distribution of relative accessibility of first-level hospitals; (b) Distribution of relative accessibility of second-level hospitals; (c) Distribution of relative accessibility of third-level hospitals.
The figure shows the distribution of relative hospital accessibility at all levels (Figure 7). A value of “positive -0 -negative” for the relative accessibility of community units means that the comprehensive accessibility of public transport services is “better than -- equal to -- worse than” taxi services, and the accessibility efficiency of public transport services is “high -- flat -- low.” In the middle of the six districts, there are large areas with low accessibility efficiency of public transport services of first-level hospitals, the edge of the flat, and sporadic distribution of high-value communities. Second-level hospitals’ overall public transport accessibility efficiency was flat, with low-value and high-value units evenly distributed in the middle. The accessibility efficiency of public transport services in third-level hospitals showed a downward trend from the centre to the centre. The phenomenon is mainly due to the sufficient medical resources and the vigorous allocation intensity of public transportation services in the central city, so the high-value units are distributed primarily in the central area, while the spatial imbalance of medical resource allocation makes the medical distance in suburban areas too long, the taxi travel cost increases, and the efficiency decreases, so the median-value units are mainly distributed in the outer regions.

The average accessibility of public transport and private cars at all levels of hospitals was 0.345 and 1.161, respectively. The overall accessibility degree of private cars was better than that of public transport. Specifically, the average accessibility of third-level, second-level, and first-level hospitals was 0.216, 0.156, and 0.661, respectively, compared with the travel time of private cars, which was 2.640, 0.150, and 0.693, respectively. Except for the fact that the average accessibility of second-level hospitals in the public transport mode is slightly higher than that of private cars, the average accessibility of third-level and first-level hospitals in the public transport mode is lower than that of private cars. In the first-level hospital, there is a large difference in the convenience of travel between the two methods, and private car travel is superior to public transport.

3.4.2. evaluation of community living quality
Table 3. Results of the Mann-Whitney U test for high and low accessibility communities

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Indicator(4)s</th>
<th>High-group median</th>
<th>Low-group median</th>
<th>Z</th>
<th>P</th>
<th>Moran’s I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Property fee (Yuan/m²/month)</td>
<td>0.649</td>
<td>1.498</td>
<td>-13.588</td>
<td>0.000**</td>
<td>0.321</td>
</tr>
<tr>
<td>Environment</td>
<td>Parking space</td>
<td>148.000</td>
<td>625.000</td>
<td>-12.198</td>
<td>0.000**</td>
<td>0.151</td>
</tr>
<tr>
<td>Community</td>
<td>Greening rate (%)</td>
<td>0.208</td>
<td>0.300</td>
<td>-15.009</td>
<td>0.000**</td>
<td>0.239</td>
</tr>
<tr>
<td></td>
<td>Construction age (year)</td>
<td>2000.000</td>
<td>2013.000</td>
<td>-20.270</td>
<td>0.000**</td>
<td>0.474</td>
</tr>
<tr>
<td></td>
<td>Plot ratio</td>
<td>2.001</td>
<td>2.011</td>
<td>-1.076</td>
<td>0.282</td>
<td>0.105</td>
</tr>
<tr>
<td>Economic level</td>
<td>House price (yuan)</td>
<td>11128.500</td>
<td>10402.500</td>
<td>-4.123</td>
<td>0.000**</td>
<td>0.273</td>
</tr>
<tr>
<td>Geographical</td>
<td>Distance to clinic (m)</td>
<td>282.500</td>
<td>492.500</td>
<td>-10.404</td>
<td>0.000**</td>
<td>0.234</td>
</tr>
<tr>
<td>Conditions</td>
<td>Distance from business district (m)</td>
<td>761.500</td>
<td>2042.000</td>
<td>-17.916</td>
<td>0.000**</td>
<td>0.888</td>
</tr>
<tr>
<td></td>
<td>Distance from kindergarten (m)</td>
<td>255.000</td>
<td>350.500</td>
<td>-8.721</td>
<td>0.000**</td>
<td>0.487</td>
</tr>
<tr>
<td></td>
<td>Distance to primary school (m)</td>
<td>310.500</td>
<td>846.500</td>
<td>-19.118</td>
<td>0.000**</td>
<td>0.550</td>
</tr>
<tr>
<td></td>
<td>Distance to middle school (m)</td>
<td>396.500</td>
<td>1003.500</td>
<td>-18.211</td>
<td>0.000**</td>
<td>0.574</td>
</tr>
<tr>
<td></td>
<td>Distance to park (m)</td>
<td>1081.500</td>
<td>2608.500</td>
<td>-17.198</td>
<td>0.000**</td>
<td>0.648</td>
</tr>
<tr>
<td></td>
<td>Distance from scenic spot (m)</td>
<td>2661.000</td>
<td>10713.500</td>
<td>-28.782</td>
<td>0.000**</td>
<td>0.941</td>
</tr>
<tr>
<td>Traffic conditions</td>
<td>Distance to subway station (m)</td>
<td>380.500</td>
<td>1193.500</td>
<td>-18.166</td>
<td>0.000**</td>
<td>0.936</td>
</tr>
<tr>
<td></td>
<td>Distance to public transport (m)</td>
<td>155.750</td>
<td>278.143</td>
<td>-13.820</td>
<td>0.000**</td>
<td>0.219</td>
</tr>
<tr>
<td></td>
<td>Accessibility to hospitals by using public transport</td>
<td>1.360</td>
<td>0.462</td>
<td>-30.385</td>
<td>0.000**</td>
<td>0.717</td>
</tr>
</tbody>
</table>

The paper takes the method of spatial cluster analysis to analyze the values of accessibility to medical
facilities (Table 3), all with P values less than 5% and Moran’s I index greater than 0. The results indicate that
the spatial distribution of communities with specific indicators is nonrandom, with communities characterized
by spatial clustering distribution and strong spatial autocorrelation. All the indicators use the Mann–Whitney
U method to test, and all 15 indicators were more fantastic than 0.1%, except for the floor area ratio, indicating
a significant difference in the average for each indicator between high- and low-accessibility communities.
High-accessibility communities have lower property management fees, fewer parking spaces, lower green
rates, longer completion times, and lower quality of life than low-accessibility communities but have better
locations, abundant amenities, and better access to health care.

Disadvantaged groups tend to consider community housing prices when choosing their place of
residence and distinguish different groups based on average community housing prices. Low-price
communities are concentrated in areas with low accessibility values, so relative low accessibility for vulnerable
groups is low. Communities in the old central city have space scarcity and resource intensity due to their high
density, outdated community facilities, saturated urban development, and ample facilities. At the same time,
with urban expansion, the communities’ construction in the edge areas is large, and the supporting
infrastructure often lags behind the central urban areas. Therefore, communities with poor overall living
quality in central city areas have higher housing prices and better community health accessibility than those
with better overall living quality on the urban fringes. In the current spatial distribution of medical resources,
vulnerable groups have a deprivation effect.

4. Discussion

There are three main factors affecting accessibility: the supply of facilities, the demand for facilities by the
population, and the cost of transportation between supply and demand points.

The collection of supply data occurred without regard to the different demands of specific patients in
various specialized hospitals. By considering the population demands of particular patients and the supply quantity of specialized hospitals to further analyze the spatial fairness of medical facilities, it is helpful to improve the specialization level of specialized hospitals and prevent the phenomenon of surplus resources in some units of analysis.

From the perspective of population demands, the paper selects the number of community households as the basic unit of analysis for measuring population demands. The unit size of noncentral urban areas is larger than the unit size of central urban areas, and the number of households is larger than the number of central urban areas, but the actual number of homeowners is smaller than the number of homeowners in central urban areas. If the paper takes the community as the basic unit, the existing population of noncentral urban areas may differ from the estimated population. As a result, an increasing number of studies are using regular polygonal meshes as units of analysis for evaluation studies (43) to avoid significant differences in unit size.

Regarding travel data, it only considers real-time travel data from 9:00 to 11:00 without comparing the distribution of accessibility of medical facilities over time and the different impacts of different travel times on the accessibility of medical facilities. Measuring the accessibility of medical facilities over time can reduce travel time and improve treatment efficiency for community residents.

There is no consideration of different groups on factors such as physical condition or health insurance. The time required to receive a diagnosis is directly related to the survival of the patient, especially in the case of a critical health condition (36); Medicare and age factors have a significant impact on health care facility selection (44,45), thus affecting spatial equity in health care settings.

5. Conclusion

In the accessibility measurement of potential models, the quantitative results of accessibility at different levels of hospitals were in complete contrast to the data distribution over the shortest time. The comprehensive
accessibility value of third-level hospitals is the highest, while that of first-level hospitals is the lowest. The phenomenon is due to the introduction of a time threshold that considers the impact of hospital levels on residents’ choices of medical facilities. Within the time threshold, residents’ travel times to third-level hospitals are more inclusive, and the standard of accessibility for third-level hospitals is high. For first-level hospitals, the ideal travel time limit is 20 minutes, which is more than 20 minutes. At the same time, people are more likely to increase the cost of going to a higher-level hospital, and first-level hospitals have fewer beds and people to serve. Therefore, it is necessary to increase the number of first-level hospitals, improve the equipment and facilities of existing first-level hospitals and improve the quality attractiveness of first-level hospitals.

Analyzing the accessibility equilibrium and adequacy degrees of medical facilities found that almost all first-level hospitals have inferior equilibrium and adequacy degrees on all streets. The third-level hospitals were generally better than second-level hospitals and first-level hospitals. At the same time, due to the difficulty and high cost of constructing new third-level hospitals, we should prioritize the construction of medical services in areas where secondary and primary hospitals are insufficient. It is crucial to ensure that all community residents have access to essential medical services, improve the accessibility of medical care to the general public and prevent the need for medical care from being concentrated at a higher level, leading to a waste of medical resources. Attention must be paid to areas with low levels of equalization of medical facilities, and the minimum medical demands of community residents should be met.

The results, based on the deprivation degree of accessibility of medical facilities for vulnerable groups, showed that, due to urban expansion and economic development, vulnerable groups are at a disadvantage in terms of access to health care resources, which are more readily available to those with better economic conditions. Central-city populations are more likely to access medical facilities than suburban populations. In addition, owing to the high dependence of low-income people on public transport, marginalized urban
communities have worse public transport than the central city, resulting in a dual deprivation of resources and location. In response to this phenomenon, priority should be placed on developing public transport network routes to provide efficient public transport services to the population and reduce the deprivation phenomenon among vulnerable groups.

The study of the spatial fairness of medical facilities is instructive for the practical application of the spatial layout of urban public service facilities. In evaluating space fairness in medical institutions, the coordination mechanism should be gradually improved according to the degree of unfairness in the space of medical institutions, from heavy to light. Then, the implementation sequence according to the matching degree of supply and demand in different states of high demand-zero supply, high demand-low supply, low demand-zero supply, and low demand-low supply were analyzed. Urban planning proposals were succinctly and accurately communicated in response to the inequity of medical facility space, ultimately promoting equity in local medical areas, increasing the balance and adequacy of accessibility, and reducing poverty among vulnerable groups. This paper systematically evaluates the spatial fairness of medical systems in large cities and optimizes them accordingly.

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Declarations

Ethics approval and consent to participate

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Authors’ contributions

1 Xiong and 2 Chen proposed the research idea and designed the research scheme. 1 Xiong collected, cleaned,
and analyzed the data, drafted the manuscript, and revised the final version.

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Availability of data and materials

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Reference


