Healthcare Facility Accessibility for the Elderly Population in Lanzhou: A Postprint Study

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Abstract

Against the backdrop of population aging and the Healthy China strategy, the rational allocation of urban medical facilities is of great significance for improving the health status of the elderly population and enhancing public welfare. Based on multi-source data including the seventh national population census, Points of Interest (POI) of medical facilities, and route planning, this study employs methods such as Average Nearest Neighbor, Improved Two-Step Floating Catchment Area, and Bivariate Local Spatial Autocorrelation to investigate the healthcare accessibility for the elderly population in Lanzhou City in 2020 and its supply-demand matching degree. The results indicate that: (1) The spatial distribution of the elderly population in Lanzhou City is unbalanced, with both elderly population density and aging rate exhibiting a "dual-core" structure. (2) The three types of medical facilities display distinct spatial agglomeration characteristics. Municipal-level medical facilities assume a "single-center" structural pattern, district-level medical facilities demonstrate a "one primary, multiple secondary" distribution pattern, while street-level medical facilities exhibit a "multi-center" distribution configuration. (3) Significant disparities exist in the spatial distribution of accessibility across different levels of medical facilities. Specifically, the accessibility distribution of municipal-level and district-level medical facilities is unbalanced; street-level medical facilities have the most extensive distribution of high-accessibility value areas, yet individual streets still contain "blind spots" with low accessibility. (4) Due to the uneven spatial distribution of medical facilities, varying degrees of spatial mismatch between the elderly population and medical facilities persist at municipal, district, and street scales. The findings can provide a basis for rational allocation of urban medical facilities and healthy city construction.

Full Text

Accessibility of Medical Facilities in Lanzhou City from the Perspective of the Elderly Population

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Abstract

In the context of population aging and the "Healthy China"strategy, the rational allocation of urban medical facilities is crucial for enhancing the health and well-being of elderly populations. Based on multi-source data including the Seventh National Population Census, points of interest (POI) for medical facilities, and path planning data, this study employs methodologies such as average nearest neighbor analysis, an improved two-step floating catchment area method, and bivariate local spatial autocorrelation to investigate the accessibility of medical services for the elderly and the alignment of supply and demand in Lanzhou City in 2020. The results reveal four key findings. (1) The spatial distribution of the elderly population in Lanzhou is uneven, with both elderly population density and aging rates exhibiting a "dual-core" structure. (2) Different levels of medical facilities display distinct spatial clustering characteristics: city-level facilities show a "single-center" structure, district-level facilities follow a "one main, multiple secondary" distribution pattern, and street-level facilities adopt a "multi-center" distribution pattern. (3) Accessibility varies significantly across different levels of medical facilities. City-level and district-level facilities show considerable spatial inequality in accessibility, while street-level facilities have the broadest distribution of high-accessibility areas, though some streets still suffer from low-accessibility "blind spots." (4) Due to the uneven spatial distribution of medical facilities, mismatches between the elderly population and medical services exist to varying degrees at the city, district, and street levels. These findings provide valuable insights for the rational allocation of urban medical facilities and the development of healthy cities.

Keywords: elderly population; medical facilities; accessibility; matching degree; Lanzhou City

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1. Study Area and Methods

1.1 Study Area Overview Lanzhou, the capital city of Gansu Province, has jurisdiction over five districts (Chengguan, Qilihe, Anning, Xigu, and Honggu) and three counties (Yongdeng, Gaolan, and Yuzhong). The city is characterized by its valley topography, with mountains flanking the north and south and the Yellow River flowing eastward through the urban core. The main urban area, serving as the primary concentration zone for economic activity and population,

comprises Chengguan, Qilihe, Anning, and Xigu districts. In 2020, the permanent resident population of the main urban area was 2.9059 million, including 471,300 elderly individuals aged 65 and above, accounting for 16.22% of the total population and representing 65.27% of Lanzhou' s elderly population. The aging rate in the main urban area has continued to rise, increasing by 4.05 percentage points compared to 2010. As the elderly population continues to grow and the aging rate deepens, demand for medical facilities has increased substantially, highlighting increasingly prominent contradictions between supply and demand structures. Therefore, this study focuses on the main urban area of Lanzhou, encompassing 53 research units across 51 streets and 2 high-tech development zones.

1.2 Data Sources The research data include elderly population data, administrative division data, medical facility data, and path planning data for Lanzhou' s main urban area. (1) **Elderly population data**: Obtained from the Seventh National Population Census, including total population and the number of elderly individuals aged 65 and above for each street. (2) **Administrative division data**: Derived from basic geographic information spatial data obtained from Google remote sensing imagery. In accessibility analysis, considering that the elderly have limited activity ranges and are relatively immobile, they are treated as a static population, with the geometric centroid of street polygons used to represent the spatial distribution center of the elderly population. (3) **Medical facility data**: Collected through Python programming using the Amap API to obtain point data for medical facilities in Lanzhou' s main urban area in 2020, including name, address, type, and latitude/longitude information. After excluding facilities such as maternity hospitals, children' s hospitals, and cosmetic surgery centers, a total of 1,260 medical facility points were selected (Table 1). Considering that service capacity varies by facility level, medical facilities were classified into city-level, district-level, and street-level categories based on the "Guiding Principles for Medical Institution Planning (2021-2025)" and relevant research. Facility service capacity was measured by the number of beds, with city-level bed counts collected from hospital websites and district- and street-level bed counts set according to the Gansu Provincial Health Statistics Bulletin and other references. (4) **Path planning data**: Using the Amap API multi-route planning interface (https://lbs.amap.com/product/path), real-time travel times between supply and demand points were obtained. Considering that elderly travel primarily occurs during non-commuting hours, travel times were calculated for off-peak periods.

1.3 Methods 1.3.1 Aging Rate

The aging rate refers to the percentage of the population aged 65 and above relative to the total population. When this ratio exceeds 7%, the region is considered an aging society; when it reaches 14%, the region has entered the later stage of aging.

1.3.2 Average Nearest Neighbor Analysis

Average nearest neighbor analysis assesses the degree of spatial clustering of point features, providing an overall measure of spatial proximity.

1.3.3 Kernel Density Analysis

Kernel density analysis objectively reflects the dispersion or aggregation state of point features in geographic space and is widely used in medical facility distribution research.

1.3.4 Improved Two-Step Floating Catchment Area Method

The two-step floating catchment area (2SFCA) method provides a comprehensive and straightforward approach to calculating medical facility accessibility from both supply and demand perspectives. To more accurately measure accessibility, this study improves the method by introducing a distance decay function and establishing multiple search radii. The specific steps are as follows:

Step 1: For each medical facility (v), using travel time threshold (Tr) as the search radius, search all streets (u) within the threshold range to calculate the supply-demand ratio (R_v) for each facility:

$$R_v = \frac{S_v}{\sum_u P_u \times G(T_{uv})}$$

where: - S_v is the service capacity of medical facility v, measured by bed count - $G(T_{uv})$ is a Gaussian function considering time decay, which declines more gradually near the threshold 起点 compared to power, exponential, or kernel density functions, better reflecting actual medical travel behavior - T_{uv} is the travel time between facility v and street u - P_u is the total elderly population in street u within the threshold range (persons)

Step 2: For each street (u), identify all medical facilities (v) within the travel time threshold (Tr), multiply their supply-demand ratios (R_v) by the Gaussian decay function, and sum these weighted ratios to obtain the medical accessibility index (A_u) for street u:

$$A_u = \sum_v R_v \times G(T_{uv})$$

Regarding service thresholds, research indicates that although the proportion of private car and emergency vehicle use for medical visits is increasing annually, walking and public transport remain the primary modes for the elderly. Therefore, this study considers "walking" and "public transport" as the two main travel modes. Based on Lanzhou' s "15-minute living circle" planning and previous research, a 15-minute walking threshold was set for street-level facilities. Considering that the golden hour for medical emergencies is 60 minutes, a 60-minute public transport threshold was set for city-level facilities. A 30-minute public transport threshold was set for district-level facilities, referencing studies that identify this as a reasonable medical travel time.

1.3.5 Bivariate Local Spatial Autocorrelation

Bivariate local spatial autocorrelation reflects the spatial association patterns between the elderly population and medical facilities, which can be categorized into four cluster types based on spatial correlation results: high-high, low-low, high-low, and low-high.

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2. Results

2.1 Spatial Distribution Characteristics of the Elderly Population Using three indicators—elderly population size, elderly population density, and aging rate—this study analyzes the spatial distribution patterns of the elderly population in Lanzhou' s main urban area. The Jenks natural breaks method was applied to classify each indicator into five levels, with areas having $ $13,788 elderly persons designated as high-population zones and areas with density $ $8,131.31 persons/km^{2}$ designated as high-density zones (Figure 2).

The results show that high-population zones include 11 streets, primarily distributed in Yanbei and Caochang streets in Chengguan, Xihu and Dunhuang roads in Qilihe, Xilu street in Anning, and Fuli road in Xigu. Yanbei street has the largest elderly population (20,004 persons), while Fulongping street has the fewest (only 1,234 persons)—a 16-fold difference. High-density zones comprise 12 streets, mainly in Jiuquan road, Gaolan road, Railway West Village, Railway East Village in Chengguan, and Fuli road in Xigu. Railway East Village has the highest elderly population density (28,787 persons/km^2), while Shajingyi street has the lowest (1,135 persons/km^2), making the former 25 times denser than the latter.

A total of 28 streets have aging rates exceeding 14%, primarily in Chengguan, Qilihe, and Xigu districts, with 20% of streets in the later aging stage. Xianfeng road in Xigu has the highest aging rate at 26.36%. Overall, the spatial distribution of the elderly population in Lanzhou' s main urban area shows significant variation, with both elderly population density and aging rates exhibiting a "dual-core" structure centered on Zhangye road in Chengguan and Fuli road in Xigu. This pattern relates to historical development inertia, urban functional positioning, and industrial development. As the political, commercial, and scientific-educational center, Chengguan has a long development history and relatively complete supporting facilities, making it a primary gathering area for the elderly. Xigu, known as the "cradle of China' s petrochemical industry" during the planned economy era, was a key national industrial base. The aging of employees from large enterprises like "Lanlian" and "Lanhua" has resulted in high elderly population numbers, density, and aging rates in Xigu.

2.2 Spatial Clustering Characteristics of Medical Facilities Average nearest neighbor analysis reveals that all three levels of medical facilities in Lanzhou show significant spatial clustering, though clustering intensity varies.

The average nearest neighbor indices are all less than 1 and pass significance tests, with clustering intensity ranking as: street-level (0.42) > district-level (0.53) > city-level (0.65). This occurs because street-level facilities have smaller footprints, flexible spatial layouts, and strong market-driven "location preferences" and "population preferences," leading to stronger clustering. City- and district-level facilities, with larger footprints, broader service coverage, and greater social impact, are more deeply guided and regulated by government planning, resulting in relatively lower clustering intensity.

Kernel density analysis further characterizes the spatial clustering patterns (Figure 3). City-level facilities show a "single-center" structure, concentrated in Weiyuan road, Jiayuguan road, and Tuanjie New Village in Chengguan, with scattered distribution in other streets. District-level facilities display a "one main, multiple secondary" pattern, with a primary center forming a contiguous cluster around Zhangye road, Jiuquan road, and Gaolan road in Chengguan, and secondary centers appearing as dispersed points in Xiyuan, Gongjiawan, Jianlan road, Dunhuang road, Xigu city, and Fuli road streets. Street-level facilities exhibit a "multi-center" pattern, which can be roughly divided into clusters centered on Zhangye road/Jiuquan road, Xiyuan/Gongjiawan/Jianlan road/Dunhuang road, and Xigu city/Fuli road.

2.3 Analysis of Elderly Medical Accessibility 2.3.1 Differences in Elderly Medical Commute Times

Analysis of average shortest medical commute times reveals significant differences across facility levels: city-level (30.48 min), district-level (19.91 min), and street-level (6.33 min). The valley topography creates a banded cluster structure, resulting in persistent transportation challenges of "east-west congestion and north-south blockage." City- and district-level facilities are concentrated in Chengguan and Qilihe districts, making cross-district medical visits increasingly common and significantly increasing commute times for elderly residents in peripheral areas of Anning and Xigu districts. For example, elderly residents in Shajingyi street (westernmost Anning) traveling to Lanzhou University First Hospital (a national key clinical department for geriatrics in eastern Chengguan) face 84.92-minute commutes—4.3 times the average. Although street-level clinics and pharmacies offer convenience for daily medical needs, some streets still have long commute times. Jingyuan road street averages 27.37 minutes, far exceeding the 15-minute target for basic medical services in Lanzhou' s planning documents. The proportion of elderly population covered within 15 minutes by street-level facilities is 98.07%, while city-level facilities cover only 6.33% within 15 minutes, indicating that more grassroots facilities have lower coverage proportions and require strengthened coverage.

2.3.2 Analysis of Elderly Medical Accessibility

The improved 2SFCA method was applied to calculate accessibility indices for each street, which were then standardized and classified into five levels using Jenks natural breaks: high, relatively high, medium, relatively low, and low (Fig-

ure 4). Results show significant spatial variation in accessibility across facility levels.

City-level facilities have an average accessibility index of 0.29, with only 29.81% of streets above this average. High-accessibility streets (9.62%) concentrate in Zhangye road, Jiuquan road, and Gaolan road in Chengguan and Jianlan road and Xihu in Qilihe, while 42.86% of Anning streets and 62.5% of Xigu streets are low-accessibility zones, indicating uneven distribution.

District-level facilities show high-accessibility in 4 streets (Linxia road, Zhangye road, High-tech Zone in Chengguan, and Jianlan road in Qilihe). Relatively high-accessibility streets surround these areas, including Donggang West road, Xiuchuan, and Gongjiawan, but remain concentrated in Chengguan and Qilihe. Medium-accessibility streets encircle high-accessibility areas, while low-accessibility streets are located in peripheral zones. Although high-accessibility streets are more numerous than for city-level facilities, distribution remains uneven.

Street-level facilities have the broadest high-accessibility distribution, with high and relatively high-accessibility streets comprising 20% of the total, distributed across all four districts. However, some streets still have low-accessibility "blind spots." For example, Donggang West road in old Chengguan has an aging rate of 18.77% but an accessibility index of only 0.31, indicating that street-level facility construction does not fully align with elderly population distribution. Overall, accessibility across all levels shows a gradual decrease from centers (Zhangye road, Fuli road) to peripheries and edge areas, because central zones have denser medical facilities, road networks, and more developed public transport services.

2.4 Matching Degree Analysis Between Elderly Population and Medical Accessibility Gini coefficients were calculated for accessibility indices at each facility level, and Lorenz curves were plotted to analyze matching degrees (Figure 5). According to UNDP standards, Gini coefficients of 0.30-0.39 indicate relative rationality, while 0.40-0.59 indicate large disparities. City-level and district-level facilities have Gini coefficients of 0.45 and 0.43, respectively, indicating large disparities. Street-level facilities have a Gini coefficient of 0.38, falling within the relative rationality range. This shows that city- and district-level facilities fail to serve elderly populations in most streets, with poor matching between elderly distribution and accessibility.

Bivariate local spatial autocorrelation analysis between accessibility indices and elderly population identifies four cluster types (Figure 6). **High-high clusters** (high accessibility and high elderly population) include Zhangye road, Jiuquan road, and Gaolan road in old Chengguan, featuring long history, convenient transport, large elderly populations, and comprehensive medical facilities with high matching. **Low-low clusters** (low accessibility and low elderly population) include Shajingyi, Anningbao, and Qingbaishi streets in peripheral areas, showing a "dual-low"state of low supply and demand. **High-low clusters** (high

accessibility, low elderly population) include Kongjiaya, Xiuchuan, and Donggang streets in peripheral areas with excess facility capacity relative to elderly population. **Low-high clusters** (low accessibility, high elderly population) include Baiyin road, Wuquan road, and Railway Station streets surrounding high-high clusters, where large elderly populations face severe medical supply shortages. Differentiated improvement strategies are needed for each matching type.

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3. Discussion

Facing increasing pressure on medical services from deepening population aging, meeting elderly medical needs and improving accessibility is theoretically and practically significant for enhancing elderly well-being and implementing the Healthy China strategy. This study analyzes urban medical facility accessibility and supply-demand matching from the elderly perspective, revealing significant spatial disparities that decrease from center to periphery, consistent with findings in eastern plain cities like Shanghai and Nanjing. However, Lanzhou' s main urban area is located in the Yellow River valley between north-south mountains, extending east-west along the river in a banded distribution, forming a "multi-center, cluster" urban structure. The elongated east-west topography perpetuates transportation challenges, resulting in long commute times and low accessibility for peripheral elderly residents, particularly for city- and district-level care.

This research complements and extends previous medical accessibility studies by focusing on different facility levels from the elderly perspective and incorporating path planning data to overcome traditional static road network constraints, enabling more scientific and precise accessibility measurement. However, limitations remain: due to data availability, only bed counts were used to measure service capacity, while future research should integrate facility scale and medical staff numbers for comprehensive service equity assessment. Additionally, elderly medical decision-making is complex, influenced by disease type, hospital preference, and other factors. Future studies should leverage micro-level spatiotemporal behavioral big data to explore elderly medical preferences and behaviors in greater depth.

Based on the findings, strategies for Lanzhou' s main urban area include: (1) All facility levels show "core-periphery" distribution patterns, with Chengguan and Qilihe as concentration areas. Future planning should prioritize Anning and Xigu districts. (2) Significant accessibility disparities exist across levels, requiring balanced city- and district-level facility allocation and expanded street-level coverage. (3) Differentiated improvements should target specific matching types: increase supply in streets with large elderly populations but low accessibility; optimize existing facility layouts and improve transport networks in streets with small elderly populations and low accessibility.

4. Conclusions

This study draws four main conclusions. (1) The elderly population in Lanzhou is unevenly distributed, with high-population zones across Chengguan, Qilihe, Anning, and Xigu districts. Both elderly population density and aging rates exhibit a "dual-core" structure centered on Zhangye road in Chengguan and Fuli road in Xigu. (2) All three facility levels show clustered distributions with distinct spatial characteristics: city-level facilities form a "single-center" structure, district-level facilities follow a "one main, multiple secondary" pattern, and street-level facilities display a "multi-center" pattern. (3) Accessibility varies significantly across facility levels. High-accessibility areas for city-level facilities concentrate in Chengguan and Qilihe; district-level facilities extend somewhat into Anning but remain Chengguan-Qilihe centered; street-level facilities have the broadest high-accessibility distribution, though some "blind spots" persist. (4) Uneven medical facility distribution creates spatial mismatches between the elderly population and medical services at all scales, with mismatched areas concentrated in urban core peripheries and outer districts.

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Note: Figure translations are in progress. See original paper for figures.