THE SPATIAL ACCESSIBILITY AND EQUITY OF PRIMARY HEALTH CARE FACILITIES IN NORTHWEST CHINA FROM THE PERSPECTIVE OF LIFE CIRCLE: A CASE STUDY ON KARAMAY (1139)

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Abstract. The life circle is a concept of the walkability of people in urban space to get the daily public services. Since Shanghai first proposed the 15-minute community life circle, Chinese government has promoted the convenient and walkable community life circle in major cities. Providing primary health care (PHC) is an essential way to enhance physical and mental well-being and social welfare of people. The spatial accessibility of PHC facilities is closely related to residents' health and social equity. In most cities in China, the Community Health Center (CHC) is the main form for delivering primary health care to urban residents. As Small and medium-sized cities in the northwest region are limited by their economic development level and natural geographical environment, evaluating the spatial accessibility and equity of health facilities there is of great significance for achieving the equalization of PHC services across regions. In this research, the spatial accessibility and equity of Community Health Centers (CHCs) in the central urban area of Karamay City are evaluated by improved 2SFCA method and Gini coefficient under the life circle concept. The results show that: 1) The areas with high and low accessibility of PHC facilities were interspersed in space, without exhibiting a concentric pattern. 2) The global Moran's I index was 0.77, indicating that the accessibility of PHC facilities had a significant positive clustering distribution. 3) The Gini coefficient of PHC facility accessibility reached 0.72, which means the spatial inequality was significant.

Keywords: small and medium-sized cities, public facilities, PHC, walkability, 15-minute community.

1. Introduction

The life circle is a concept of the walkability of people in urban space to get the daily public services. In the basic life-circle unit, urban and rural residents are able to enjoy the various services within a suitable daily walking range in their whole life cycle of work and living. The life circle also integrates multiple functions of "suitable for business, living, leisure, health, and learning", leading a future-oriented, healthy and low-carbon lifestyle (Spatial planning guidance：community life unit, 2021).Providing primary health care (PHC) is an essential way to enhance the physical and mental well-being and

social welfare of the people, as well as the most inclusive, equitable and cost-effective approach to achieve universal health coverage (UHC) (WHO, 2018. https://www.uhc2030.org/). In China, PHC is an integral part of the national health system. It is not only the entry point for individuals, families and communities to access the health system, but also the most convenient and continuous channel for obtaining health services in daily life (Ministry of Health, 2006). Urban health care facilities are a general term established to engage in disease diagnosis, treatment, rehabilitation and health care (LIU Zhaowen, 2006). Hospitals and primary health care institutions are their main forms. The hospital primarily offer medical treatment to the city dwellers, whereas the Community Health Center (CHC) focuses on delivering primary health care to them. By arranging CHCs reasonably, residents can access PHC services conveniently and equitably. The spatial accessibility of CHCs is an important indicator to explain urban health service provision, and vital essential for attending universal health coverage and health fairness.

The concept of accessibility was proposed by Hansen (1959), human geographers further extended the concept of accessibility to the spatial dimension, describing the ease of moving from one place to another (Guy C M, 1983). Nowadays, spatial accessibility is widely used in the research of land use, transportation planning, facility location and other fields (Zhan Dongsheng, 2019). It also becomes an important basis for evaluating the spatial layout of public facilities such as health care facilities, urban parks and green spaces, educational facilities and so on (Coulter P B, 2008).

In all kinds of public facilities, the study on spatial accessibility of health care facilities is one of the most extensive and in-depth researches. In recent years, the research on spatial accessibility of health care facilities mainly shows the following trends: 1) Analyzing the spatial accessibility under different transportation scenarios by using the hierarchical features of health care facilities (GUO Chenchen et al, 2022); 2) Applying improved analytical models and techniques to examine health care facilities (Talen, 1998; Luo et al, 2003; Boone et al, 2009); 3) Addressing the disparities in health care accessibility among different groups (ZENG Wen et al, 2017; TAO Yinhua et al, 2018), and shifting from a spatial equity to a spatial justice perspective (TAO Zhuolin et al, 2023); 4) Focusing on the supply-demand relationship and satisfaction perspective (CAO Yang, 2018); 5) Exploring the factors that affect spatial accessibility and the relationship between health care behavior (ZENG wen, 2017; CHEN Shuting, 2022).

These studies also have strong regional characteristics. Large cities are usually the areas with the most abundant medical resources (ZHANG Zhonghao et al, 2020). Therefore, there are many studies on the spatial accessibility of health care facilities in large cities (ZHONG Shaoying et al, 2016; SHEN yue et al, 2021). In China, most of the existing studies focus on the cities such as Shanghai and Beijing, as well as some provincial

capitals in the western region such as Xi'an and Lanzhou (ZHANG Qi et al, 2016).However, there is still a lack of research on small and medium-sized cities, especially those in the Northwest China. Although the health condition of residents in China has improved significantly with the development of economy, there is still a large gap in health care services between small and medium-sized cities in the northwest region and large cities, due to the influence of economic development level and geographical environment (14th Five-Year Plan for Public Services, 2021).

Based on the facts and relative literature review, this study adopts the commonly used 2SFCA method under the walking scenario, and aims to examine the spatial accessibility and equity of PHC facilities in a small and medium-sized city in northwest China. The findings of this study may offer some new insights for the research in this field.

2. Methodology

2.1. Research Area

The region of Northwest China is commonly known as the "Northwest Five Provinces" in China's administrative divisions, which consists of Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang. There are 51 prefecture-level cities in this region, of which 40 are small and medium-sized cities. It means about 78% of cities in this region have a permanent urban population of less than 1 million people (Statistical Year Book, 2022). Almost all prefecture-level cities except the provincial capitals fall into the category of small and medium-sized cities. Karamay, the study case of this research is located in the northern part of Xinjiang, with a permanent population of 490,000 people (Seventh National Population Census, 2020).

Central urban areas are key zones for urban development. This study examines the spatial accessibility of primary health care facilities in the central urban area of Karamay City, with the objective of investigating the spatial variation and inequity of primary health care provision in small and medium-sized cities. The specific scope of this study includes five sub-districts which are Tianshanlu Sub-district, Yinhelu Sub-district, Kunlunlu Sub-district, Yingbin Sub-district and Guhai Sub-district, containing 67 community in total.

Previous studies on spatial accessibility within cities often use sub-districts or neighborhoods as the smallest analysis units (ZHANG Zhonghao et al, 2020), but this method fails to capture the accessibility differences among different residential compounds within the same unit (Zhan Dongsheng, 2019). To better reflect the accessibility situation of specific residents, this study collects data at the residential-compound level and uses residential compounds as the smallest analysis units and neighborhoods as the basic analysis units.

2.2. Data Collection

This study relies on the following data and information sources: We obtained the list and floor areas of PHC facilities in Karamay's central urban area from the Health Commission of Karamay. We collected the spatial coordinates of PHC facilities and residential compound entrances and exits from Baidu Maps. The urban road network data came from OpenStreetMap (www.openstreetmap.org), an open source map data website. The seventh national census provided the permanent population data by age group of each community, with data accuracy reaching the residential compound level. Other socio-economic statistical data came from the China Economic and Social Big Data Research Platform (https://data.cnki.net), which provides the Karamay City Urban Statistical Yearbook (Figure 1).

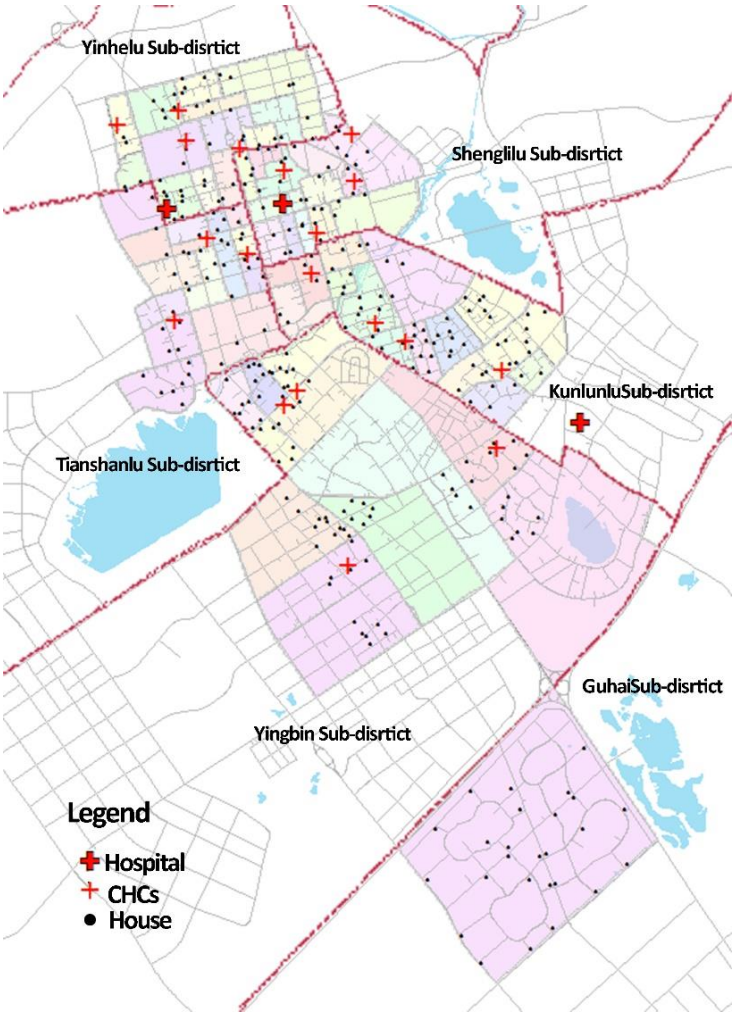

Figure 1. The central urban area of Karamay

2.3. Methods

This study consists of three main parts: (1) Assessing the spatial accessibility of PHC facilities in the central urban zone of Karamay; (2) Examining the spatial variation of accessibility of PHC facilities; (3) Evaluating the inequity of facility distribution according to the outcomes.

1) Gaussian 2SFCA analysis

The traditional two-step floating catchment area (2SFCA) method measures the accessibility of health care facilities by searching twice from the supply and demand locations within a certain search range (Luo et al, 2003). The formula is as follows:

$$A_i^F = \sum_{j \in \{d_{ij} \le d_0\}} R_j = \sum_{j \in \{d_{ij} \le d_0\}} \left(\frac{S_j}{\sum_{k \in \{d_{kj} \le d_0\}} D_k} \right)$$

In this formula: **i** represents the demand point; **j** represents the supply point; $\mathbf{A^F_i}$ represents the accessibility of demand point i calculated by 2SFCA; $\mathbf{d_{ij}}$ is the distance between demand point **i** and supply point **j**; $\mathbf{R_j}$ is the ratio of the facility size of supply point **j** to the population served within the search radius ($\mathbf{d_0}$); $\mathbf{S_j}$ represents the supply size of supply point **j**; $\mathbf{D_k}$ represents the demand size of demand point **k**.

a) Using the supply point S as the center, search for all the demand points k within the service threshold d_0 (the maximum walking distance: 1.5 kilometers) of S, and calculate the supply-demand ratio Gj of the supply quantity Sj at point j and the demand quantity D_k of all demand points;

b) Calculating the medical service accessibility A of demand point i, search for all supply points j within the threshold distance d_0 centered on i, and add up the supply-demand ratios of all j points found.

The improved 2SFCA method incorporates a Gaussian distance decay function to reflect the degree of decline in residents' health-seeking behavior as distance increases. The Gaussian 2SFCA (Ga2SFCA) was proposed by Dai (2010, 2011) and the formula is as follows:

$$A_i = \sum_{j=1}^{n} \frac{S_j f(d_{ij})}{\sum_{k=1}^{m} D_k f(d_{kj})}$$

In the formula: A_i is the accessibility score of demand point i, which means the average facility resources accessible by each demander at demand point i; $f(d_{ij})$ is the Gaussian distance decay function.

The formula of Gaussian distance decay function is as follows:

$$f(d_{ij}) = \frac{e^{-1/2\times\left(d_{ij}/d_0\right)^2} - e^{-1/2}}{1 - e^{-1/2}},\ d_{ij} \leqslant d_0$$

2) Spatial autocorrelation analysis

This study uses the global spatial autocorrelation analysis to reveal the overall spatial variation of accessibility, and then applies the local spatial autocorrelation analysis to identify the high-value and low-value clusters of accessibility. This approach can intuitively reflect the spatial imbalance of public health service resources.

3) Lorenz curve and Gini coefficient

The Lorenz curve is a graphical representation of the distribution of spatial accessibility of PHC facilities in a population. The Gini coefficient is a measure of inequality of a distribution, a number between 0 and 1, where 0 represents perfect equality and 1 represents perfect inequality. The Lorenz curve and Gini coefficient can be used to evaluate spatial equity of health care facilities by measuring the distribution of accessibility across different regions or neighborhoods.

3. Results

3.1. The spatial distribution of PHC accessibility

This study measured the spatial accessibility of PHC facilities using an improved 2SFCA method. Based on the results, the accessibility of PHC facilities was classified into five levels: excellent (0.22-0.30), good (0.16-0.31), moderate (0.12-0.15), poor (0.06-0.11) and very poor (0.00-0.05). The accessibility values correspond to the per capita facility floor area adjusted by the distance decay function. The results showed that the spatial distribution of PHC facility accessibility did not exhibit a clear concentric pattern, and areas with high and low accessibility were interspersed in space (Figure 2).

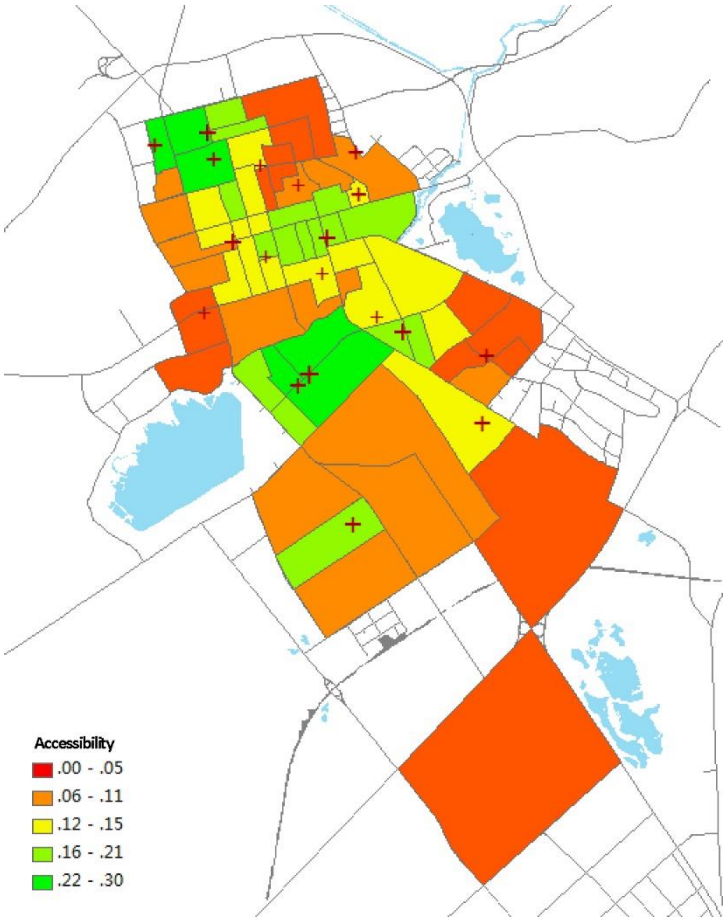

Figure 2. The spatial pattern of accessibility of PHC facilities in Karamay

The accessibility of PHC facilities varies across different areas. The areas with better accessibility are mainly located in some parts of Yinhelu Sub-district, Shenglilu Sub-district, and Yingbin Sub-district, where CHCs are not only concentrated but also have larger scales and stronger supply capacities. These areas are the most convenient for obtaining PHC services. The areas with moderate accessibility are mainly located in some parts of Tianshanlu Sub-district and Kunlunlu Sub-district, where CHCs are fewer and have lower scales and supply capacities. The areas with poor accessibility are more numerous and spatially dispersed, including some parts of Yinhelu Sub-district, Tianshanlu Sub-district, Kunlunlu Sub-district, Yingbin Sub-district, and Guhai Sub-district t. These areas currently lack the coverage of CHCs and are the most deficient in PHC resources.

3.2. The spatial agglomeration of PHC accessibility

According to the spatial autocorrelation analysis of accessibility (Figure 3), the global Moran's I index was 0.77, indicating that the accessibility of PHC facilities had a

significant positive clustering distribution. The local Moran's I index analysis further revealed the hot and cold spots of accessibility. The "High-High" clusters of accessibility of primary health care facilities were mainly distributed in 17 community committees within Yinhelu Sub-district, Yingbin Sub-district, Shenglilu Sub-district and Kunlunlu Sub-district. The "Low-Low" clusters of accessibility were mainly distributed in 12 community committees within Tianshanlu Sub-district, Shenglilu Sub-district, Yingbinlu Sub-district, Kunlunlu Sub-district and Guhai Sub-district. The "Low-Low" clusters of accessibility were more common, indicating a serious lack of PHC resources in the region.

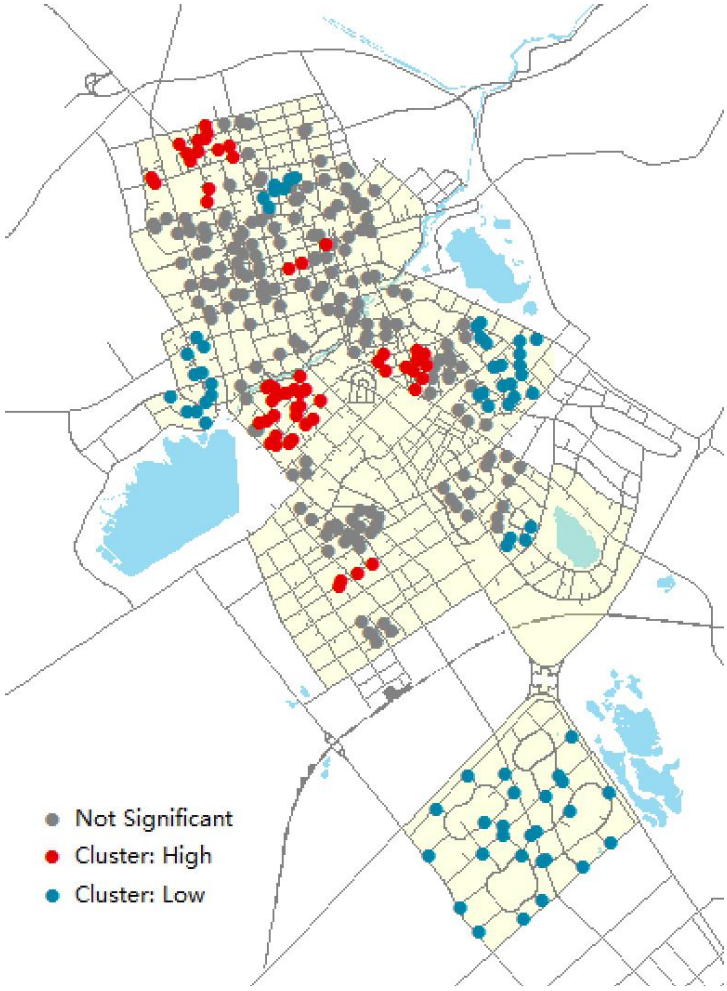

Figure 3. The spatial agglomeration characteristics of accessibility of PHC facilities in Karamay

3.3. The spatial inequality of PHC accessibility

The Gini coefficient of PHC facility accessibility reached 0.72, and spatial inequality was significant. From the perspective of the internal situation of each sub-district, Tianshanlu Sub-district, Shenglilu Sub-district and Kunlunlu Sub-district have low internal Gini coefficients and relatively balanced PHC accessibility indicators, indicating that the PHC

resource distribution in the inner city is fairer; Yinhelu Sub-district and Yingbin Sub-district have high internal Gini coefficients and significant differences in PHC accessibility indicators, indicating that the PHC resource distribution in the new urban area is uneven and prone to unfairness. Since the internal PHC accessibility of Guohai Street is 0, the result of PHC facility analysis is very fair, but very poor.

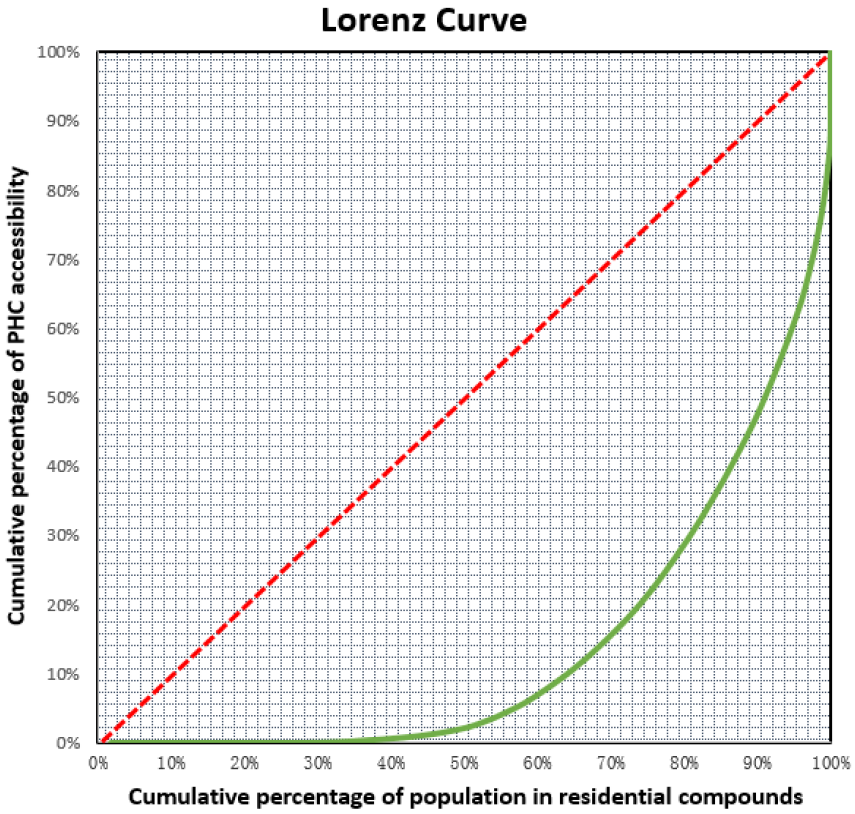

Figure 4. The Lorenz curve of PHC facility accessibility

4. Discussion

4.1. Conclusion

This research uses the central urban area of Karamay City as a case study, and applies an improved 2SFCA method to assess the spatial accessibility of PHC facilities and further examine the equity of facility distribution. The results show that: 1) The spatial distribution of PHC facility accessibility did not exhibit a concentric pattern. The areas with high and low accessibility were interspersed in space, indicating the spatial accessibility level is strongly associated with the clustering degree, scale and size of facilities; 2) The global Moran's I index was 0.77, indicating that the accessibility of PHC facilities had a significant positive clustering distribution. The "High-High" clusters were less than the "Low-Low" clusters indicating a serious lack of PHC resources in the region;

3) The Gini coefficient of PHC facility accessibility reached 0.72, indicating the spatial inequality was significant. The PHC resource distribution in the inner city is fairer than the PHC resource distribution in the new urban area.

4.2. Prospect

Universal health coverage depends on strong primary health care (PHC). The COVID-19 pandemic highlighted the vital role of PHC as the "frontline" of the health system, enabling cities to respond to public health emergencies and deliver essential public health services. PHC facilities offer basic medical and preventive care that can improve health outcomes and reduce health disparities. To ensure that everyone can access PHC services easily and fairly, we need to examine how health facilities are distributed and reached across different groups, modes of transport, and time periods. We also need to focus more on small and medium-sized cities in future research, and investigate their challenges and opportunities for enhancing health accessibility. The findings of accessibility analysis should inform urban planning and management decisions that optimize urban spatial structure and walkability. Moreover, planners should consider walkability and spatial justice as key aspects of urban design, and seek ways to create better walking environments and public spaces that increase people's access to and satisfaction with health facilities. These important topics have not received enough attention or depth in current research, and we hope to further develop and refine them in future studies.

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