

Spatial Accessibility and Social Inequality to Health Care in Urban System: A Case Study in Tianjin, China

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Abstract. In recent years, the issue of medical security has received more and more attention from the government, and ensuring people's health is an important task that cannot be ignored. In some areas, medical resources are relatively scarce, and they cannot provide a good guarantee for people's daily medical treatment. In the current paper, the spatial accessibility of medical resources and facilities in Tianjin was analyzed using the Gini coefficients, network technique, and Two-step floating catchment area. The results show that based on 2SFCA analysis, the medical facilities in Tianjin are not evenly distributed. Most of them are concentrated in the south and central parts of the city, while some areas have fewer medical resources. Most of the medical facilities are concentrated in the city center. Based on the network and population analysis, Citizens living in areas with almost complete coverage of medical resources can receive better health care. Some citizens living in an area that can be partially covered by medical resources can accept medical insurance. Living in areas where medical resources are extremely scarce, almost the majority of citizens do not have access to proper health insurance. Based on the Gini coefficients, the results show that the medical resources within 30 km and 20 km are relatively unequal, but the medical resources within 30 km are more equal in the two cases.

Keywords: Spatial Accessibility, Social Inequality, Health Care, Tianjin.

1. Introduction

At present, medical problems have gradually attracted the attention of government departments, especially the elderly, who are more willing to choose hospitals closer to home due to inconvenient travel, which has certain requirements for medical location. To solve this problem, an accessibility analysis is usually done.

Spatial accessibility refers to going from a place to a destination faster or more appropriately, such as from home to schools, shopping malls, parks, and hospitals. At present, the elderly care service is valued by the government department, and it has gradually formed a new model based on China's culture and actual situation, such as advocating home care services. However, the elderly are weaker and more likely to suffer from illness than young people. The elderly are also more likely to experience accidents and emergencies, which calls for a specific level of help and a lot of medical resources in a short amount of time. As a result, there are larger demands made on the spatial accessibility of medical treatment.

The spatial accessibility of public facilities has already been the subject of numerous prior studies. For instance, Wang and Sadahiro investigated the disparities in healthcare access for various populations in Japan during the COVID-19 pandemic using GIS-based techniques. The three demographic groups—young people, adults, and the elderly—choose public transit, driving, and walking as their preferred methods of accessing healthcare, according to network analysis, spatial accessibility analysis, and the inequality index. They discovered significant disparities in healthcare access among the senior population and low accessibility to healthcare in suburban areas and locations with little public transit [1]. In a study on the accessibility of the physiotherapy workforce in New Zealand in relation to the local population, Buhler et al. gathered information from the 2018 New Zealand Census with geocoded locations of 5,582 physiotherapists. They then used a 3-step floating catchment method to arrive at the conclusion that the physiotherapy population ratio in New Zealand is above average. But the distribution of labor force is not equal [2]. Thus, using the 2SFCA methodology, this study examines the geographical accessibility of healthcare in Tianjin.

Using the floating catchment method and taking into consideration the spatial distribution of local residents, Ouidad et al. investigated the spatial accessibility of public hospitals by car in the Casablanca area and reached the conclusion that it would assist the government in ensuring an equitable distribution of medical and automotive services [3]. Li and Wang assessed the walkability of urban parks with an emphasis on the elderly using an age-based two-step floating catchment approach. The findings reveal an association between the accessibility of people and the general aging of society, which can assist governments, urban planners, and facility operators in making informed decisions [4]. In order to examine the accessibility and spatial pattern of vehicle campgrounds in Beijing based on the road network structure, Luo employed ArcGIS software, spatial analytic technologies, and an accessibility model. The research results demonstrated that Beijing's auto campsite accessibility progressively declined from the city center to the outskirts, with the central and south-central regions having easier access than the northwest and southwest. This indicated that the accessibility spatial pattern was highly uneven [5]. The R2SFCA method can be utilized to reach commercial centers under various modes of transportation, according to Ni et al.'s review of the accessibility of commercial centers in Nanjing's real network using the enhanced two-step floating catchment area strategy. Their results showed that there are clear variations in the spatial distribution of clients' access to commercial centers under various modes of transportation and that the new two-step floating area technique closes the information gap regarding accessibility of single traffic modes or rough road networks [6]. By taking into account the impact of various time and transportation modes, Coefficients et al. examined the D2D model, Lorenz curve, and Gini coefficient in their investigation of the spatial accessibility and equity of community medical care in Nanjing. Studies reveal that community health care's geographical accessibility will evolve over time [7]. Using the Gini coefficient and the THEIL index to adjust for hourly inter- and intra-regional differences, Li et al. studied the time change factors of healthcare accessibility and equity based on public transportation in Shanghai. It was demonstrated that healthcare access varies throughout the day, resulting in temporal changes in health care equity [8]. These three methods are very suitable for studying spatial accessibility and are widely and universally used.

However, there are few medical accessibility analyses for the Tianjin area. In this study, QGIS software was used to analyze the accessibility of Tianjin. The purpose is to provide convenience for the people in Tianjin to benefit from medical treatment, save time for emergency treatment, choose the appropriate hospital, and prescribe the right medicine.

2. Background of Study Area

Part of the Bohai Bay region on the east coast of the Chinese mainland, Tianjin is one of the country's four municipalities. It is separated into 16 districts, namely Heping District, Nankai District, Hedong District, Hexi District, Hebei District, Hongqiao District, and Binhai New Area.

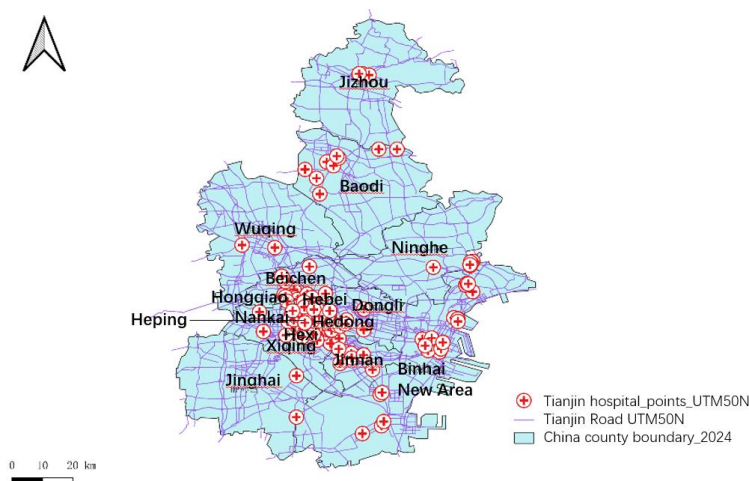


Figure 1. The areas division and network map of Tianjin (Original figure)

Tianjin's network spread and regional segmentation are shown in Figure 1. It is evident that the southern core of the city has a greater concentration of urban main highways than other regions. Additionally, the majority of the city's medical facilities are found in the southwest.

3. Data and Methods

In this article, QGIS software is used. Data includes hospital POI data, transportation network, residential data, and population data. Data sources from the Open Street Map, NASA (<https://sedac.ciesin.columbia.edu/data/set/gpw-v4-population-density-rev11>), Tianjin statistical yearbook (<https://stats.tj.gov.cn/nianjian/2023nj/zk/indexch.htm>).

Figure 2 illustrates the main research flow. The first is to collect data sourced from data warehouse and DBMS. Next is data management includes preprocessing, filtering, gathering, classifying, and performing other data-related tasks. For accessibility analysis, three methods (2SFCA, Network, Gini coefficients) are mainly used.

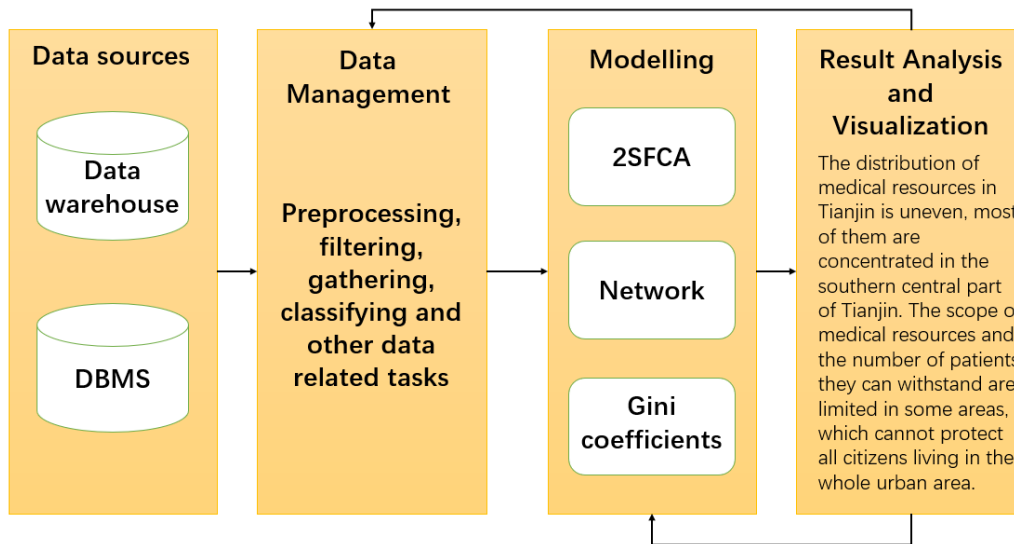


Figure 2. Flow chart (Original figure)

3.1. Two-Step Floating Catchment Area

One popular technique for determining the geographical accessibility of public service facilities is the Two-step floating catchment area. The following is the primary calculating formula:

$$R_j = \frac{S_j}{\sum_{k \in (d_{kj} \leq d_0)} P_k} \quad (1)$$

For each physician location j , look for all population locations (k) that are within a threshold travel time (d_0) from location j (that is, catchment area j). Then, calculate the physician-to-population ratio, R_j , within the catchment area. Here, P_k represents the population of tract k whose centroid falls within the catchment (that is, $d_k \leq d_0$), S_j is the number of physicians at location j , and d_{kj} is the travel time between k and j .

$$A_i^F = \sum_{j \in (d_{ij} \leq d_0)} R_j = \sum_{j \in (d_{ij} \leq d_0)} \frac{S_j}{\sum_{k \in (d_{kj} \leq d_0)} P_k} \quad (2)$$

For each population location i , seek out all physician locations (j) and sum up R_j at these locations.

3.2. Network Analysis

A collection of interrelated linear features that facilitate the movement of people, products, and materials as well as the exchange of information is known as network analysis. The following is the primary calculating formula:

$$A_i^F = \sum_{j \in (d_{ij} \leq d_0)} R_j = \sum_{j \in (d_{ij} \leq d_0)} \frac{S_j}{\sum_{k \in (d_{kj} \leq d_0)} P_k} \quad (3)$$

For a given point, the meaning of the service area is determined.

3.3. Gini Coefficients

Gini Coefficients is an index used to measure the degree of income or consumption inequality in a country or region. The main calculation formula is as follows:

$$Gini = \frac{Area_A}{Area_B} = 1 - \sum_{k=1}^n (X_k - X_{k-1})(Y_k + Y_{k-1}) \quad (4)$$

It measures the equity of a certain aspect of a country or region.

4. Results

The results of a two-step floating catchment area inquiry indicate that 'a' denotes the medical facilities located within 30 km for Tianjin inhabitants, while 'b' indicates the medical facilities located within 20 km for the same residents. As illustrated in Figure 3, Tianjin's medical facilities are distributed extremely unevenly, with the majority of them being concentrated in the city's southern and central regions and certain localities having fewer medical resources than others. Residents in outlying districts face a dearth of medical services owing to the concentration of medical facilities in the city center.

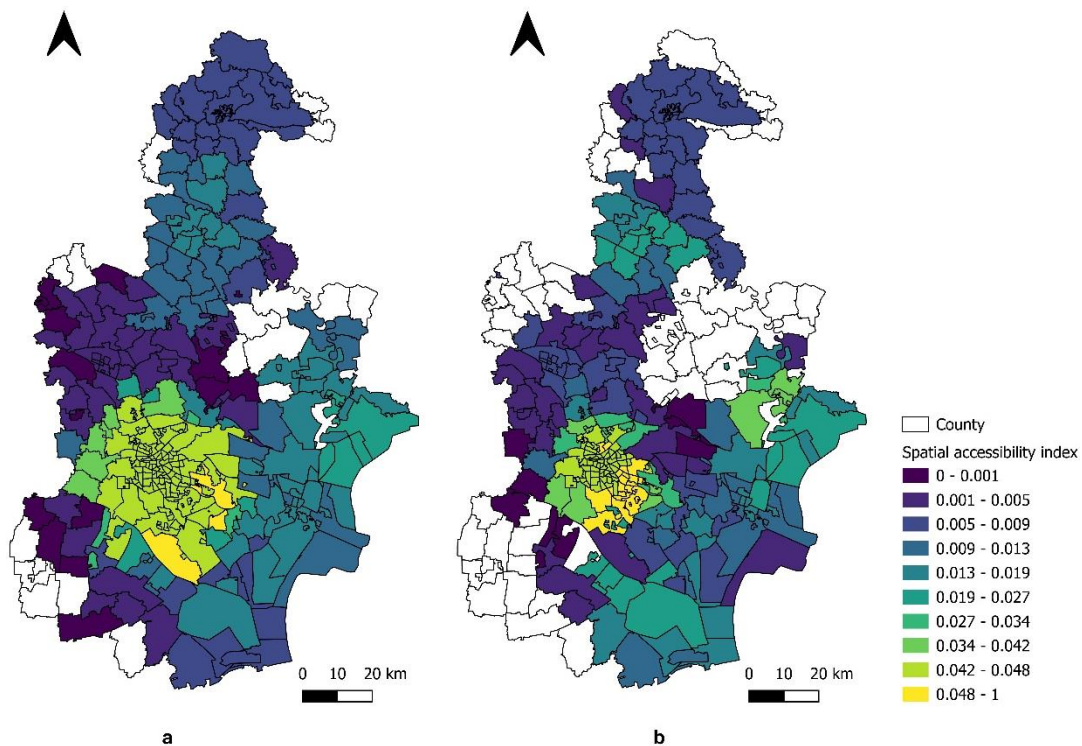


Figure 3. Two-Step Floating Catchment Area map of Tianjin (Original figure)

Based on the network analysis method, Figure 4 reveals the situation of the area where each hospital in Tianjin is located. The roads within 5km of radiation show that the distribution of hospitals in Tianjin is extremely uneven. Roughly speaking, it falls into three groups. The first group consists of the following districts: Heping District, Nankai District, Hexi District, Hedong District, Hebei District, and Hongqiao District; these districts have nearly complete access to medical resources. Citizens who live in these districts can get better medical security. The second category is the areas that medical resources can partially cover: Beichen District, Xiqing District, Dongli District, Jinnan District and Binhai New Area, where some citizens can receive medical protection. The third category

is the areas with extremely scarce medical resources: Jizhou District, Baodi District, Wuqing District, Ninghe District and Jinghai District, where the medical security of citizens living in these districts is relatively scarce, especially in Wuqing District, Ninghe District and Jinghai District, nearly most of the citizens do not have access to proper medical insurance.

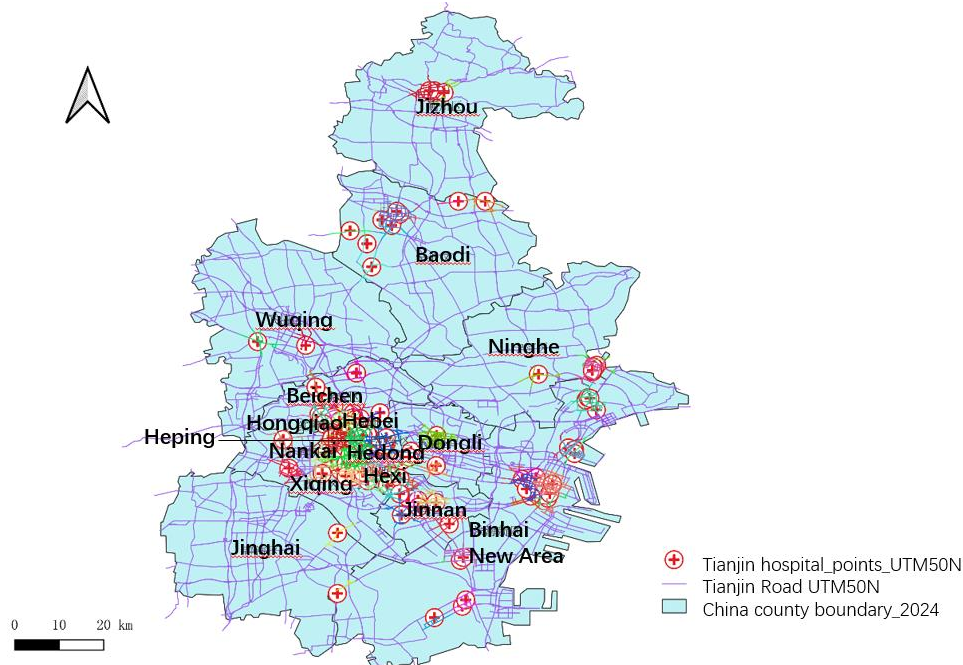


Figure 4. The network map of Tianjin (Original figure)

Moreover, this paper divides the residents of Tianjin into two categories at the macro level: elderly households (with one or more elderly people) and non-elderly households. The number of elderly families in each district of Tianjin shows that the districts such as Nankai, Hexi, Hedong, Wuqing, Jizhou, and Binhai New Area have a large number of elderly families, around 600-700, and the districts such as Beichen, Baodi, and Jinnan have a small number of elderly families around 400-600.

In light of Figure 5, the results of the Gini coefficient over a range of 30 km are presented in the figure on the left, and the results over a range of 20 km are displayed in the figure on the right. The results indicate that medical resources are relatively unequal within 30km and 20km ranges, but compared to the two situations, medical resources within 30km range are more equal.

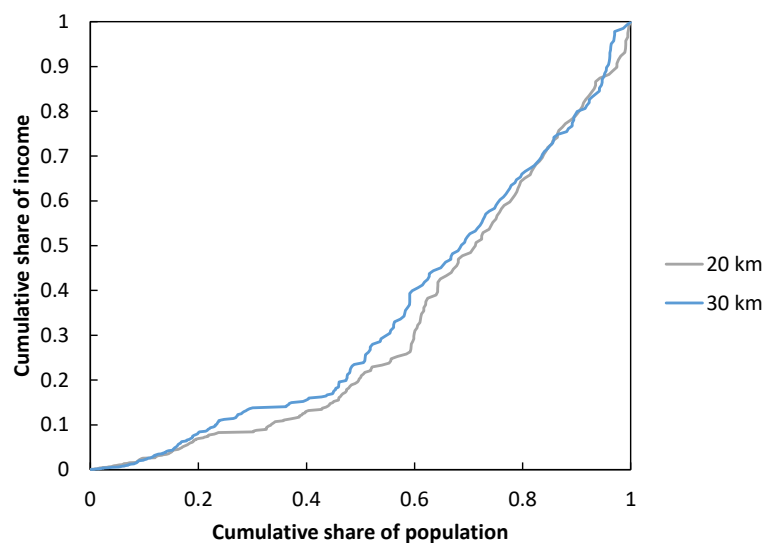


Figure 5. Gini coefficients (Original figure)

5. Discussion

5.1. Limitations of Research Methods

In a nutshell, this method has a certain universality to some extent and can be applied to places with similar situations, such as Beijing or other densely populated cities in China in flat areas. Nevertheless, there are some limitations to this study. In terms of data, the population data of the National Bureau of Statistics can only be obtained at the district level. This paper combines the data from the two sources for analysis to obtain more accurate data, which may lead to a certain bias in our data. The direction of the road network is not considered in this article when analyzing. Although many road networks have been screened, their direction cannot be obtained, so they are two-way roads by default, which may have a certain impact on the city center. In the future, more in-depth studies will be conducted to analyze the causes of inequity using regression, perhaps in terms of income, choice of study area, or even differences in population.

5.2. Assessment of Medical Spatial Accessibility

Based on the research, the current medical system in Tianjin has the problem of uneven distribution, mainly distributed in the core area and a small number in the surrounding areas. Especially in areas with many elderly people, there are fewer medical facilities. For example, in Jizhou and Wuqing districts, the elderly population has reached 600, but the number of hospitals is very small.

Generally, elderly people prefer to choose a doctor nearby rather than a doctor at a distance. However, many areas with a large elderly population have too few medical facilities to fully cover local residential areas in Tianjin, making it difficult for the elderly to seek medical treatment.

This research contributes to residents in Tianjin getting help in the fastest and best way when they need medical assistance, promoting their health and saving their lives. Otherwise, it may lead to some patients or injured people losing their life due to untimely assistance. However, the health of other populations cannot be ignored either.

There may be some reasons for the current medical distribution problem: unequal economic distribution, the construction of the hospital not keeping pace with the development of the city, and good hospitals prefer to choose core areas [9, 10].

5.3. Suggestions

Therefore, this article makes the following recommendations:

1) Building more hospitals in Beichen District, Xiqing District, Dongli District, Jinnan District, Jizhou District, Baodi District, Wuqing District, Ninghe District, Jinghai District, and Binhai New Area is advised in order to meet the daily medical needs of the public, expand the scope of available medical resources and services, and boost the number of medical staff individuals.

2) Benefit from the location of medical sites in the surrounding area, such as establishing affiliated hospitals.

3) Strengthen the training of medical personnel, such as strengthening the training of physicians and improving the salary of medical personnel.

6. Conclusion

In this paper, a spatial accessibility analysis of hospital facilities in Tianjin is carried out, and the results are as follows:

In Tianjin, medical facilities vary somewhat unevenly, with nearly all of them being in the city's center and south, and certain neighborhoods having few healthcare facilities. The heart of the city is home to a great deal of medical institutions.

The main problem is the uneven distribution of medical facilities, which cannot cover most residential areas in the city, making it difficult for people to seek medical treatment.

The proposed suggestions include establishing more new hospitals in areas with fewer medical facilities, providing a hospital site selection welfare system, establishing affiliated hospitals, strengthening the training of medical talents, and improving the salary and benefits of medical staff.

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