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Exploring Equity in a Hierarchical Medical Treatment System: A Focus on Determinants of Spatial Accessibility

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Abstract: It is essential to understand the spatial equity of healthcare services to achieve the Sustainable Development Goals. Spatial and non-spatial factors affect access to healthcare, resulting in inequality in the hierarchical medical treatment system. Thus, to provide a comprehensive equity evaluation, it is indispensable to investigate the extent to which spatial accessibility to healthcare services varies due to various factors. This study attempted to analyze the determinants of healthcare accessibility under multi-trip modes and integrate them into Theil index, as a demand index to evaluate spatial equity in the system. The results reveal an inadequate and inequitable distribution of healthcare resources. While access to primary hospitals is limited (47.37% of residential locations cannot access them on foot), 96.58% of residential locations can access general and tertiary hospitals via public transport or driving. Furthermore, inequitable access to the three-tiered medical system was evaluated on a more granular scale, with primary hospitals being closest to achieving equity (inequitable for only 48.83% of residential locations), followed by general and tertiary hospitals (82.01% and 89.20%, respectively). The unequal residential locations brought on by an abundance of medical resources are far from those with a shortage of resources (66.86% > 5.34%). It is thus suggested that services be expanded or resources be transferred to move toward a more equitable system. Our findings provide policymakers with insights into how to increase accessibility to public health.

Keywords: accessibility; equity; hierarchical medical treatment system; determinants of accessibility

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1. Introduction

Healthcare services play a vital role in health security for citizens and the achievement of the United Nations' Sustainable Development Goals (SDGs) [1,2]. In China, the acceleration of urbanization and the excessive agglomeration of residents in urban areas have placed enormous pressure on the healthcare system [3,4]. For this reason, in 2015, the Ministry of Health undertook medical reform and established a hierarchical medical treatment system [5]. This multi-tier healthcare system distributes diagnosis and treatment services to facilities with specialized functions and service capabilities to prevent the misuse of healthcare resources. It has been recommended that individuals requiring general treatment, disease prevention services, family therapy, and health education visit a primary health center for medical care; those with more complex medical needs should be referred to a superior hospital, thus aiming to prevent the overutilization of upper-tier hospitals when unnecessary [6]. Nevertheless, medical services are not structured within a gatekeeping and two-directional referral network, meaning that people have a degree of autonomy when choosing to access superior hospitals for initial diagnosis and treatment services [7–9]. It remains to be seen whether the implementation of this hierarchical treatment system will be efficacious in improving access to healthcare. Hence, the quantification of healthcare service availability and utilization is essential in order to assess the efficacy of multi-tier hospital systems.

Equity matters for every social group because it raises opportunities and supports the rights that should be available to every individual within a population. Spatial equity focuses on differences in the services utilization by different regions or social groups from the perspective of supply and demand, which could quantify the utilization for healthcare services. Inequity may lead to the inadequate supply of healthcare resources, thereby failing to meet the health needs of the population, particularly among vulnerable groups. Quantifying spatial accessibility is the foundation for measuring spatial equity in healthcare provision [10]. As such, the spatial equity of public services based on accessibility has been widely studied [11,12]. Accessibility refers to the ease of traveling from one place to another and is regarded as a critical indicator of the public service capacity [13]. Various approaches have been developed to measure accessibility in recent decades, with four main categories: opportunity-, gravity-, person-, and utility-based methods [14,15]. Of these, the two-step floating catchment area (2SFCA) method has been widely adopted in the research on accessibility because it accurately estimates the demand for healthcare services from residential locations and then allocates the services back to these locations, taking into account the balance between supply and demand. Travel-cost information is also an important component of accessibility evaluation, with the use of a static travel speed being the most common approach for road-network-based accessibility calculations [16–18]. However, the assumption that the travel speed is constant fails to capture the reality of residential travel choices, which are sensitive to dynamic traffic patterns and are inherently heterogeneous [19]. Route-planning data provide more accurate fine-scale travel information, such as routes, time, costs, speed limits, traffic jams, and one-way streets, thus enabling researchers to conduct more detailed research on accessibility related to green spaces [20], job opportunities [21], and health services [22]. Consequently, route-planning data have become more widely employed in accessibility analyses to accurately quantify the accessibility of multi-tier healthcare services and avoid the misleading findings that arise from the limitations of traditional network analyses. Moreover, individuals often adopt different trip modes to access services in their daily lives. Thus, it is necessary to measure spatial accessibility based on multiple trip modes to accurately reflect accessibility status [23].

The disparities in access to public services are affected by a variety of spatial (e.g., geographic location or surrounding environment) and non-spatial factors (e.g., socioeconomic and demographic characteristics) that are likely to limit healthcare opportunities, thereby leading to disparities in the equitable allocation [24–30]. The travel distance to public services depends on their geographic location and has a negative correlation with the accessibility [31]. Heavy traffic, especially at peak times, increases the travel cost to healthcare services, influencing the accessibility of healthcare facilities in the city center [32]. It has also been shown that public transport (PT) [33], income [34], the population distribution [35,36], and demographic statuses [37] affect access to public services. To evaluate the equity of access to healthcare services, it is essential to analyze whether and to what degree the difference in healthcare accessibility aligns with variations in both spatial and non-spatial factors [38–42]. However, most studies tend to focus on only a particular factor to describe service demands, while disregarding other potential and comprehensive demands. Consequently, taking into account the determinants of spatial accessibility and obtaining a comprehensive view of demands can provide an all-encompassing evaluation of the equity of public services for urban residents.

To fill in the gap, this paper endeavors to incorporate the determining of healthcare accessibility into the assessment of equity to characterize local demands. The central urban area of Shenyang was selected as the case-study site to explore the spatial equity of the hierarchical medical system, as it is the largest new first-tier city in Northeast China and has experienced the strong centralization of its healthcare services. Route-planning data taken from an Internet map application were first used to accurately determine the spatial accessibility of different tiers of healthcare facilities, using 2SFCA, in terms of walking, PT, and driving. Secondly, to identify determinants and quantify their impact on the accessibility of these hospitals, variables related to the location, neighborhood, income, and population were analyzed using the GeoDetector. Finally, the Theil index incorporated the determinants related to spatial accessibility to evaluate spatial equity in the access to the multi-tier hospital system. This paper thus provides a more comprehensive evaluation of equity for multi-tier medical resources, which would be helpful in identifying and optimizing areas with health resource shortages and in building more livable cities.

The remainder of this paper is organized as follows. Section 2 introduces the study area, data processing, and methodology used in this study, while Section 3 describes the research results in detail. Section 4 then discusses the results, and a conclusion and suggestions for future work are presented in Section 5.

2. Materials and Methods

2.1. Study Area

Shenyang, the capital of Liaoning Province, China, is a megacity with a population of over 9 million people. The entire administrative region of Shenyang consists of nine districts and three counties and one county-level city. In this study, we chose the central urban area of Shenyang as our study area, which contains nine districts covering an area of 1353 km^2 (Figure 1). As one of the national metropolitan areas in China, population, transport, and medical conditions in Shenyang matter to neighboring cities. According to the 2020 census, its population was recorded as 9.07 million, with 11.40% of the population aged between 0 and 14 and 23.24% aged over 60. In terms of transport, the current construction of a high-speed railway network can guarantee that residents can reach the main cities of Mid-Southern Liaoning, Beijing–Tianjin–Hebei, and Ha-Chang urban agglomerations within 2 h [43]. In addition, the current length of metro lines has reached 117 km, ranking 17th in China, and the length of bus lines has reached 5261 km [44]. However, some problems still remain, such as an unbalanced distribution of PT resources, a large number of overlapping lines, and a low operational speed. Like other public resources, health services are mainly concentrated in the central urban area, especially high-quality hospitals. Medical facilities are the public services that most effectively ensure the well-being of residents; thus, they should be well-distributed, making it crucial to accurately measure the equity of healthcare services.

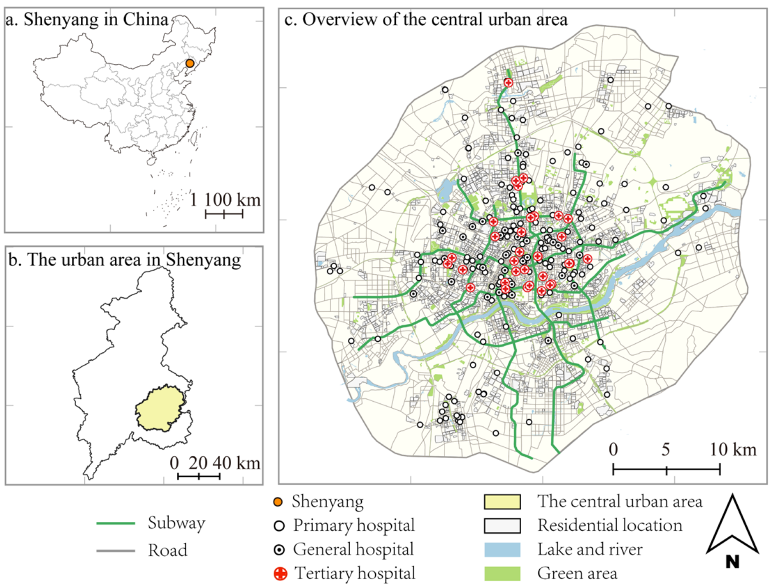

Figure 1. Spatial context of the study area: (**a**) Shenyang in China; (**b**) The urban area in Shenyang; (**c**) Overview of the central urban area.

2.2. Data Preprocessing

The data used in this study consist of three categories: location attribute data, multi-tier hospital, and planning data. The location attribute data included geographic information data from the AutoNavi Open Platform (https://lbs.amap.com, accessed on 10 January 2020), statistical data from the Shenyang Bureau of Statistics for 2020 (http://tjj.shenyang.gov.cn/, accessed on 18 November 2021), and nighttime light data from Luojia 1-01 (http://www.hbeos.org.cn/, accessed on 17 March 2019). Projection conversion, resampling, standardization, and other forms of preprocessing were conducted on these data.

As the origin points, residential locations belong to location attribute data, which were derived from the AutoNavi Open Platform, using the web crawler tool. To ensure the accuracy, a Python program was used to get the coordinates of original residential points, as well as their corresponding boundaries, and then vector boundary data were produced. Finally, a total of 2601 residential points were captured using the boundary data and served as the origin points for obtaining the route-planning data.

Hospital data were formed by the 232 public hospitals, which tend to be higher quality and more likely to be part of the social insurance system than private or specialist hospitals. Three tiers of hospitals were distinguished in the multi-tier system: 32 tertiary hospitals, 33 general hospitals, and 167 primary hospitals. The hospital information included their location, taken from the AutoNavi Open Platform; and the number of hospital sickbeds, taken from 99 Hospital Library (https://yyk.99.com.cn/, accessed on 25 December 2019), Drugdataexpy (https://db.yaozh.com/hmap, accessed on 25 December 2019), and "Community Health Center Service Capacity Evaluation Guide (2019 Edition)".

Route-planning data were derived from the AutoNavi Open Platform (https://restapi.amap.com/v5/direction/transit?parameters, accessed on 10 January 2020), which allows users to find the ideal routes according to predetermined routing strategies, e.g., shortest time, lowest cost, or minimum transfers for transit in particular. The origin and destination points were firstly transformed from GPS coordinates to AutoNavi coordinates, and then a path-planning API was used to initiate the path-planning request of walking, PT and driving modes taking the AutoNavi coordinates as parameters at 7 a.m.to 11 a.m. on weekdays, of which the travel strategy selected the default recommendation mode after the comprehensive weight, and it is the most likely to be used by residents [45]. In total, 772,497 routes with travel distances, times, fares, and routes information were produced.

2.3. Methodology

Based on the above data, this study first quantified the spatial accessibility of different tiers of healthcare facilities using 2SFCA. Then, the GeoDetector was used to identify determinants and quantify their impact on accessibility to different tiers hospitals. Finally, the Theil index incorporated the determinants of spatial accessibility that were used to evaluate spatial equity in the access to the multi-tier hospital system. The flowchart of this paper is shown in Figure 2.

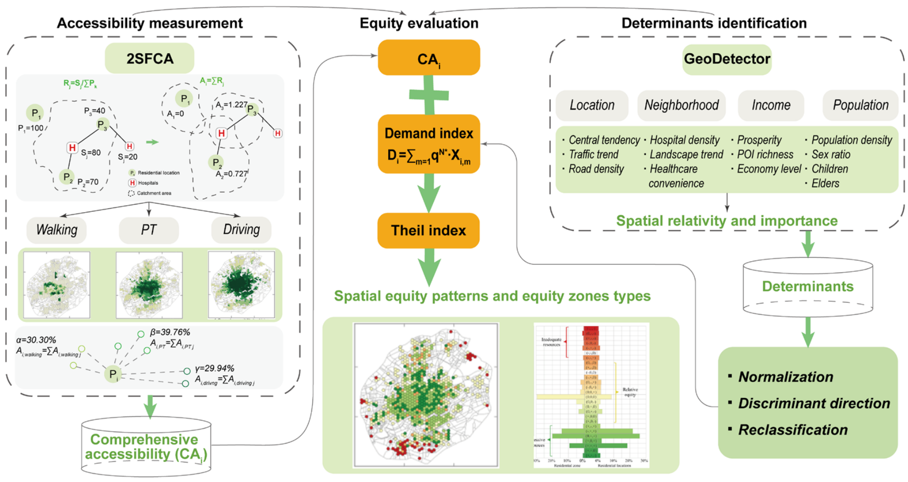

Figure 2. Flowchart of the present study.

2.3.1. Calculation of Accessibility under Multi-Trip Modes

The 2SFCA method was used to measure the accessibility of the hospitals based on the real-time route-planning data, which accurately reflect the route information between each residential location and the three tiers of hospitals. Based on the travel habits of residents, the accessibility of primary hospitals was measured for walking, while the accessibility of general and tertiary hospitals was measured for walking, PT, and driving. Using the planned route data, accessibility was calculated using two steps [46]. The first step was the calculation of the supply–demand ratio, R_j, for the three tiers of hospitals under the three modes of travel. The catchment of the hospital, j, was defined as the area consisting of all residential locations, k, within threshold time, d_0, which was set to 15 min for walking, 1 h for PT, and 30 min for driving, in accordance with the spatial planning of community life unit and previous studies [43,45,47,48]. The R_j for the catchment area was computed using Equation (1):

$$R_j = \frac{S_j}{\sum_{k \in \{d_{ij} \le d_0\}} P_k} \tag{1}$$

where S_j represents the capacity of each hospital, j (measured as the number of sickbeds); d_{ij} is the travel time between residential location, i, and hospital, j; and P_k is the residential demand for the catchment.

The second step was the calculation of the accessibility for the hospitals under multi-trip modes. All hospitals, j, within the threshold time, d_0, for residential location i were determined, and the R_j for these hospitals were summed (Equation (2)):

$$A_i = \sum_{k \in \{d_{ij} \le d_0\}} R_j \tag{2}$$

where A_i is the final accessibility assigned to the residential location, i.

According to an investigation on citizens' travel in Shenyang, we learn that the proportions of walking, cycling, PT, and driving modes were 25%, 17.5%, 32.8%, and 24.7%, respectively. Since this study only focuses on walking, PT, and driving modes, the above proportions were recalculated to obtain the weights after omitting the cycling mode. For the present study, these weights were 30.30%, 39.76%, and 29.94%, respectively. Comprehensive accessibility, CA_i, was employed to quantify the multi-tier hospitals' accessibility under different travel modes [49], using Equation (3):

$$CA_i = \alpha A_{i,walking} + \beta A_{i,PT} + \gamma A_{i,driving} \tag{3}$$

where α, β, and γ are weights for the three travel modes, $A_{i,walking}$, $A_{i,PT}$, and $A_{i,driving}$, respectively, representing their accessibility.

Hexagons, which offer a richer spatial topology and minimal edge effects, were used to demonstrate accessibility, thus avoiding the visualization problems caused by dense residential locations [50,51]. The experimental analysis determined that the optimal diameter for the hexagons was 1 km in the study area, which covered an average of 2.2 residential locations.

2.3.2. Identification of Determinants to Healthcare Accessibility

The GeoDetector is a statistical tool that has been maturely applied to quantify the determinants of spatially stratified heterogeneity [52] in the landscape [53], ecological [54], and social fields [55]. It is based on the principle that any factor that has an important influence on a target-dependent variable will have a similar spatial distribution to that variable [52]. Therefore, we used the GeoDetector to quantify the effect of potential factors on medical service accessibility for the three tiers of hospitals. The explanatory power, q, of a factor indicates that factor X explains $100 \times q$% of the variable Y, $q \in [0-1]$; the higher the value, the greater the influence, and vice versa. The p-value indicates the reliability of q, which is the significance of factor X. It was calculated using Equation (4):

$$q = 1 - \frac{1}{n\sigma^2} \sum_{h=1}^{L} n_h \sigma_h^2 \tag{4}$$

where $h = 1, \ldots, L$ is the stratification of variable Y or factor X; n_h and n are the number of units in the stratification, h, and the whole region; σ_h^2 and σ^2 are the variance of Y values in the stratification, h, and the whole region; and $n\sigma^2$ is the total variance.

To be consistent with previous studies [26,28,30–37], four categories of variables were used in this research: (i) location characteristics reflecting the geographical advantages; (ii) neighborhood characteristics representing the surrounding environment; (iii) income characteristics affected by regional development and the strength of the economy; and (iv) population characteristics considering the health needs of various groups. The specific indicators are summarized in Table 1.

Table 1. Impact factors for spatial accessibility of a multi-tier hospital system.

Variable Types	Variable (X_m)	Definition
Location	Central tendency (X_1)	Mean distance to the city center in each hexagon (m)
	Traffic trend (X_2)	Mean number of PT stations within a 500 m walk in each hexagon (n)
	Road density (X_3)	The ratio of the road length to area in each hexagon (%)
Neighborhood	Hospital density (X_4)	The number of hospitals per unit area in each hexagon (n/m^2)
	Landscape trend (X_5)	Mean area of green and water within a 500 m walk in each hexagon (m^2)
	Healthcare convenience (X_6)	Mean distance to the closet hospital in each hexagon (m)
Income	Prosperity (X_7)	Mean DN in each hexagon (W/m^2·sr·μm)
	POI richness (X_8)	Number of POI categories in each hexagon (n)
	Economy level (X_9)	Tax value per capita (CNY)
Population	Population density (X_{10})	Population per unit area (%)
	Sex ratio (X_{11})	Proportion of men and women (%)
	Children (X_{12})	Proportion of the population aged 0–15 years (%)
	Elders (X_{13})	Proportion of the population aged 65 and above (%)

2.3.3. Evaluation of Equity

The Theil index has the advantage of being able to be decomposed into inequality within and between different defined population subgroups, providing insight into the relationship between demand and accessibility [56]. To explore an overall evaluation of equity, we integrated the determinants of spatial accessibility into the Theil index as a demand index, which reflects the disparities in healthcare opportunities across regions. First, the explanatory power, q^*, of determinants was normalized using Equation (5):

$$q^{N*} = \frac{q^* - Min}{Max - Min} \tag{5}$$

where q^* denotes the explanatory power, q, through the significant test; Max and Min denote the maximum and minimum explanatory power of determinants; and q^{N*} is the explanatory power after normalization.

Then, demand index, D_i, which contains all the determinants and better expresses regional differentiated demand, was determined using Equation (6):

$$D_i = \sum_{m=1}^{13} q^{N*} \cdot X_{i,m} \tag{6}$$

where $X_{i,m}$ denotes the value of the significant factor.

Finally, the comprehensive accessibility, CA_i, and demand index, D_i, were incorporated into the Theil index, using Equation (7):

$$T = \sum_{i=1}^{g} \left(\frac{D_i}{D_{tot}} \frac{CA_i}{\overline{CA}} \right) \ln\left(\frac{CA_i}{\overline{CA}} \right) \quad (7)$$

where g is the number of residential locations in each hexagonal grid; D_{tot} is the sum of the residential demand index, D_i, in a grid; $\overline{CA}$ is the average comprehensive accessibility, CA_i; and T is the health equity in each hexagonal grid, which ranges from -1 to 1. The closer T is to 0, the more equitable the grid is, and vice versa.

Based on the value of the Theil index, residential zones were categorized into five types: residential zones without service within a threshold are the type of rigid demand; residential zones with resource competitiveness fall under the elastic demand type; residential zones with comparatively ample services fall under the type of relative equity; limit adjustment type is the presence of resource wastes in residential zones; and residential zones with a resource surplus problem fall under the quantitative adjustment type.

3. Results

3.1. Accessibility to Multi-Tier Hospital System

Using the route-planning data, the spatial accessibility patterns were obtained for the three tiers of hospitals under three travel modes (Figure 3). The spatial accessibility pattern for primary hospitals was characterized by the presence of multiple dispersed points and the lack of a central core (Figure 3a), with nearly half the residential locations (47.37%) lacking access to medical services, meaning that the goal of a 15-min community-life unit could not be achieved. This, it can be concluded that the current service allocation is not coordinated with city planning. With regard to general hospitals, spatial accessibility varied sharply under three travel modes. Specifically, walking accessibility was much more centralized than for primary hospitals, leading to inefficient health services, while PT or driving greatly increased access to these services. In fact, only 0.23% of the residential locations could not access general hospitals by public or private vehicles (Figure 3b,d,f,h). Tertiary hospitals were concentrated in the central urban area, and they were accessible to 22.61% of the residential locations on foot, while more than 85% of the residential locations could reach tertiary hospitals with PT or private vehicles. Overall, only 3.42% of residential locations were outside the service range of tertiary hospitals (Figure 3c,e,g,i).

From a travel perspective, 37.91% of residential locations were not able to walk to hospitals within 15 min, indicating that, nearby, the service capacity in the study area was weak (Figure 3a–c). Primary hospitals filled the gap between the city core and periphery arising from the uneven distribution of upper-tier hospitals. With PT, 6.77% of residential locations had no access to hospitals, with these locations primarily in the south, far away from upper-tier hospitals (Figure 3d,e). With private vehicles, accessibility significantly improved, with only 0.38% of residential locations, mostly found in the south and east, outside the service area. Generally, the northern axis connected to the core had the highest accessibility (Figure 3f,g).

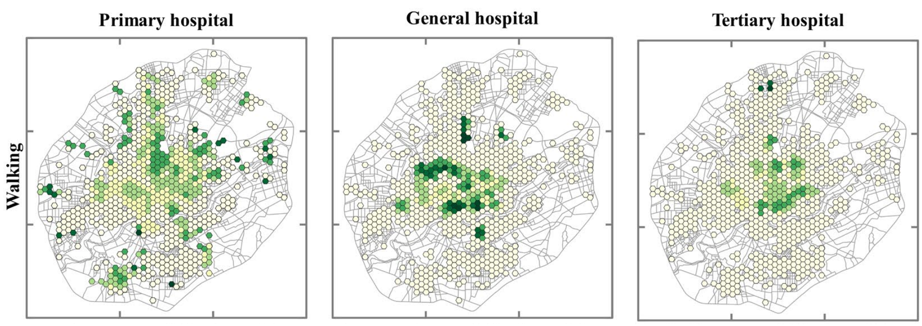

Figure 3. *Cont.*

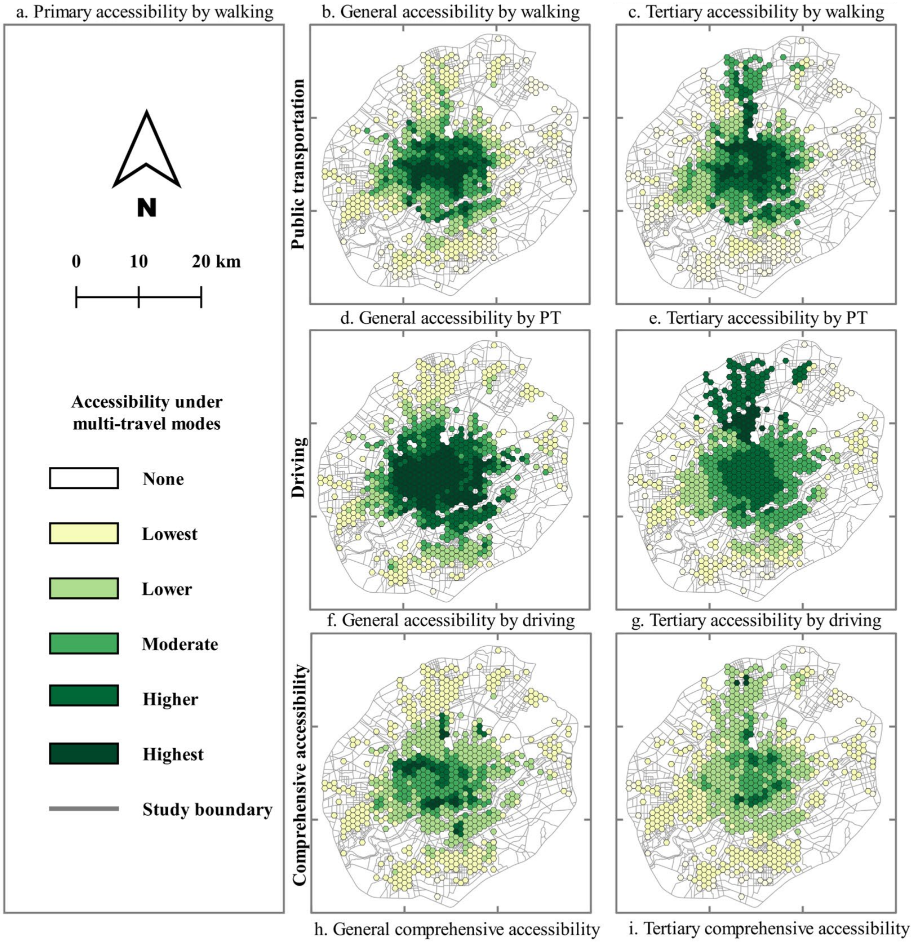

Figure 3. Spatial accessibility to the three tiers of hospitals under multi-trip modes: (**a**) Primary accessibility by walking; (**b**) General accessibility by walking; (**c**) Tertiary accessibility by walking; (**d**) General accessibility by PT; (**e**) Tertiary accessibility by PT; (**f**) General accessibility by driving; (**g**) Tertiary accessibility by driving; (**h**) General comprehensive accessibility; (**i**) Tertiary comprehensive accessibility.

3.2. Determinants of Accessibility in Multi-Tier Hospital System

The GeoDetector was used to investigate the effects of a range of factors on spatial accessibility. Figure 4 shows that neighborhood and population characteristics were the most influential factors determining differences in spatial accessibility, while the power of location and income characteristics on accessibility were limited. Except for the landscape trend, most variables had a significant effect on CA_i ($p < 0.01$). The explanatory power of these factors for primary hospital accessibility had a range of 8.0–26.9%. The most influential factors were the hospital density (26.9%) and healthcare convenience, indicating the importance of meeting population demand with primary hospitals. In addition, population density and the size of the elderly population also had a strong influence on accessibility differences for primary hospitals. The effect of the influential factors on general hospitals was stronger than on primary hospitals, with a range of 6.3–32.2%. Population density and healthcare convenience were the most important factors, suggesting that population demand directed medical supply allocation, while prosperity, POI richness, and economic level also had a relatively strong explanatory power, with fluctuating around 15%. For tertiary hospitals, the effect on accessibility ranged between 2.5% and 15.5%. The most important factors were consistent with those for general hospitals, with population density being the primary influence. Healthcare convenience was the second most important factor, with an explanatory power of 12.9%. Unlike the other tiers of hospitals, the accessibility of tertiary hospitals was more dependent on POI richness, probably because POI categories represent the citizens' physical conditions, which are related to healthcare resources.

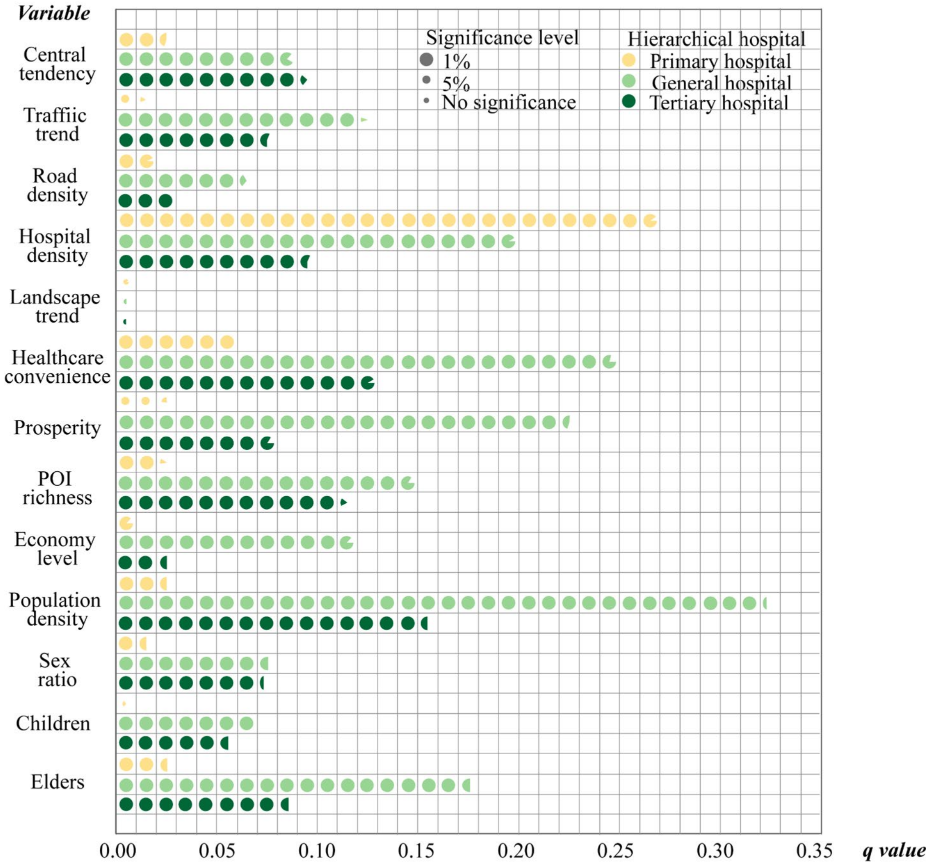

Figure 4. Influencing degrees of determinants of spatial accessibility to the three tiers of hospitals.

3.3. Equity in Multi-Tier Hospital System

For general and tertiary hospitals, the majority of residential locations were in the quantitative adjustment type, whereas for primary hospitals, 51.17% of residential locations were in the relative equity type. As shown in Figure 5, there were rigid and elastic demands in 23.10%, 7.57%, and 10.77% of the residential locations, which were insufficiently served by primary, general, and tertiary hospitals, respectively. The rigid demand zone for primary and tertiary hospitals were widely distributed in the central city, where medical facilities were difficult to reach via any mode of transport, suggesting that primary or tertiary hospitals should be established there. The lack of a primary hospital created an inequity situation for residential locations in the south and west, where the demand was elastic. Moreover, the suburbs contained a number of residential locations with an elastic need for general and tertiary hospitals. It is suggested that three tiers of hospitals be built in the south and that resources be redistributed appropriately to reduce the regional gap. Zones with relatively equitable access to primary hospitals were distributed around the city margin, where the resources should be transferred to the rigid demand zone. For primary, general, and tertiary hospitals, 25.72%, 74.43%, and 78.43% of the residential locations had either required quantitative or limited adjustment. These two types of zones gradually extended to the periphery, and shifting resources to the suburbs with rigid or elastic demand is recommended.

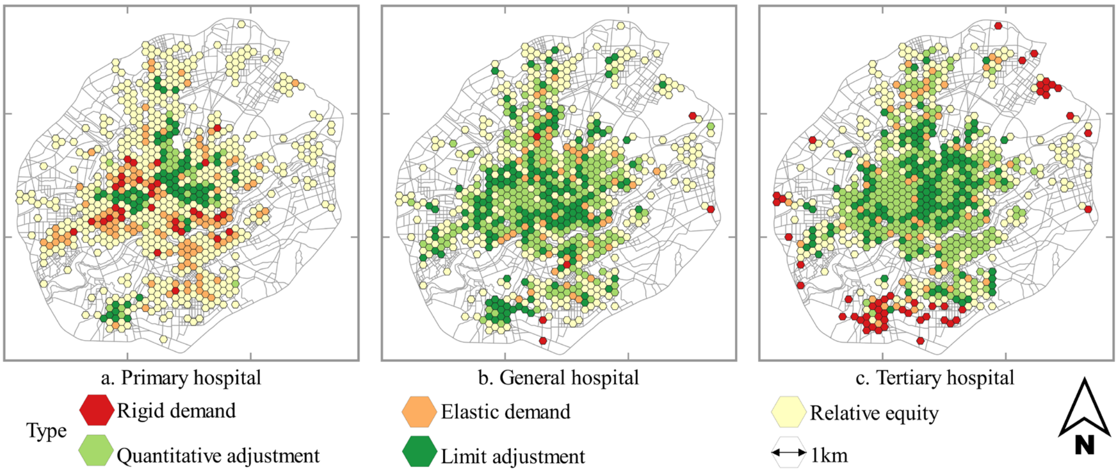

Figure 5. Spatial equity patterns for the multi-tier hospital system: (**a**) Primary hospital; (**b**) General hospital; (**c**) Tertiary hospital.

Drawing on these results, the equity of each tier hospital can be summarized into three categories: inequity of the shortage (−), relative equity (0), and inequity of the abundance (+). Figure 6 demonstrates that 27 equity zones were identified, along with their respective proportions. There was a tight connection of redundantly resourced zones in the urban core, with 66.86% of residential locations having a surplus of general and tertiary hospitals, accounting for 43.95% of the zones. A balanced distribution of three-tier hospitals outside of the urban core, with at least two types of hospitals, was present in 39.11% of the zones. On the contrary, the zones with unequal access to medical resources were isolated within the central city, where 5.34% of the residential locations lacked two or more tier hospitals. In conclusion, the spatial disparity of medical resources was substantial, which is not conducive to optimization. It is noteworthy that there were far fewer zones lacking medical resources than those with excessive resources. Thus, it is suggested that the discrepancy be narrowed through transferring existing medical resources rather than constructing new facilities in the study area.

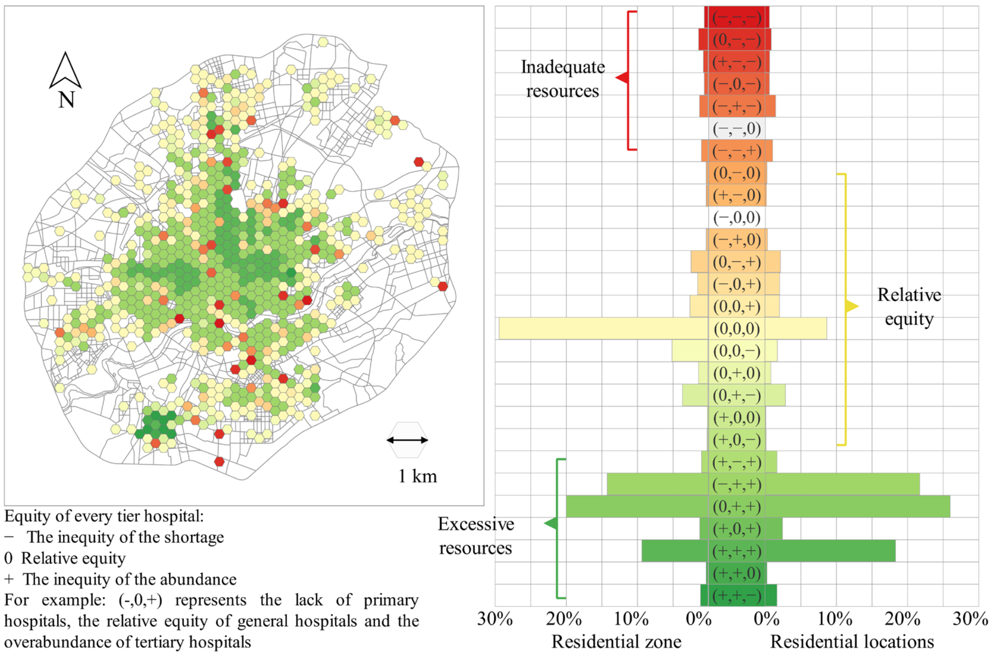

Figure 6. Equity zones and their respective proportions.

4. Discussion

Accessibility equity is critical for the sustainable development of public services, especially public healthcare services. Research on accessibility and equity in healthcare has intensified over the last decades, but few studies have examined the collective impact of determinants on accessibility as a means of representing disparities in healthcare opportunities across regions. To fill this gap, we use the determinants of healthcare accessibility as a demand index to enable a clearer understanding of equity in accessibility. The main purpose was to determine how to measure accessibility accurately to multi-tier health services, to identify what factors contributed to spatial differences in accessibility, and to resolve how to evaluate equity based on the determinants of spatial accessibility in the context of the hierarchical medical treatment system.

The principle underlying the implementation of a hierarchical medical treatment system is that everyone has access to medical services. While residents should ideally have access to the treatment tier of their choice for all transport options, this is not always the case. In the central urban area of Shenyang, nearly half of residential locations have no direct access to primary hospitals, and this issue is related to the distribution of residents. This inequity suggests that upper-tier hospitals may take on a greater patient burden than expected, while primary hospitals are underutilized, thereby impeding the purpose and effectiveness of the hierarchical medical treatment system. To this end, further discussion is necessary to identify the determinants contributing to the disparities in accessibility at different levels or regions.

Access to medical services is contingent on a variety of spatial and non-spatial factors. This research attempted to identify and quantify the location, neighborhood, income, and population variables affecting this access. It was determined that resource, economic, and demographic differences were the main drivers of spatial differentiation in healthcare accessibility, which is in accordance with previous studies [14,22,26]. In addition, many factors had a significant impact on the accessibility of general hospitals, e.g., a high population density or greater wealth made it easier to access a general hospital.

To effectively assess and address disparities in healthcare equity between zones, the Theil index was used to combine accessibility and its determining factors. Our study revealed that the zones lacking services had less inequity in comparison to those with excessive resources, suggesting that the current medical resources are adequate for the residents in the zone. The scarcity of higher-tier hospitals was particularly prevalent in the southwest and outskirts of the city, following the pattern observed in other cities [57–59]. To address this inequity, our recommendation is to open branches or arrange regular visits of primary and tertiary hospitals to densely populated regions, thus utilizing existing medical resources rather than establishing new facilities to reduce regional disparities. This research identified zones corresponding to 27 types of health resource allocation and proposed policies to mitigate the conflict between supply and demand, thereby reducing the burden on upper-tier hospitals.

5. Conclusions

The importance of equitable access in a hierarchical medical treatment system for the health and well-being of residents has been widely acknowledged. Previous studies have primarily focused on evaluating the equity of healthcare access from a single medical-demand perspective. Accordingly, this study sought to address the collective impact of both spatial and non-spatial factors on accessibility, providing a more comprehensive understanding of disparities in opportunities. By comparison, we found that the current distribution of medical facilities in Shenyang is extremely unbalanced. As such, it is recommended that primary and tertiary medical resources be transferred to the southwest region of Shenyang and branches of upper-tier hospitals be established around the urban perimeter. Such results suggest that the determinants, as a demand index, help us to understand the disparities in healthcare accessibility from a spatial perspective and have great implications for resolving how to evaluate equity based on the determinants of spatial accessibility in the context of the hierarchical medical treatment system.

The approach used on this study that considered the determinants of spatial accessibility can be used as an effective tool for urban planners and policymakers to accurately identify zones that are underserved by urban public facilities, and it has significant implications for promoting spatial equity. Nevertheless, this study has certain limitations that present prospects for future research. While this study focused on diversiform factors influencing healthcare accessibility, other factors, such as affordability, personal preferences, and the reputation of the hospital, also shape health behavior. Additionally, the route-planning data from a single month utilized in this study may not precisely capture the access differences in different seasons or climates, thus necessitating further research to fully explore the accessibility of urban public facilities in a winter city.

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