Unequable spatial accessibility to hospitals in developing megacities: New evidence from Beijing

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A B S T R A C T

The increasing inequality in spatial accessibility to hospitals in developing countries has been attracting attention from researchers and politicians. The situation seems to be worse in growing megacities where more than 10 million people live and rapid urban sprawl has caused serious problems with the supply of health and public transport services. The recent global COVID-19 pandemic calls for particular attention to be afforded to the matter of equal access to basic medical facilities and services for people across different neighborhoods. Although some studies have already been undertaken into the subject of health-focused inequality in the cities of developing countries, the spatial inequity in hospital accessibility has rarely been discussed to date. In this paper, I aim to provide new evidence by considering Beijing as a case study. With the results of my analysis, I show that low-income neighborhoods have experienced lower levels of accessibility not only to high-tier hospitals (secondary and tertiary hospitals) but also to primary healthcare services (primary hospital and neighborhood clinics). The rate at which high-income neighborhoods access secondary and tertiary hospitals is approximately 4 times and 1.5 times as high as that of low-income neighborhoods. Low-income face nearly twice the travel time of those from high-income neighborhoods to reach the nearest primary hospital or neighborhood clinics. Suburban neighborhoods have less access to medical services than neighborhoods that are located in the central urban areas. It seems that the rapid urban sprawl has been worsening spatial inequality in the context of access to medical services in the growing megacity of Beijing. Equal access to healthcare services should be prioritized in future policy discussions, especially in relation to the urban growth management of megacities in developing countries in order to ensure that fair and inclusive urbanization processes are undertaken. Equal access to healthcare services would also be widely beneficial in the context of managing the COVID-19 pandemic.

1. Introduction

To build fair cities and equal urban living environment is one of major new sustainable development goals by UN-Habitat. This goal was especially addressed in the New Urban Agenda, which was adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in Quito, Ecuador, on October 20, 2016. According to the agenda, to improve the social, spatial and economic equality in access to basic urban facilities and services is vital.

Accessibility refers to the ease of accessing urban opportunities, such as employment, education and healthcare (Hansen, 1959). Accessibility is an outcome of potential opportunities combining the geographical distribution of the population (demand), facilities (supply) and the transportation resources (Geurs and Van Wee, 2004). Accessibility to healthcare is a main research topic in the area of accessibility measures

and analysis, because it has important theoretical and policy bearings (Wang, 2012). In theory and methodology, a better and clearer definition and calculation of accessibility to healthcare is very important for the local governments and transportation agencies to response to the geographical and transportation obstacles preventing people from timely and accurate diagnosing and treatments, which are essential for their health and wellbeing. Better accessibility to hospitals contributes to higher healthcare utilization, especially for people with chronic diseases (Hare and Barcus, 2007). Improving access to hospitals can also lower infant, maternal (Jones et al., 1999; Urassa et al., 1995) and emergency mortality (Nicholl et al., 2007). In this sense, improving access to hospitals is beneficial to enhancing health outcomes and quality of life, especially for socially disadvantaged people such as low-income earners, young children and women. In policy, many international organizations and countries have also addressed the

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significance of hospital accessibility and regard improving hospital accessibility as an important initiative in public health invention. As one of the bulletins of World Health Organization (WHO) notes, physically easy reach to the healthcare is an essential strategy to promote public health for all the population, especially for the marginal and vulnerable population groups (World Health Organization (WHO), 2013). A report from General Accounting Office of the United States shows that the annual expenditure on accessibility issues in healthcare-short areas in the US exceed 1 billion dollars a year (GAO, 1995). Health China 2030 also includes accessibility to the primary care services in China as an important strategy towards more equitable healthcare services. The proposal mentions that till 2030, the neighborhood physical reach to the primary care institutions of individual should be within 15 min (the State Council of China (SCC), 2016).

Recently, inequality in accessibility to hospitals has been increasingly attracting attentions by researchers and politicians (Wang, 2012, Geurs and Van Wee, 2004). Promoting equity in health, namely fairness, means providing equal opportunities for all groups of people, especially the social disadvantaged to be healthy (Braveman and Gruskin, 2003). Previous studies found that people in lower socioeconomic strata have higher disease risk and healthcare needs than people in higher strata (Hare and Barcus, 2007; Jones et al., 1999; Urassa et al., 1995). However, they may face inferior access to healthcare, especially the specialist healthcare services. For example, a research found inequity in access to healthcare in Organization for Economic Cooperation and Development (OECD) countries. While general practitioner care is distributed almost spatially equally and favors the poor people, the specialist care is inclined towards rich people (Van Doorslaer et al., 2006). Transport-related obstacles can worsen disparities in health outcomes for people of different socioeconomic strata (Kenyon et al., 2002). These difficulties can prevent them from accessing hospitals, delaying disease prevention, diagnosis, and treatment, which increases suffering, disease dispersion and mortality. The recent global COVID-19 pandemic has highlighted the need for equal access to basic medical facilities and services to be afforded to all people, whatever their backgrounds and neighborhoods.

Although some studies have been done, the existing studies have several limitations. Firstly, these studies have mainly been conducted using population census tracts as the unit of analysis. While census tracts facilitate geographic analysis, it is difficult to apply the results to hospital and transportation planning. The neighborhood is a more desirable analysis unit because it is a more nuanced unit to conduct urban planning and health intervention at the neighborhood level. It can also provide more detailed socioeconomic information on neighborhood-level facilities which can identify deprived residents (Bell et al., 2013; Kawakami et al., 2011; Kirby and Kaneda, 2005). However, studies investigating to hospitals at the neighborhood level remain rare.

Secondly, these studies rarely take into account heterogeneity in healthcare services. In previous studies, physicians and healthcare providers were considered as homogeneous potential opportunities regardless of their service quality, service targets and service costs. Accordingly, previous studies may have overestimated hospital accessibility, especially for low-income populations. For example, low-income residents were found to depend more on inpatient hospitals and take medications than their counterparts (Lemstra et al., 2009). Therefore, accessibility to hospitals of different levels should be considered separately to allow more accurate planning implications.

Thirdly, in terms of travel modes, existing studies have mainly investigated automobile access to hospitals, while public transit accessibility is rarely explored (Martin et al., 2002, 2008; Mao and Nekorchuk, 2013). However, residents living in households without automobiles usually take a longer time to reach destinations than if they drove, because of the time taken to walk to and from transit stops, the frequent stops along transit routes, and waiting and transfer times (Blumenberg and Pierce, 2014). In high-density countries such as those in East Asia, public transit has an essential role in daily travel, especially

for urban dwellers. Therefore, calculating hospital accessibility based on driving alone generally overestimates accessibility, especially for low-income neighborhood residents who are typically transit-dependent. Moreover, existing studies exploring hospital accessibility via public transit are mainly based on one type of public transit system (Delmelle and Casas, 2012), but few studies have explored hospital accessibility via multiple modes of public transit (e.g. metro and bus). Different public transit systems have their own pros and cons in terms of speed, coverage, service and cost, which provides passengers with choice. Incorporating multiple modes of public transit in accessibility measurements would better evaluate individuals' accessibility to hospitals.

Fourthly, empirical evidences from developing countries remain scarce (Peters et al., 2008; Makinen et al., 2000). The last decades witnessed rapid urbanization in developing countries. Such rapid population growth is often accompanied by a shortage in health resources and poor public transport services (Tanser et al., 2006). In particular, spatial inequality in accessibility to hospitals between deprived neighborhoods and other neighborhoods has become a key issue (Basu et al., 2018; Zhao, 2015; Zhao et al., 2009; Zhao and Lu, 2010). For example, in China, there is a mismatch between the health care demand and supply in rapid urbanization. Data from National Bureau of Statistics show that till the end of 2017, the population living in the urban areas in China have amounted to 813.47 million, equal to 58.52% of the whole population. The rapid population growth in Chinese cities lead to the relative shortage in healthcare resources (the State Council of China (SCC), 2015). What is worse, healthcare resources in China, especially the top-tier hospitals are unequally distributed in geography. Top-tier hospitals are agglomerated in the city centers of large- and medium-sized cities, while in small cities, suburban areas and rural areas, it is difficult for low-income households to access even primary hospitals. One important reason resides in the special characteristic in health care system in China. In the Western countries, most of the high-quality hospitals are mainly privatized, while the public hospitals are funded by the central and local governments. In contrast, in China, most of the top-tier hospitals are public, and the funding from the public finance has dwindled as the financial reform in China. As a result, top-tier hospitals are rarely located in the deprived areas, with lower affordability of healthcare services. Additionally, local governments are also less willing to locate the high-quality hospitals in deprived areas, which could lead to fewer revenues in public finance. In view of the unequal distribution of healthcare resources in China, transportation accessibility to these healthcare institutions are becoming important. With more affluent transportation resources, the distance barrier to hospitals could be mitigated. However, it is still unclear how transportation play a role in hospital accessibility in Chinese cities.

Taking Beijing, the capital of China, as a case study, this paper aims to investigate neighborhood accessibility to hospitals by means of public transportation or travel by car. This study aims to examine two main questions: (1) The differences of accessibility to different levels of hospitals by neighborhood socio-economic status and residential location (urban versus suburb). (2) the differences of accessibility to different levels of hospitals by different travel modes (private versus public transit). Accessibility to top-tier hospitals was measured by the Gaussian 2SFCA, while accessibility to local hospitals was evaluated by travel time to the nearest primary or neighborhood hospital. The results among different socioeconomic-level neighborhoods were compared.

2. Dataset and methods

2.1. Healthcare provision system in Beijing

The healthcare institutions in China include hospitals, neighborhood clinics, professional public health institutions and other institutions. Hospitals could be further typed into general hospitals, Chinese medical hospitals, hospitals of integrated Chinese and Western medicine,

specialized hospitals and nurseries (National Health and Family Planning Commission of China, 2014). In this study, healthcare services focus on public general hospitals and neighborhood clinics, because they compromise 63.6% of the total treatments in Beijing in 2015, and could be considered as the main healthcare providers of residents living in Beijing (Health And Family Planning Commission Of Beijin–, 2017).

It should be noted that private healthcare institutions were not included in the analysis for two reasons leading to their much inferior role in Chinese health care system. One reason is that top-tier hospitals in China are dominated by public hospitals. In 2012, private hospitals with more than 300 beds compromise only 2.16% of all the private hospitals, while 29.39% of public hospitals have more than 300 beds (National Health and Family Planning Commission of China, 2014). Secondly, private hospitals are deprived of the healthcare insurance provided by the governments for urban residents. The medicine and treatment costs would not be covered if Beijing residents choose to get diagnosed and treated in private hospitals, indicating that their choices are restricted within public hospitals and public neighborhood clinics if they would like reimbursements under the public healthcare insurance (Zhou et al., 2010).

China's cities, including Beijing, have a three-tier system for hospitals; it was devised by the Ministry of Health in China (National Health and Family Planning Commission of China, 1989) (see Fig. 1). All hospitals are classified into three groups in accordance with their service level (number of beds, professionals, and departments), hospital facilities, technical skills, and administration management level. Third-tier hospitals are called "tertiary hospitals", which provide the highest quality of care. Second-tier hospitals are known as "secondary hospitals", which offer lower levels of service than the tertiary hospitals. First-tier hospitals are described as "primary hospitals" and offer neighborhood clinics at neighborhood level (Fig. 2).

These primary hospitals and neighborhood clinics in Beijing provide the required resources for the public in accordance with the regulations of the municipal government. Each and every neighborhood must be able to provide a primary hospital – or neighborhood clinics – at the bare minimum. The municipal government stipulates standard requirements regarding the minimum number of doctors and nurses who must staff the primary hospitals and neighborhood clinics. These primary hospitals or neighborhood clinics provide timely and convenient basic diagnoses and healthcare services at the local neighborhood level. They do not usually provide inpatient services and consequently have very few – if any – patient beds. Secondary and tertiary hospitals provide healthcare services at the city level and even attract patients from outside the city.

An official report (Health and Family Planning Commission of Beijing, 2017) stated the details of hospital use in Beijing. In an official survey in 2015, 71.3% of the respondents reported that their priorities of choosing healthcare services when they feel uncomfortable would be among the primary, secondary hospitals and neighborhood clinics,

while the tertiary hospitals serve for both local people and patients from the other provinces. For example, in 2015, patients coming from the other provinces other than Beijing compromise 33% of all the patients in tertiary hospitals. Among all the tiers of hospitals, the usage rate is positively related to the rankings of hospitals. In 2015, the usage rate of beds in all hospitals was 71.8%. The rate for primary, secondary and tertiary hospitals were 38.7%, 67.0% and 85.3% respectively.

2.2. Study area

Beijing is the capital of China. It had a population of 21 million and covered an area of 41,000 km^2 as of 2014 (Beijing Municipal Bureau of Statistics, 2015). This study uses the whole metropolitan area of Beijing, excluding the ecological conservation area. The ecological conservation area consists of five municipal districts covering an area of 8747 km^2, and has a population of 1.766 million people. This area has a low population density and low public transit coverage and, therefore, was excluded from the study.

Beijing is one of the pioneer cities for public transit in China. According to official reports, public transit trips comprise nearly half of all trips in Beijing. In other words, public transit has become the dominant travel mode in Beijing. This is mainly due to the extension of the metro system, exclusive bus lanes, and the improvement of bus services. To the end of 2014, there were 877 bus lines in Beijing covering 20,249 km. Additionally, there were 18 metro lines covering 11 municipal districts, with a total length of 527 km (Guo et al., 2015).

Figs. 2 and 3 show the transportation system in the study area. As the figures show, roads, bus lines and metro lines extend across the whole city. However, it is undeniable that transportation system is unevenly distributed spatially. The density of bus lines decreases from the city center to the suburban areas, and the metro lines are mainly concentrated in the city center. Although the metro lines extend to suburban areas, the metro services there are still limited. Compared to bus and metro lines, roads are more evenly distributed in Beijing, but the density in the city center is still higher than that in the suburbs, especially high-level roads.

Fig. 4 illustrates the distribution of the different levels of hospitals in the study area. Tertiary hospitals are clustered at the city core and are less numerous in suburban areas. The distribution of secondary and primary hospitals demonstrates a similar pattern. The spatial distribution of neighborhood hospitals in the study area is also far from consistent. Neighborhood hospitals are evenly scattered within the city core but are quite rare in the peripheral areas. The spatial distribution of all hospitals approximately represents the distribution of all healthcare resources in Beijing (Tian et al., 2010).
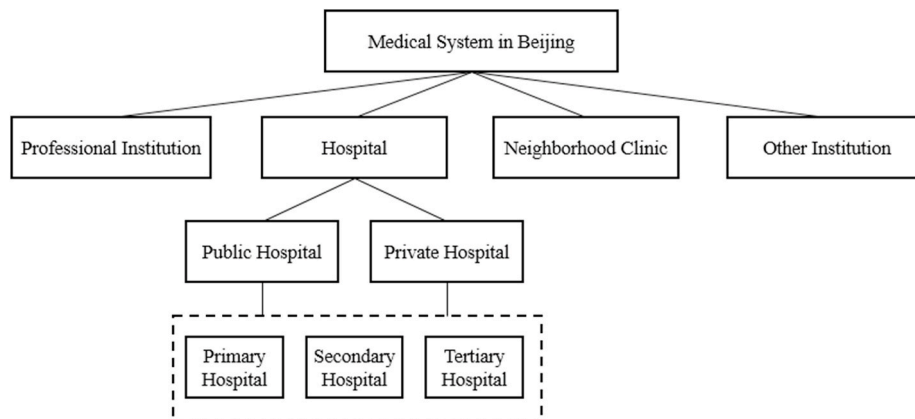

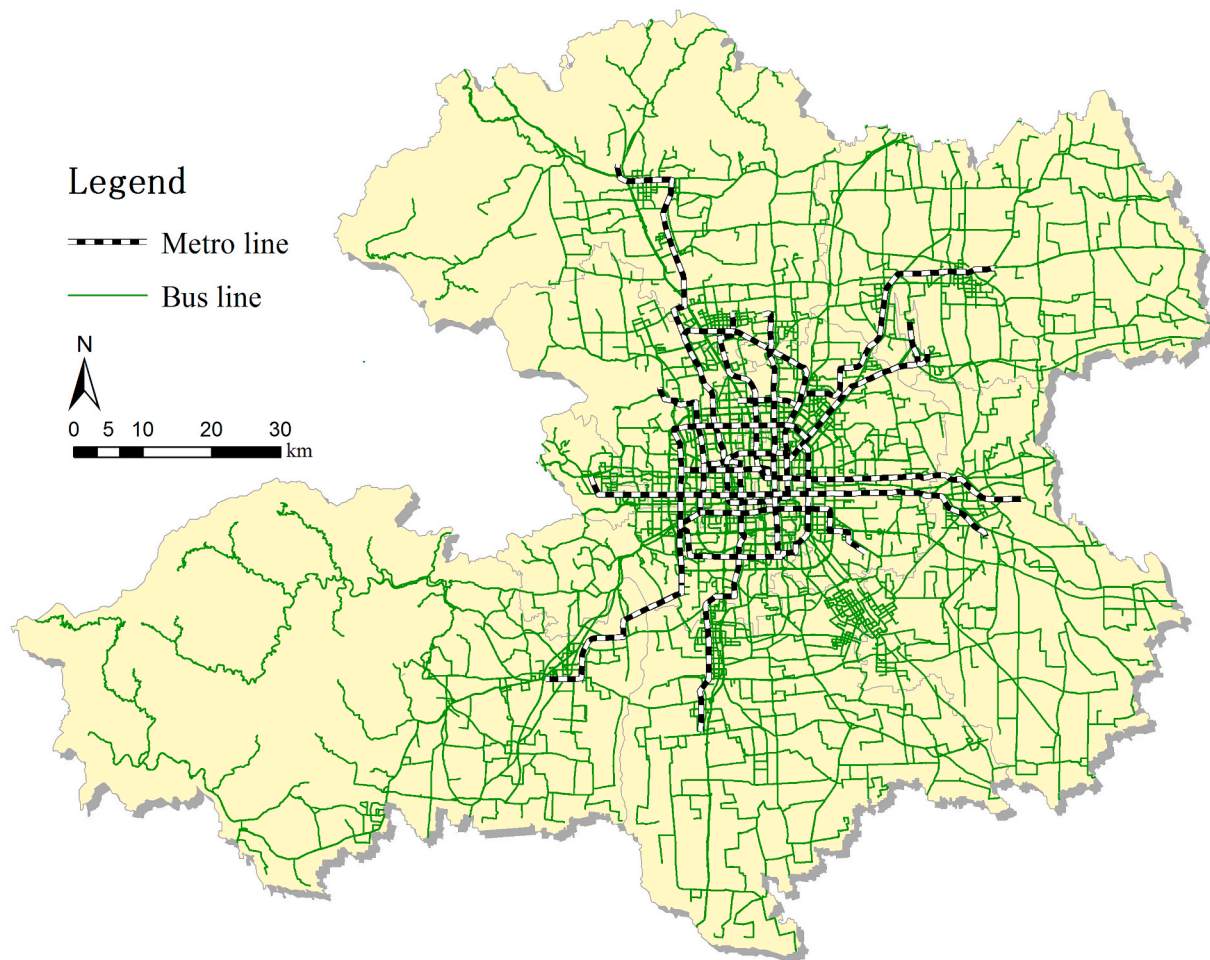**Fig. 1.** Public health system in Beijing.

Fig. 2. Public transit system in Beijing.

2.3. Dataset

In this paper, I investigate the accessibility of different levels of hospitals across different neighborhoods in Beijing, based on two main methods of transportation: public transit and travel by car. Therefore, data on the following parameters are analyzed: travel time by public transit or car, the distribution of neighborhoods according to socioeconomic strata, and the distribution of hospitals according to their levels and number of beds. Travel time data were not calculated by distance and a hypothetical speed based on vector maps, but collected by using Baidu Map API with help of digital maps and dynamic traffic information from data provider (http://developer.baidu.com/map/). The shortest travel time between neighborhoods and hospitals by public transit and car was calculated separately. In Baidu Map API, public transit mainly includes the use of the metro or buses. In calculating travel time by public transit, I included the time that individuals had spent walking between destinations such as metro or bus stations, the time that they had spent onboard forms of public transportation, and transfer time. From all of the possible routes between a neighborhood and a hospital, I selected the route that had the shortest travel time by metro and bus as the travel time for public transit for the purposes of my study. Similarly, I also selected the routes that had the shortest travel time among all of the possible routes for car travel.

A basic assumption of this study was that the housing price per square meter in Beijing was positively associated with the residents' socioeconomic status. Hence, people of higher socioeconomic status were assumed to live in more expensive houses. The neighborhood data that I collected included average house prices and details of the total

number of households in each neighborhood. I obtained this information in May 2017 from the GeoHey website (https://geohey.com/): an open-access geographic data platform. The centroid of a neighborhood is used in the process of measuring healthcare accessibility for the neighborhood. Since this paper focuses on healthcare accessibility in the urban area of Beijing, neither the ecological conservation areas nor the rural areas that are outside the urban area are not considered.

Judging from the distribution of the houses and the representativeness of GeoHey and the examination of housing prices in these neighborhoods, these houses approximately represent the real estate market in Beijing. Some 7464 neighborhoods located in the study area were chosen from the dataset (Fig. 3). We used the Jenks method to divide housing prices into different socioeconomic strata to make distinctions among different groups as best as possible. Housing prices in the urban area of Beijing have been soaring in recent decades. The average house price for a neighborhood provides a reliable indicator of the general income level of households for those who live in the neighborhood. The neighborhoods were divided into four strata: low-income (average housing price/m^2 < 44,782 RMB), medium-low income (average housing price/m^2 = 44,782–73813 RMB), medium-high income (average housing price/m^2 = 73,813–110,326 RMB) and high-income neighborhoods (average housing price/m^2 > 110,326 RMB).

It is clear that as the distance to the city center increases, the socioeconomic stratum to which the neighborhood belongs decreases. Nevertheless, most high-income neighborhoods were located in the central city area. This is because high-quality education, healthcare and public service facilities are highly concentrated in the city core. The hospital data including address, level and number of beds were retrieved
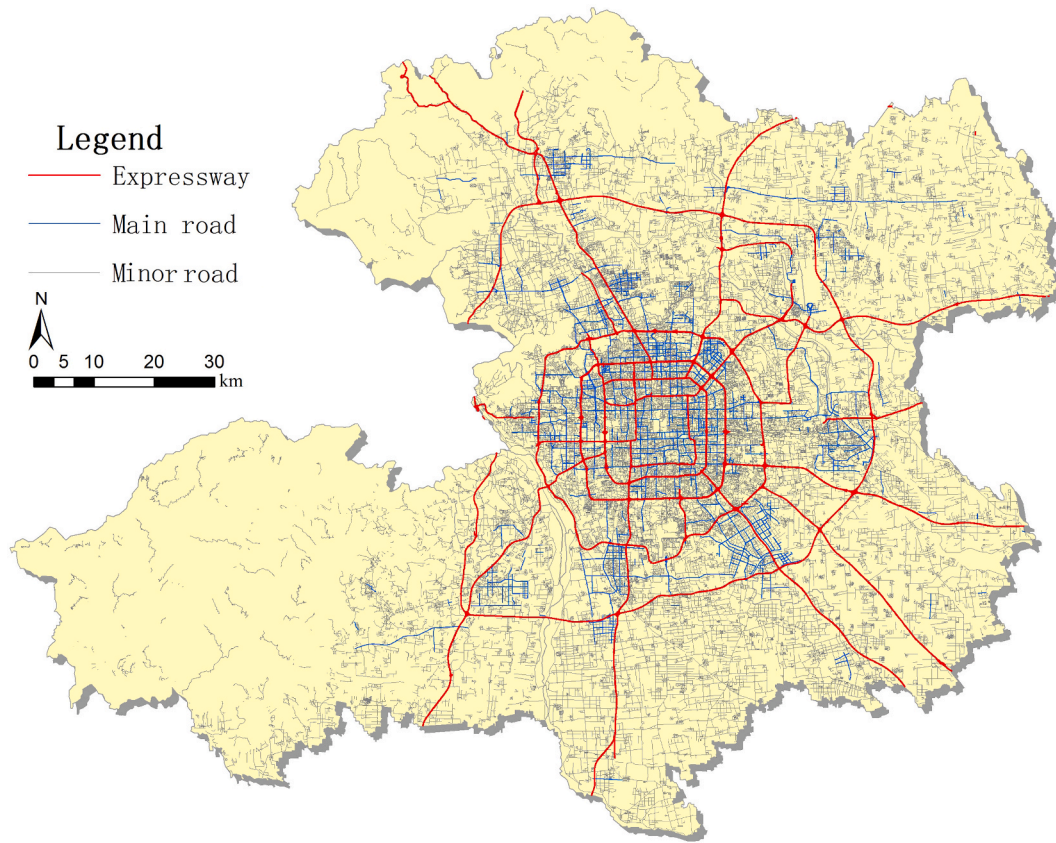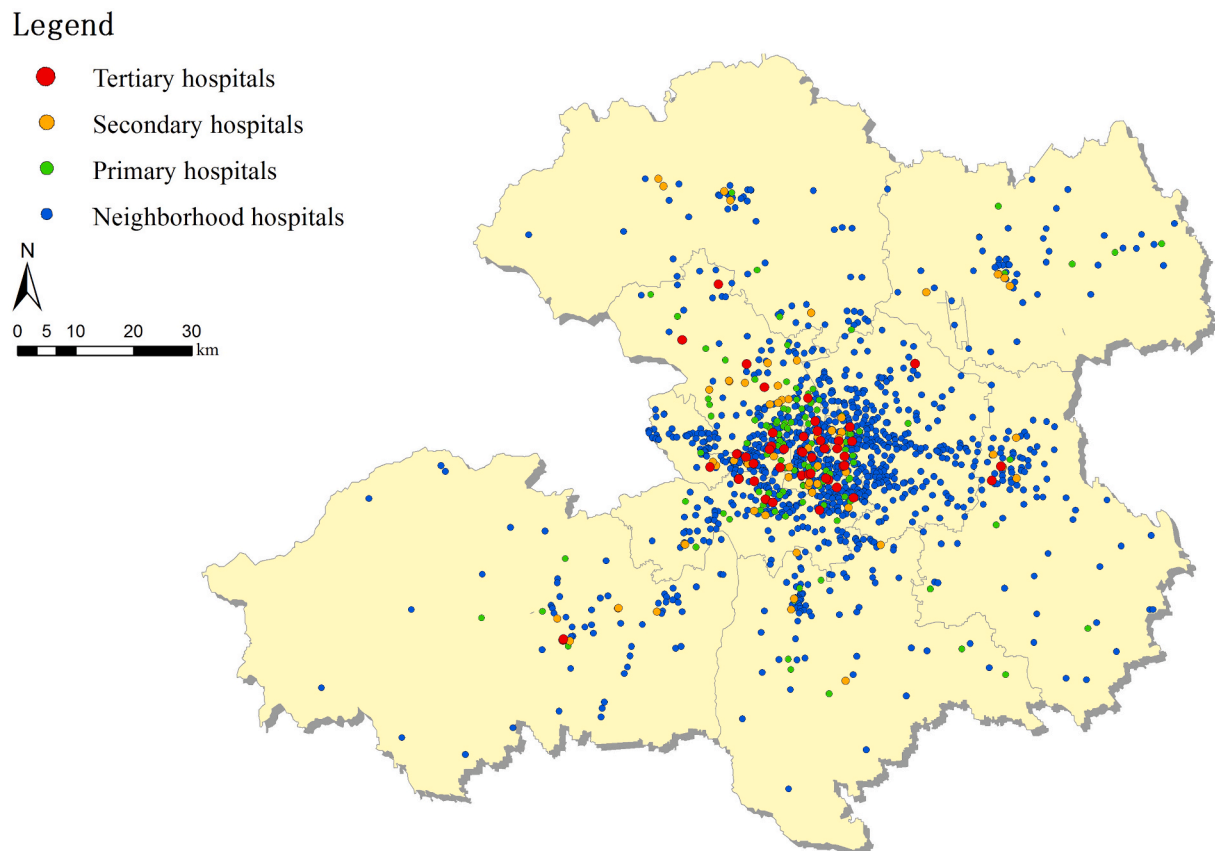
Fig. 3. Road system in Beijing.

Fig. 4. Hospital distribution in the Beijing study area.

from the website 99 health (http://www.99.com.cn/) in October 2017, and the hospitals of different levels (tertiary, secondary, primary and neighborhood) were geocoded in GIS according to their addresses. Private hospitals were excluded from our analysis due to their inferior role in Chinese medical system.

2.4. Methodology

The main measurements of hospital accessibility includes proximity measure, cumulative opportunities measure, gravity-based accessibility model and Two-step floating catchment area (2SFCA) method (Wang, 2012). Proximity measure calculates the shortest distance or quickest travel time from demand centers to opportunities. This method is very intuitive, easy to calculate and easy to be interpreted to policy makers, so it is widely used in many researches. But it doesn't take the number of opportunities, the capacity of supply or the competition for supply into account. Cumulative opportunities measure summarizes the number of sites or opportunities accessible to a resident within a given time or distance. This measure is an intuitive way and is easy to interpret, but it is often criticized by its simplification in method (Paez et al., 2010). Meanwhile, this measure emphasizes on the number of opportunities instead of supply volume, this could become problematic when capacity plays a more important role than number of opportunities, which is usually true for healthcare supply. Gravity models attempt to calculate accessibility from one residential point to all healthcare service centers, taking into account capacity of supply, and distances or times. This method is widely used in geography research and recent studies have incorporated the competitive effect of hospitals in the model (Geurs and Van Wee, 2004). However, this method is difficult to understand for public health specialists and the appropriate distance-decay rate to use could be a controversial issue (Wang, 2012). Two-step floating catchment area (2SFCA) method was proposed by Luo and Wang (2003) and calculates accessibility in two steps. The number of residents a physician can access within a specific driving time—the physician-to-population ratio—is derived in the first step. Then, the ratio is added up for every area within a specific driving time of a resident. This method demonstrates the interaction of physicians and residents, and is widely used in public health research (Wang, 2012; Luo and Qi, 2009).

In this paper, accessibility to tertiary and secondary hospitals was measured by an enhanced two-step floating catchment area method (E2SFCA) based on a Gaussian function proposed by Luo and Qi (2009). This method combines the strengths of two-step floating catchment area method and gravity-based model. It incorporates the interaction between supply and potential demand. In the meanwhile, travel cost is conceptualized by applying the Gaussian function as distance decay function. There are evidence showing that medical travel is an inelastic travel need and travelers are insensitive to time within a long range of time (Chen et al., 2018). So, for the purposes of this paper, I chose to use the Gaussian function rather than others because it is more sensitive to changes in distance. The E2SFCA can be formulated as follows:

$$A_i = \sum_{j \in \{t_{ij} \leq t_0\}} R_j W(t_{ij}, t_0) = \sum_{j \in \{t_{ij} \leq t_0\}} \frac{S_j W(t_{ij}, t_0)}{\sum_{k \in \{t_{jk} \leq t_0\}} D_k W(t_{jk}, t_0)} \# \quad (1)$$

where R_j is the supply-to-demand ratio at supply location j falling within them catchment centered at demand location i ($t_{ij} \leq t_0$), t_0 is the catchment size (i.e., threshold travel time in this paper), t_{ij} is the travel time between i and j, S_j is the capacity of supply at location j (i.e., number of beds in this paper), and D_k is the demand at location k falling in the catchment of j (i.e., $t_{jk} \leq t_0$), represented by the number of households in neighborhood k. W is the friction-of-distance based on the Gaussian function listed below:

$$W(t_{ij}, t_0) = \begin{cases} \dfrac{e^{-\frac{1}{2} * \left(\frac{t_{ij}}{t_0}\right)^2} - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} & if \ t_{ij} \leq t_0 \# \\ 0 & if \ t_{ij} > t_0 \end{cases} \quad (2)$$

In the above function, t_0 is determined by the average travel time from all neighborhoods to hospitals of a specific level (i.e., tertiary and secondary in this paper). Accessibility via public transit and car are both calculated for the purposes of examining the mode variations in hospital accessibility. Therefore, there are four values for t_0 in this paper, which is 82.93 min for tertiary hospitals via public transit, 24.69 min for tertiary hospitals via car transportation, 97.14 min for secondary hospitals via public transit, and 29.84 min for secondary hospitals via car travel.

I decided to measure the accessibility of primary and neighborhood hospitals by travel time to the nearest primary or neighborhood hospital for the following reasons. As aforementioned, primary hospitals and neighborhood clinics are third-tier hospitals in China's cities. They serve as providers of basic diagnoses and healthcare services at the local neighborhood level. They belong to the basic public services that must be provided in accordance with the guidelines of the municipal government. Similarly, the municipal government determines the standard requirements of such resources, including the minimum number of doctors and nurses who must staff primary hospitals and neighborhood clinics.

Therefore, there is no issue in relation to the supply capacity of these two types of hospitals. When it comes to basic healthcare needs, convenience is the first thing to consider (Li et al., 2019). Proximity and travel time – that is to say, as short a travel time as possible – are the most important factors in determining the accessibility of these two types of hospitals. For first-tier and second-tier hospitals, tertiary and secondary hospitals, however, there is an issue with supply capacity; these hospitals attract patients across the whole city or from outside the city. Therefore, we measure the accessibility of tertiary and secondary hospitals by using the 2SFCA model while we do so for primary hospitals and neighborhood clinics by using travel time.

3. Analysis results

Fig. 5 shows the geographical distribution of hospital accessibility of different neighborhoods in Beijing. As the distribution of hospitals is highly concentrated, accessibility to hospitals of different levels shows a similar pattern. It is clear that as the distance to the city center increases, the travel time to neighborhood and primary hospital increases and the accessibility to secondary and tertiary hospitals decreases. This is true both for public transportation and for travel by car. Some regions, such as the administrative centers of suburbs, have high accessibility compared with the surrounding areas. Two main reasons contribute to this result. One is that tertiary and secondary hospitals are clustered in these locations, and primary/neighborhood hospitals are also denser here than in other areas. The other possible reason is that these areas have better road and transit service, and access to hospitals may be more convenient (see Fig. 6).

Tables 1–3 shows the comparison results for accessibility to various levels of hospitals for residents living in different socio-economic strata. It shows that the low-income population have poorer accessibility to all hospitals. For tertiary hospitals, low-income neighborhoods only have a public transit accessibility rating of 3.25, while for medium-low-, medium-high- and high-income neighborhoods, the numbers are 5.85, 9.98, and 12.49 respectively. Similar inequity is evident in the levels of accessibility for travel by car. Generally, accessibility in high-income neighborhoods is 3 times greater than that in low-income neighborhoods. For secondary hospitals, the difference among neighborhoods is smaller but still significant. Low-income populations have an accessibility rating of 2.36 via public transit, which is significantly smaller than
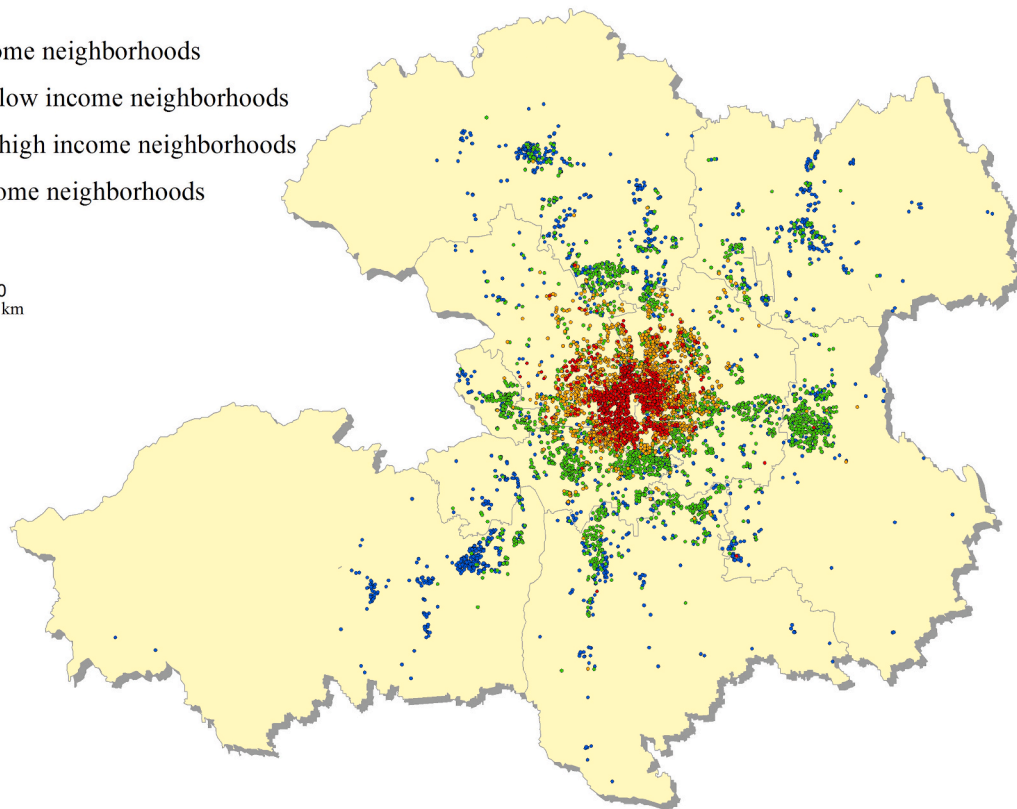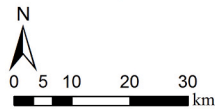
Legend

Fig. 5. Distribution of neighborhoods of different socioeconomic strata.

that of medium-low-income-, medium-high-income- and high-income populations. However, in relation to those who travel by car, the difference between low-income and medium-low-income neighborhoods is not significant. Generally speaking, accessibility to secondary hospitals in high-income neighborhoods is 1.5 times as high as that in low-income neighborhood. It is worth mentioning that, compared to travel by car, public transit accessibility shows a great gap among neighborhoods of different socioeconomic strata, indicating that attempts to mitigate local inequity through developing public transport, especially constructing metro lines in Beijing, fails to some extent. There may be two reasons for that. First, metro lines and stations are usually built in bustling areas to promote efficiency, this is especially typical in the central city. Second, the construction of metro lines itself may increase surrounding house prices, thus drive the poor away. Table 4 shows that it takes low-income population 39.02 min in average to get to the nearest primary or neighborhood hospital via public transit, while high-income population need only 22.65 min, which is approximately 50% shorter. A more detailed analysis shows that 11.75% of low-income neighborhoods need more than an hour to get to the nearest primary or neighborhood hospital, while that number for medium-low-, medium-high-, and high-income neighborhoods are only 3.58%, 0.78% and 0.10%, respectively. The travel time needed to reach the nearest primary or neighborhood hospital by car is also shorter for richer people, indicating that low-level hospitals fail to fill the gap in their high-level counterparts as expected. The results show that rich neighborhoods can reach basic healthcare easier than the poor, both by transit or by car. Additionally, the modal mismatch in terms of car ownership among different socioeconomic strata make the disparities to hospitals even worse (Zhao et al., 2011).

The geographical disparity of accessibility to different levels of hospitals of various socio-economic groups is further explored by dividing the whole city of Beijing into central city and suburb. The boundary of central city and suburb is the 5th Ring Road, across which

shows divergent variations in hospital and transportation system distribution. According to Table 4, the inequity in the central city is similar to that in the whole city. It is clear that low-income neighborhoods have lower accessibility to hospitals of all levels. Accessibility to tertiary hospitals rises from 6.75 for public transit and 6.90 for travel by car in low-income neighborhoods to 12.54 and 12.92 in high-income neighborhoods for public transit and travel by car, respectively. Similar trends can also be found in secondary, primary and neighborhood hospitals. In contrast, accessibility disparity in the suburban area show a distinct pattern. For tertiary hospitals, medium-low-income population have the highest public transit accessibility of 2.12; for travel by car, medium-high-income neighborhoods have the highest accessibility of 1.81. In both modes, low-income neighborhoods have no distinct disadvantage comparing to their rich counterparts while high-income population have the lowest accessibility. It is interesting that low-income neighborhoods have the highest access to secondary hospitals and that value falls while the level of neighborhoods increases.

Table 5 shows no significant evidence of inequity in high level hospitals in the suburbs across different social groups. The explanation may be that suburban medium-high- and high-income neighborhoods are usually low-density communities or villas far from administrative centers of suburbs where high-level hospitals cluster. As for primary and neighborhood hospitals, high-income neighborhoods have the shortest average travel time while the difference among neighborhoods is not very prominent, indicating that high-level neighborhoods still have better accessibility to local hospitals and clinics compared with low-income neighborhoods. It demonstrates that the accessibility disparity between different socio-economic groups in Beijing mainly stem from variations in central city.

4. Discussion and policy implications

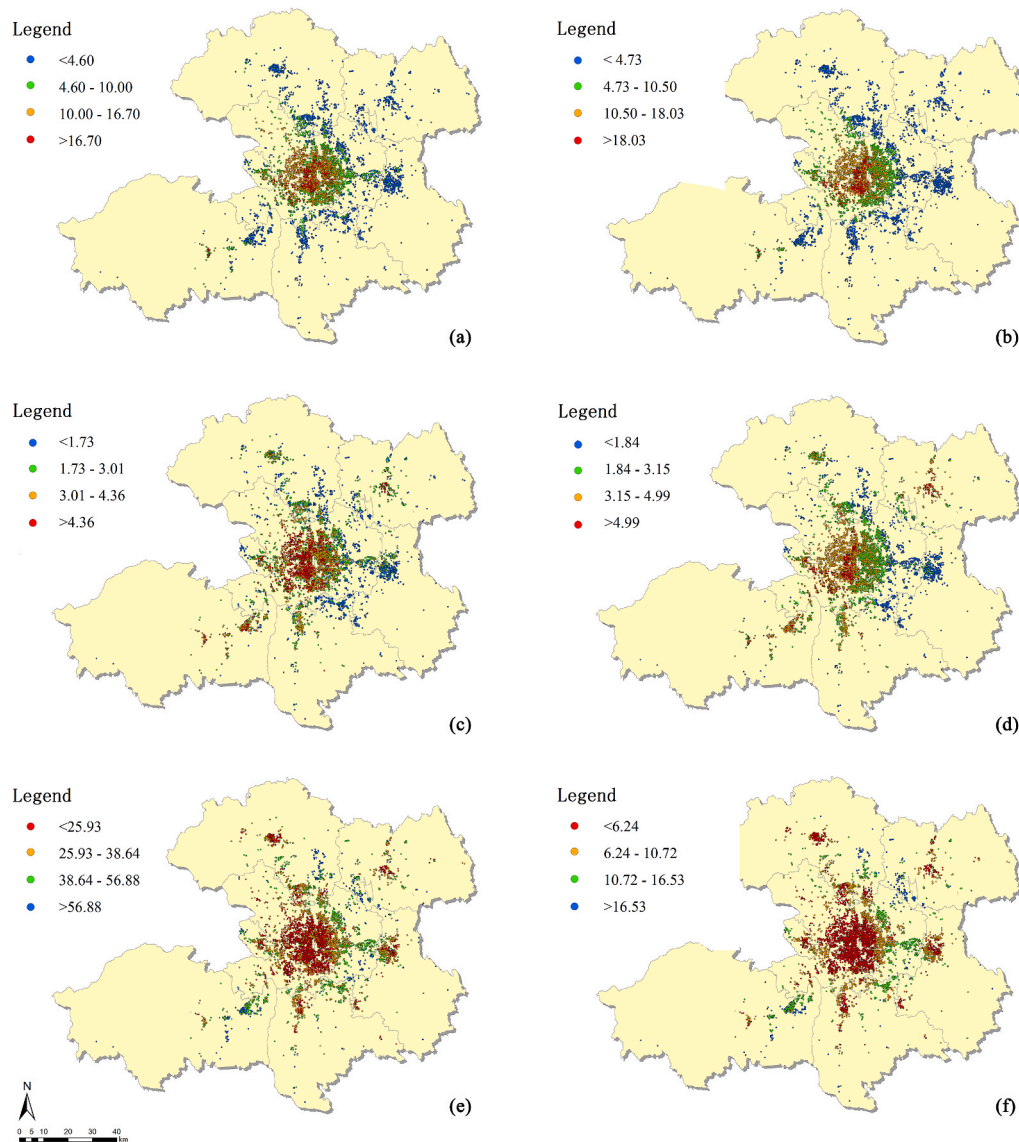The increasing inequality in the spatial accessibility of hospitals in

Fig. 6. Hospital accessibility of different levels via different transport modes

Notes : a) Tertiary hospitals via public transit; b) tertiary hospitals via travel by car; c) secondary hospitals via public transportation; d) secondary hospitals via travel by car; e) primary and neighborhood hospitals via public transit; f) primary and neighborhood hospitals via travel by car.

developing countries has been attracting attention from researchers and politicians alike. However, studies that explore the inequality of hospital access among different socioeconomic neighborhoods remain scarce (Bell et al., 2013; Kawakami et al., 2011; Kirby and Kaneda, 2005). By disentangling the different socioeconomic groups that are affected by this issue, one can formulate more tailored transportation improvement plans for different socioeconomic groups. This study provides new evidence regarding the unequal spatial accessibility of hospitals in developing megacities, focusing on Beijing as a case study. The following three issues are discussed in accordance with the results of my analysis that I have detailed above.

Firstly, comparisons of the accessibility of different levels of hospitals show that the accessibility of top-tier hospitals varied highly between different socioeconomic groups. This variability was even higher for local hospitals. Previous studies take all hospitals as being equal, which this study shows to be problematic. Several studies show that the equal distribution of primary healthcare resources is an effective way to lower health disparities (Kawakami et al., 2011; Kirby and Kaneda, 2005), but few studies have revealed that unequal access to top-tier hospitals may exacerbate health disparities among the low-income

population. This is because top-tier hospitals have the best healthcare facilities and doctors, which people of the poorest health status really need. What is worse, public health studies indicate that people of lower socioeconomic status are also at higher risk of suffering from chronic and serious diseases, such that they have the largest potential demand for top-level healthcare (Hare and Barcus, 2007; Jones et al., 1999; Urassa et al., 1995). This study, focusing on Beijing, shows that low-income neighborhoods have much more restricted access to high-tier hospitals (secondary and tertiary hospitals) than high-income neighborhoods. The hospital accessibility rates of high-income neighborhoods to tertiary hospitals and secondary hospitals are approximately 4 times and 1.5 times as high as those of low-income neighborhoods. The results of this study echo the findings of Bell et al. (2013).

Secondly, those who come from low-income neighborhoods also have limited access to primary healthcare services (primary hospital and neighborhood clinics). The results of my analysis show that it takes low-income people nearly twice the time to get to the nearest primary hospital or neighborhood clinics that it takes those from high-income neighborhoods. However, low-income neighborhoods ought to have

Table 1
One-way ANOVA for accessibility to tertiary hospitals.

Travel mode	Neighborhood type	Average accessibility	S.E.	Mean difference with low-income neighborhoods	Sig
Public	Low-income	3.25	3.77		***
	Medium-low-income	5.85	4.52	2.59	***
	Medium-high-income	9.98	4.57	6.72	***
	High-income	12.49	4.41	9.24	***
F		1351.57			
Sig		***			
Private	Low-income	3.13	3.90		***
	Medium-low-income	5.75	4.90	2.62	***
	Medium-high-income	10.48	4.84	7.35	***
	High-income	12.87	4.75	9.73	***
F		1380.43			
Sig		***			

Note: *p < 0.1, **p < 0.05. ***p < 0.01.

Table 2
One-way ANOVA for accessibility to secondary hospitals.

Travel mode	Neighborhood type	Average accessibility	S.E.	Mean difference with low-income neighborhoods	Sig
Public	Low-income	2.36	1.26		
	Medium-low-income	2.62	1.24	0.26	***
	Medium-high-income	3.41	1.14	1.05	***
	High-income	3.81	1.02	1.45	***
F		475.01			
Sig		***			
Private	Low-income	2.62	1.45		
	Medium-low-income	2.60	1.33	−0.02	
	Medium-high-income	3.19	1.05	0.57	***
	High-income	3.48	0.98	0.86	***
F		180.27			
Sig		***			

Note: *p < 0.1, **p < 0.05, ***p < 0.01.

Table 3
One-way ANOVA for accessibility to primary hospitals and neighborhood clinics.

Travel mode	Neighborhood type	Average travel time/min	S.E.	Mean difference with low-income neighborhoods	Sig
Public	Low-income	39.02	16.60		
	Medium-low-income	32.73	12.64	−6.29	***
	Medium-high-income	26.39	9.16	−12.62	***
	High-income	22.65	5.82	−16.37	***
F		508.78			
Sig		***			
Private	Low-income	9.89	5.55		
	Medium-low-income	7.91	4.00	−1.98	***
	Medium-high-income	5.86	2.83	−4.02	***
	High-income	4.63	1.80	−5.26	***
F		499.03			
Sig		***			

Note: *p < 0.1, **p < 0.05, ***p < 0.01.

Table 4
Accessibility to hospitals of different levels in the urban areas.

Travel mode	Neighborhood type	Tertiary hospitals	Secondary hospitals	Primary and neighborhood hospitals/min
Public	Low-income	6.75	2.69	33.48
	Medium-low-income	7.97	3.00	30.35
	Medium-high-income	10.10	3.44	26.11
	High-income	12.54	3.82	22.61
Private	Low-income	6.90	2.70	8.02
	Medium-low-income	8.15	2.93	7.15
	Medium-high-income	10.61	3.21	5.78
	High-income	12.92	3.49	4.61

Table 5
Accessibility to hospitals of different levels in the suburban area.

Travel mode	Neighborhood type	Tertiary hospitals	Secondary hospitals	Primary and neighborhood hospitals/min
Public	Low-income	1.84	2.23	41.25
	Medium-low-income	2.12	1.95	36.91
	Medium-high-income	1.70	1.52	46.05
	High-income	1.42	1.29	30.37
Private	Low-income	1.61	2.59	10.64
	Medium-low-income	1.55	2.02	9.24
	Medium-high-income	1.81	1.88	11.31
	High-income	0.86	1.66	8.15

better access to primary hospitals or neighborhood clinics at the very least because such sites are deemed to be the basic necessities of the public services that are supplied by the government. My results reveal the government's failure to distribute primary healthcare services equally in the context of rapid urbanization in Beijing. There could be two major reasons for this. One reason is that the average size of a new neighborhood is larger than that of the traditional neighborhood. In particular, new social housing neighborhoods where low-income people live are characterized by large households. For example, Honglongguan neighborhood was 8.5 km² in size and inhabited by 460,000 people in 2015. The other reason is that the supply of public transit services lagged behind low-income neighborhood development in the context of rapid urbanization.

Thirdly, transit provision is an important factor that affects levels of social inequity in relation to hospital accessibility. Previous research has mainly focused on the unequal spatial distribution of public health services (Wang, 2012), but has rarely taken into account the unequal distribution of transit services. In both developed and developing countries, public transit is considered to be the main transport mode for low-income people without cars. Therefore, improving public transit services for the low-income population is considered to be an important way to improve the accessibility of public services, including healthcare services (Jones and Lucas, 2012; Lucas, 2012; Blumenberg and Manville, 2004). The results of my analysis show that low-income neighborhoods not only have fewer choices in terms of accessible hospitals when compared with those from high-income neighborhoods but also that their access to all levels of hospitals by public transit is also generally lower than their counterparts. In this sense, an overall improvement of public transit across the whole city may not mitigate the inequity in accessibility of healthcare services between low- and high-income neighborhoods. Therefore, improving the forms of public

transportation that are available to targeted low-income neighborhoods could be a more practical and effective way of enhancing social equity in hospital accessibility.

Fourthly, those from suburban neighborhoods experience more restricted access to medical services than those whose neighborhoods are located in central urban areas. In Beijing, hospitals – especially top-level hospitals – are mainly clustered in the city center and inner suburbs. There is a spatial mismatch of healthcare resources and deprived neighborhoods. In the meantime, like other megacities in developing countries, Beijing is still growing in the context of rapid urbanization. The ongoing urban sprawl is worsening the spatial inequality that is being experienced in relation to access to medical services; action needs to be taken.

For example, research has shown that some low-income neighborhoods on the urban fringe have extremely low levels of access to primary hospitals and neighborhood clinics. Such hospital provision is very important to this population for addressing medical emergencies and securing diagnoses as these hospitals are more affordable than top-tier hospitals. Those who live in low-income neighborhoods are typically less likely to own a car, and so having the ability to access primary hospitals and neighborhood clinics by using public transportation is very important for their health. The task of providing an efficient and convenient system of public transportation on the urban fringe of Beijing is, though, often a challenging one for the government (Zhao, 2010).

Fifthly, housing policies need to be extended in order to tackle the problem of unequal access to hospitals (Jones and Lucas, 2012; Lucas, 2012). Hospitals were found to have significant influences on nearby housing prices in Beijing (Ding et al., 2010). As a result, low-income neighborhoods are pushed away by the real estate market as a result of the capitalization of high-quality healthcare resources. What is worse, the unequal distribution of transportation services may reduce the hospital accessibility of deprived neighborhoods. Therefore, many patients and their carers live near these hospitals to overcome the transportation obstacles reducing access to top-tier hospitals in Beijing. Many apartments near hospitals are constructed and renovated without approval to decrease rental costs per household and accommodate a certain number of households. Problems such as overloading of water and electricity utilities, or overcrowding, make these residences unsafe (Luan, 2013). However, improving public transit to top-tier hospitals for low-income neighborhoods may be an effective way to reduce informal housing near top-tier hospitals.

For future research, several caveats of this paper should be acknowledged. First, the capacity of supply was evaluated by number of beds in this paper, which may miss several important factors such as the level of medical facilities and medical stuff as well as the specialty of hospitals. Second, socioeconomic attributes were inferred from second-hand housing prices, which will not assess hospital accessibility for those living in informal houses. However, this population, which includes early-career young adults and migrant workers, raises very important social equity implications. There is considerable evidence that shows that most migrant workers live in low-income neighborhoods (Huang and Jiang, 2009; Zhao, 2013). Low rates of housing rent and the low costs of daily necessities in low-income neighborhoods are major sources of attraction (Deng, 2017). Additionally, the correlation of housing prices and socioeconomic status should be supported with more robust data. Finally, this study was unable to explore the relationship between hospital accessibility and actual hospital usage and health outcomes at the neighborhood level, due to a lack of data.

5. Conclusions

To build fair cities with equal urban living environment for all is one of key issues in relation to the achievement of new sustainable development goals by UN-Habitat. In particular, equal accessibility to basic medical facilities and services between different people and neighborhoods is a primary condition for the development of fair city. However,

the recent years have witnessed an increasing inequality in accessibility to hospitals in developing countries. The situation seems to be worse in growing megacities where more than 10 million people live and rapid urban sprawl has caused serious problems with supply of health and public transport services. Recently, COVID-19 emerged as a worldwide pandemic that has impacted the quality of life of nearly everyone in cities. Equal access to basic medical facilities and services for all individuals from all neighborhoods could play an important role in combating the COVID-19 pandemic.

Although some studies about health inequality in cities of developing countries have been done, the spatial inequity in hospital accessibility between neighborhoods in megacities is an important yet rarely discussed topic. This paper aims to fill these gaps by looking at Beijing as a case study. I have shown, through the results of my analysis, that those who come from low-income neighborhoods experience more limited access not only to high-tier hospitals (secondary and tertiary hospitals) but also to primary healthcare services (primary hospitals and neighborhood clinics). The hospital accessibility rates of high-income neighborhoods to tertiary hospitals and secondary hospitals are approximately 4 times and 1.5 times as high as those of low-income neighborhoods. It takes low-income people nearly twice the time to get to the nearest primary hospital or neighborhood clinics when compared with those from high-income neighborhoods. Those who come from low-income neighborhoods should, at the very least, have better access to these primary hospital or neighborhood clinics which are seen as necessities aspects of public services, supplied by the governments. This is mainly due to the unequal provision of healthcare and public transportation services. In addition, suburban neighborhoods have more limited access to medical services than neighborhoods that are located in central urban areas. The rapid urban sprawl has been worsening the spatial inequality in access to medical services in growing megacities. For future policy, equal access to healthcare services should be prioritized, especially in the context of the urban growth management of megacities in developing countries in order to ensure a fair and inclusive urbanization process. Equal access to healthcare services would also be most helpful in managing the COVID-19 pandemic.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.healthplace.2020.102406.

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