Equity of pediatric diagnosis and treatment hospital allocation from the perspective of supply and demand: a case study from Shanghai, China

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Abstract
It has become a consensus to promote a balanced and equitable distribution of regional medical and health facilities, and hospitals that provide paediatric care are an important place and the last line of defence in safeguarding children's health. However, problems such as uneven distribution of medical resources and poor accessibility to nearby services are common. In order to understand whether there is equity in the allocation of paediatric hospitals, from the perspective of 'supply and demand', taking into account the spatial distribution and supply of hospitals, as well as the distribution of children and their demand, to explores whether there is an imbalance between the supply and demand for resources in different regions.

Keywords: Supply and demand balance, social justice, vulnerable groups, pediatric hospitals

1 Introduction

There is currently widespread concern about social issues related to children's health, and ensuring that the need to safeguard children's healthy development is not overlooked has become an important consideration in facility planning. Hospitals, as key venues for safeguarding children's health, serve as the last line of defence for their physical and mental well-being. This study examines the distribution of children's healthcare facilities from a supply-demand perspective to investigate how hospital layout impacts children's access to nearby services and the balance between supply and demand, thereby providing planning recommendations for the allocation of medical resources.

The urban-rural dichotomy has led to issues such as uneven distribution of medical facilities between urban and rural areas (Ni et al., 2025). Therefore, many scholars have conducted research on the distribution and accessibility of medical facilities. Existing studies have used various research units, including counties (Cheng et al., 2016) and townships/subdistricts (Zhong, Yang and Chen et al., 2016), and common measurement methods include the proportional model method (Kong, Li, and Zhang et al., 2008), the minimum distance model (Fan et al., 2017), the two-step moving search method (Deng et al., 2015), and the potential model (Wu et al., 2017). This study comprehensively considers the spatial distribution of the research subjects, as well as supply and demand factors, to analyse the differences in the supply and demand of children's healthcare resources across different regions.

2 Data and Methods

2.1 Research area and subjects

Shanghai Municipality was selected as the study area. Chongming Island was temporarily excluded from consideration due to its geographical isolation. The study scale was based on the administrative divisions of towns and sub-districts in Shanghai (Fig. 1). The population aged 0–14 years in each sub-district was considered the demand side, while hospitals providing paediatric care were considered the supply side. The study analysed the proximity of paediatric healthcare services, supply-demand balance, and facility competition, and proposed an evaluation of the layout of paediatric care hospitals in the city.

Fig. 1. Administrative divisions of Shanghai municipalities (excluding Chongming Island).

2.2 Data Sources and Processing

(1) Child Population Data.

The number of children aged 0–14 in each subdistrict of Shanghai was extracted from the seventh national census to serve as the demand volume for healthcare services. The centroid of each subdistrict was used as the location for healthcare service demand, with a total of 202 subdistrict demand points.

(2) Paediatric Hospital Data.

Referring to the Shanghai Municipal Government's 'List of Major Medical Institutions Providing Paediatric Medical Services in Shanghai,' paediatric care-providing hospitals were selected from Shanghai's medical POI data, including both general and specialised hospitals, as the locations of healthcare providers. The actual number of available beds at each hospital was queried as the supply volume of healthcare providers. Due to the inclusion of branch hospitals under the main hospital, a total of 84 hospital supply points were extracted.

2.3 Research Methods

Considering that medical institutions are public welfare facilities, the study first employs service area analysis to examine their proximity service capacity. It then uses the moving search method and two-step moving search method to analyse their supply-demand relationships. Finally, the Huff model is applied to analyse the influence ranges of each hospital, reflecting a certain degree of facility competition, thereby proposing evaluations and recommendations for the current distribution of paediatric hospitals.

3 Results and Analysis

3.1 Distribution of the Child Population and Paediatric Healthcare Facilities

First, the data was visually analysed using graded symbols to indicate the number of people aged 0–14, divided into ten categories based on natural breaks. As shown in Fig. 2 (a), children and adolescents are primarily distributed in suburban areas, with significant concentrations in districts such as Baoshan, Minhang, Pudong, and Putuo. In central urban areas, the distribution is densely concentrated, but each neighbourhood has a relatively small population.

From Fig. 2 (b), which shows the distribution of paediatric hospitals and the number of beds, it can be seen that hospitals in the central urban areas are generally larger in scale. This is likely because comprehensive hospitals are typically headquartered in the central urban areas, resulting in a higher number of beds. For example, Huangpu and Jing'an districts have several large medical institutions offering paediatric care. In peripheral areas, each district generally has one or two large medical institutions, with some smaller affiliated hospitals distributed around the periphery to meet local healthcare needs.

(a) Population aged 0–14 each subdistrict. (b) paediatric hospitals and number of beds.

Fig. 2. Spatial distribution of research subjects in Shanghai.

3.2 Proximity Service Analysis

Proximity services primarily consider the spatial relationship between supply points and demand points. Starting from a customer-oriented perspective, the nearest supply point for each demand point is determined. Due to the large spatial scale, Euclidean distance is used for calculation. Through GIS nearest neighbour analysis, the hospitals closest to each subdistrict demand point are identified. Figure 3 shows the number of times each hospital is the nearest facility. It can be seen that some hospitals are the nearest hospitals for five surrounding subdistricts demand points, while others are not the nearest hospitals for any demand point, indicating an uneven spatial distribution.

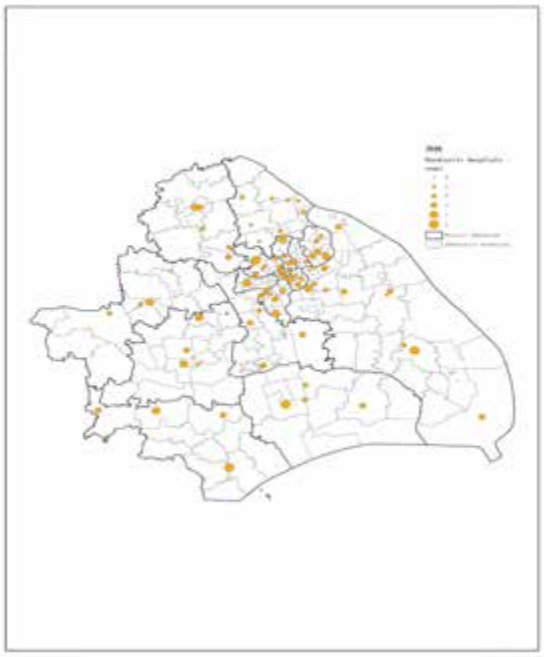

Fig. 3. Number of paediatric diagnostic and treatment hospitals in Shanghai as the nearest facility.

Secondly, from a facility-oriented perspective, buffer zone analysis (Fig. 4) shows that within a 5 km service radius of the hospital, i.e. a 15-minute commute, the central urban area is basically fully covered, but there are still a large number of demand points in the suburbs of Shanghai that are not covered. Within a 10 km service radius, i.e., a 30-minute commute, only a few demand points remain unaccounted for, and within a 15 km radius, all townships are within the service area. From a facility-oriented perspective, the central urban area is highly concentrated, making medical travel very convenient, while medical travel for children in suburban areas generally requires a longer time.

(a) 5km buffer (b) 10km buffer (c) 15km buffer

Fig. 4. Coverage of 5km, 10km and 15km service radius of Shanghai paediatric diagnostic and treatment hospitals.

3.3 Supply-Demand Balance Analysis

Supply-demand balance analysis primarily considers the capacity limits of facilities. The mobile search method is employed to simultaneously account for proximity-based service provision and supply-demand balance. As hospitals are public welfare facilities, the mobile search method is suitable for calculating the maximum service capacity available at each demand point. Given that paediatric healthcare facilities must achieve full coverage, and based on the '1560' healthcare circle planning in Shanghai, which stipulates that a tertiary hospital must be reachable within 60 minutes, a distance threshold of 15 km was selected for this study.

Figure 5 shows the maximum likelihood of obtaining services at each demand point, visualised using geometrical intervals. The supply-demand ratios in the central urban areas are relatively high, with supply fully meeting children's needs. Some townships in Baoshan District, Songjiang District, Minhang District, and Pudong New Area are also close to hospitals, with relatively high supply-demand ratios. However, some townships in the outer suburban areas have very low supply-demand ratios, with significant supply-demand imbalances observed in the northwestern and southeastern suburban areas.

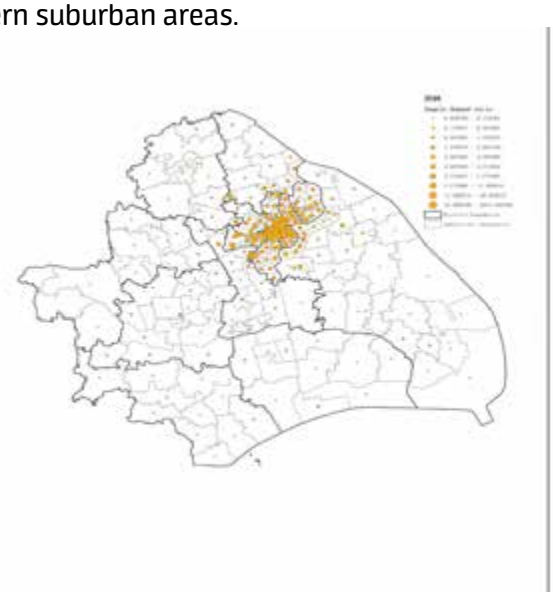

Fig. 5. Ratio of supply and demand of hospitals for children in subdistrict of Shanghai.

Furthermore, the two-step moving search method is employed to consider scenarios where supply points serve multiple demand points simultaneously. The two-step moving search method analyses the accessibility of facilities through supply-demand relationships, ensuring that the supply-demand ratio within the search threshold range adequately accounts for both supply and demand (Zong et al., 2021).

As shown in Fig. 6, when considering the simultaneous provision of services at supply points, the central urban area has the highest service accessibility, while the southern suburban area has relatively improved medical accessibility, mainly because there are fewer demand points sharing the same hospital in the surrounding areas, allowing hospital resources to better serve local children. However, the current suburban areas of Qingpu and Jiading still face issues of poor accessibility. Spatial connectivity better reflects the supply-demand balance of paediatric healthcare facilities, with better conditions in the central urban area and southwestern suburban areas, and poorer conditions in the northwestern and eastern peripheral regions of Shanghai.

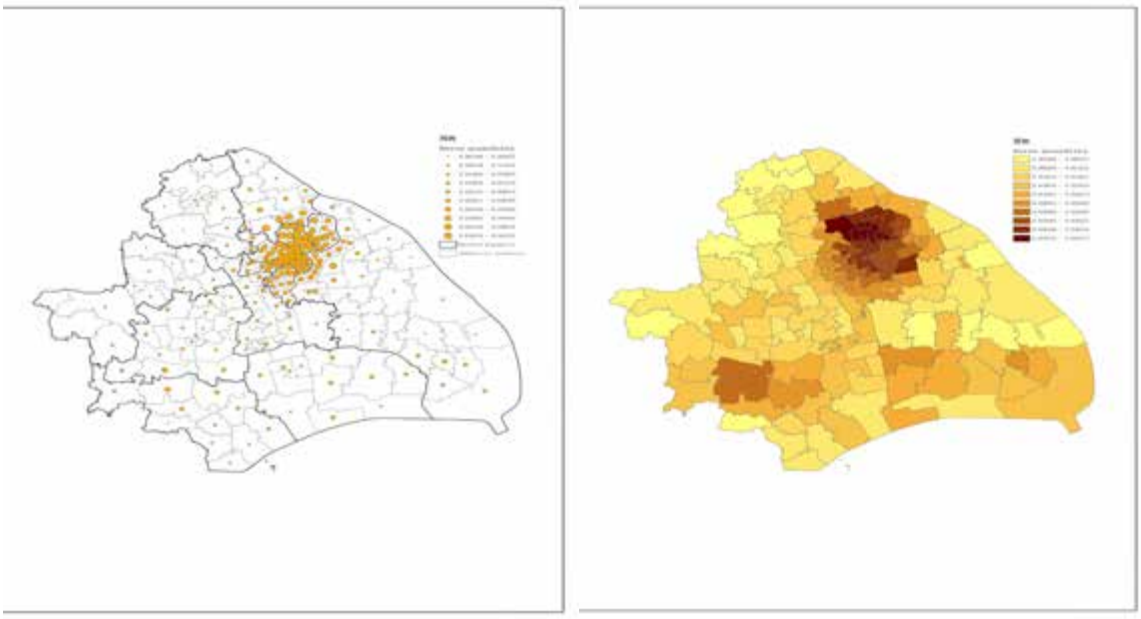

Fig. 6. Accessibility of children's medical services each subdistrict in Shanghai.

3.4 Facility Competition Analysis

There is also an issue of patient preference for hospitals. Although hospitals are public service facilities, it is necessary to consider competition between different hospitals. The aforementioned supply-demand relationship reflects the opportunities for children to choose hospitals, while facility competition reflects their preferences. The Huff model from the interaction model is selected, with hospital grading (Grade A > Grade B, Grade 3 > Grade 2) as the basis for determining attractiveness. with attraction increasing sequentially from Grade 2 Grade B to Grade 3 Grade A, and the power function distance decaying with a coefficient of 2. The maximum potential of each demand point is calculated (Fig. 7). Hospitals in suburban areas generally have greater potential in district centres, as medical institutions tend to be located in district centres to better serve the surrounding areas.

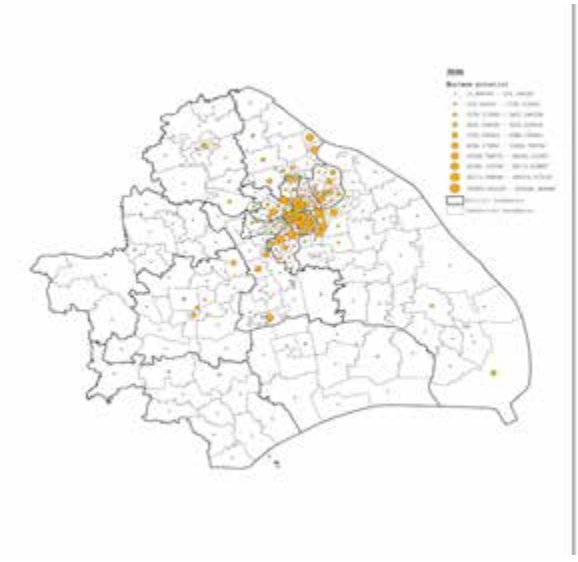

Fig. 7. Maximum potential of children's medical treatment in Shanghai.

From the sphere of influence (Fig. 8), it can be seen that under certain attraction settings, paediatric hospitals have their own main service areas. Competition is fierce in the central urban areas, with each hospital basically occupying one subdistrict. The suburbs are relatively loose. Based on attraction and distance, some hospitals need to serve the medical needs of children in a larger area. Overall, the further out the hospital is, the more subdistricts and townships it serves, but it is also relatively balanced, with each hospital serving several areas.

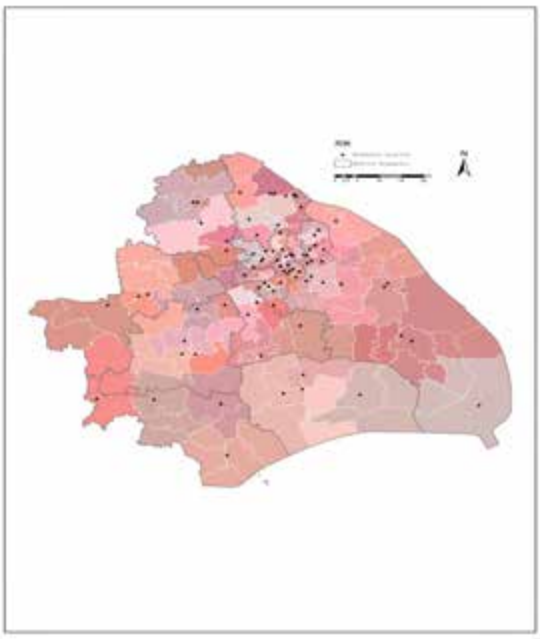

Fig. 8. Areas of influence of paediatric hospitals in Shanghai.

4 Summary

4.1 Conclusions

(1) From the perspective of spatial distribution characteristics, children and adolescents are primarily concentrated in the northern part of Shanghai, with a higher concentration in districts such as Baoshan, Jiading, and Pudong. Hospitals providing paediatric healthcare services are predominantly located in urban centres, with relatively balanced distribution in outlying areas, and each district has its own leading hospital.

(2) From the perspective of spatial proximity, hospitals located in district centres provide more services and are the nearest facilities to a higher number of demand points.

(3) From the perspective of spatial supply and demand, the central area has significantly higher supply and demand, while the central parts of Pudong, the southern part of Jinshan, and the central parts of Qingpu and Songjiang have relatively lower supply and demand. Considering the constraints on simultaneous supply capacity, the northwestern and eastern parts of Shanghai have poorer supply and demand, as these areas have a large number of children but fewer hospitals.

(4) From the perspective of hospital quality appeal and distance, the central urban area, Baoshan District, and Minhang District all have significant medical potential. From the perspective of influence distribution, hospitals in the outer suburbs serve the paediatric healthcare needs of more sub-districts, with relatively balanced distribution across corresponding sub-districts and towns.

4.2 Recommendations

Based on the above conclusions, the study proposes the following recommendations: (1) Overall, from a supply and demand perspective, Pudong, Qingpu, and Jiading districts have relatively insufficient paediatric hospitals. It is necessary to further supplement local medical resources and establish more hospitals specialising in paediatric care. (2) In terms of quality, Pudong has a higher concentration of attractive hospitals, while Qingpu and Jinshan districts lack sufficient hospital appeal. The penetration of tertiary hospitals, including service quality, lags behind other regions. It is necessary to further decentralise high-quality resources to local areas and build higher-quality paediatric hospitals.

Hospitals providing paediatric care serve as a crucial line of defence for ensuring children's healthy development. They should achieve full coverage within the region and maximise accessibility for children seeking medical care, thereby reducing the time required to reach a hospital. From the current layout of paediatric care hospitals, the supply-demand balance and accessibility in Shanghai's central urban areas are at a relatively high level, while suburban areas exhibit varying degrees of disparity in supply-demand balance and accessibility. In the future, it is recommended to adopt medical consortiums and resource sharing to drive the development of local paediatric hospitals. For example, medical consortiums can be used to integrate and reorganise the talent, technology, and information resources of medical institutions at all levels (Chen, Li and Zeng et al., 2018), optimise their supply and demand structure, promote the downward flow of high-quality medical resources, and provide more high-level hospitals for the treatment of children's diseases in a wider area, thereby driving the high-quality coverage of medical resources across the entire region.

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