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Original Paper

Research on the Matching of Supply and Demand of Basic Public Education Services in the Main Urban Area of Zhengzhou Based on Accessibility

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Abstract

There is an imbalance between urban and rural people in basic public education services. At present, there are few studies on the matching of supply and demand considering the actual living population of residential communities at the street level and the number of degrees provided by basic public education services. From the perspective of the matching of supply and demand of basic public education services in space, taking Zhengzhou as an example, this paper makes an in-depth analysis of the accessibility of primary and secondary schools in the main urban area of Zhengzhou by improving the two-step mobile search method, and further analyzes the spatial imbalance of supply and demand matching. The results show that most of the central areas in the main urban area belong to high demand and high supply areas, but they still cannot meet the needs of educational resources, and the matching degree of supply and demand of educational resources in primary and secondary schools is low. The periphery of the central area, namely the southwest of Erqi District, the north of Huiji District and the northeast of Jinshui District, belongs to the low-demand high-supply or low-demand medium-supply area, and the supply and demand matching degree is high. The competent authorities need to pay close attention to the development trend of the city and the change of the resident population, so as to adjust the layout of educational resources in time. Encourage and support the flow of high-quality educational resources to marginal areas, narrow the educational gap between regions, and steadily promote the goal of high-quality and balanced basic public education services.

Keywords

basic public education services, improved two-step mobile search method, accessibility, supply and demand matching, zhengzhou

1. Introduction

Basic public education service (Note 1) refers to the basic public service provided in the field of education. It has four main characteristics: public, inclusive, basic and developmental. It is the basic premise and foundation for realizing the lifelong development of human beings. Equalization of basic public education service is one of the core contents of public service planning in China (Jia & Li, 2023). The Central Committee of the Communist Party of China clearly proposed to "optimize the allocation of regional education resources and establish a basic public education service supply mechanism coordinated with population changes". This deployment aims to promote education equity and enhance the balance and accessibility of basic public services.

Supply and demand matching is a concept often used in economics (Wang & Mo, 2024). The application of in the field of education refers to the fact that the supply and demand of educational resources can achieve a coordinated state in quantity and structure. There is neither a waste caused by the surplus of educational resources nor a social injustice caused by the shortage of educational resources, that is, the supply of educational resources can fully meet the social demand for educational resources. The existing research mainly focuses on the three dimensions of supply, demand or the combination of supply and demand. The research on the supply dimension of educational resources often uses accessibility to evaluate the service level of facilities (Sheng & Cai, 2018). The commonly used accessibility calculation methods include the nearest distance method, the supply and demand ratio method, the potential model , the cumulative opportunities measure, two-step floating catchment area and the optimal supply and demand allocation model (Wei, Yang, & Hong, 2023; Wang et al., 2020; Guagliardo, 2004; Yan, 2016; Luo & Wang, 2003; Kim & Wang, 2019; Williams & Wang, 2014). In summary, the basic assumption of the nearest distance method is that individuals tend to choose to use the nearest public service facility, but this method ignores the multiple factors that affect decision-making in real life, and does not take into account the service capacity of the facility itself; the law of supply and demand ratio evaluates the allocation of resources by calculating the ratio of supply and demand of facilities in a specific area. It assumes that the facilities only serve the residents within their preset service radius, but in fact there may be cross-regional use; the potential model aims to estimate the use pattern by quantifying the attenuation of facility attraction with the change of geographical distance, but in practice, it is difficult to find the distance attenuation coefficient that matches the reality. The cumulative opportunity measure is based on a fixed upper limit of time or distance to count the number of public service facilities that can be reached from a certain location, but ignores the willingness to visit that decreases with the increase of distance; the optimal supply and demand allocation model is that the overall service capacity of public service facilities should reach or exceed the level of total demand. In contrast, the two-step floating catchment area better reflects the supply and demand situation of the facility and its spatial accessibility by introducing the concept of threshold, and is more and more applied in the study of accessibility (Wei, Yang, & Hong, 2023; Wang

et al., 2020; Guagliardo, 2004; Yan, 2016; Luo & Wang, 2003; Kim & Wang, 2019; Williams & Wang, 2014; Zhai et al., 2022; Song et al., 2010).

However, the imbalance of basic public education services between different groups in urban and rural areas is still prominent. The existing literature pays more attention to the imbalance of educational resources between urban and rural areas, ignoring the accessibility and convenience of education services among different groups in urban areas (Zhang et al., 2023; Li, Yang, & Wu, 2021; Han, Li, & Zhang, 2015; Xue, 2016). At present, there are few studies on the matching of supply and demand considering the actual living population of residential communities at the street level and the number of degrees provided by basic public education services. Taking Zhengzhou, the capital city of Henan Province, a populous province, as an example, this paper studies the matching of supply and demand of basic public education services in the main urban area of Zhengzhou according to the educational needs of the actual residential population size of the residential area, and clarifies the direction of supply and demand optimization of basic public education services in the next step, which can provide reference for the high-quality and balanced development of basic public education services in various regions of the main urban area of Zhengzhou.

2. Overview of the Study Area and Data Description

2.1 Overview of the Study Area

Zhengzhou is the capital of Henan Province, the national central city and the core city of the Central Plains urban agglomeration. The main urban area of Zhengzhou includes Erqi District, Zhongyuan District, Guancheng District, Huiji District, Jinshui District and Shangjie District. Since Shangjie District is an enclave, this paper will not discuss it for the time being. At the end of 2022, the permanent population in the main urban area of Zhengzhou was 7.109 million. According to the notice of the State Council on adjusting the standard of urban scale division in 2014, Zhengzhou has entered the ranks of megacities.Figure 1 is the research Location Map.

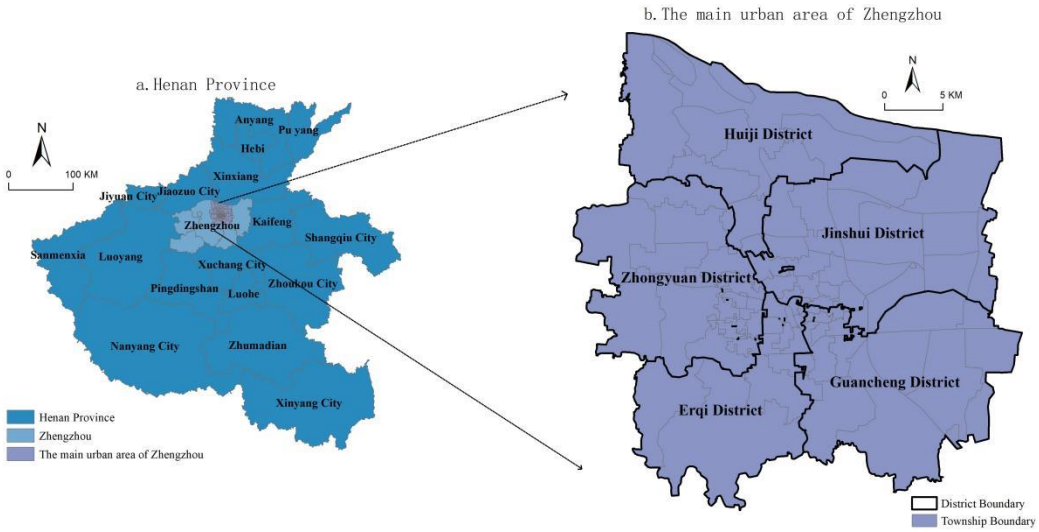

Figure 1. Research Location Map

2.2 Data Source and Processing

2.2.1 Residential Quarter and Population Data

The spatial location of the residential area, the number of households and other information are obtained from the residents by Python crawler technology. After data cleaning, the residential area is divided according to the administrative division of the main urban area of Zhengzhou.

Taking the resident population data of residential quarters as the demand side of basic public education services, in order to obtain the population data of each residential quarter, the steps are as follows:

The first step is to count the total number of residential quarters collected in each administrative district of the main urban area of Zhengzhou City. The size of the population collected in each administrative district of the main urban area of Zhengzhou City = the total number of residential quarters collected in each administrative division of the main urban area of Zhengzhou City * The average population of each household (the seventh national census bulletin of Zhengzhou City shows that the average population of each household in Zhengzhou City is 2.82); In the second step, due to the error between the population size collected by each administrative region in the main urban area of Zhengzhou City and the resident population size of each administrative region in the "Zhengzhou Statistical Yearbook 2023", it is necessary to correct it. Calculate the correction coefficient, the correction coefficient = the resident population size of each administrative region in the "Zhengzhou Statistical Yearbook 2023"/the population size collected by each administrative division; The third step is to calculate the size of the resident population in each residential area, the resident population in each residential area = the number of households in each residential area * correction coefficient * average population per household. Figure 2a is the spatial distribution of residential quarters in the main urban area of Zhengzhou, and Figure 2b is the spatial distribution of population in residential areas in the main urban area of Zhengzhou.

2.2.2 Basic Public Education Service Data

Taking the number of degrees in primary and secondary schools in the main urban area of Zhengzhou as the supplier of basic public education services, the list of compulsory education is derived from the Zhengzhou Municipal Government Data Disclosure Network, and its spatial location information is obtained through Python crawler technology.

The steps to obtain the number of degrees in primary and secondary schools are as follows:

The first step is to obtain the number of classes in primary and secondary schools. The information of the number of classes is partly derived from the Zhengzhou Municipal Government Data Disclosure Network, and partly from the public number that can be searched. If the number of classes in individual schools is not searched, it is calculated according to the number of students shown in the Zhengzhou Municipal Government Data Disclosure Network and the average class size in the "Statistical Bulletin of Zhengzhou Education Development in 2023"; The second step is to obtain the supply of degrees in primary and secondary schools. The supply of degrees = the number of school classes * the standard class size of primary and secondary schools (according to the 'Urban Ordinary Primary and Secondary School Building Construction Standards' "Rural Ordinary Primary and Secondary School Construction Standards," the current standard class size of primary and secondary schools is 45 primary schools and 50 junior high schools). Figure 2c is the spatial distribution of basic public education services in the main urban area of Zhengzhou.

2.2.3 Road Network Data

The road network data is derived from OpenStreetMap and the obtained data is subjected to network data set construction and topology processing. Figure 2d is the distribution of roads in the main urban area of Zhengzhou City.

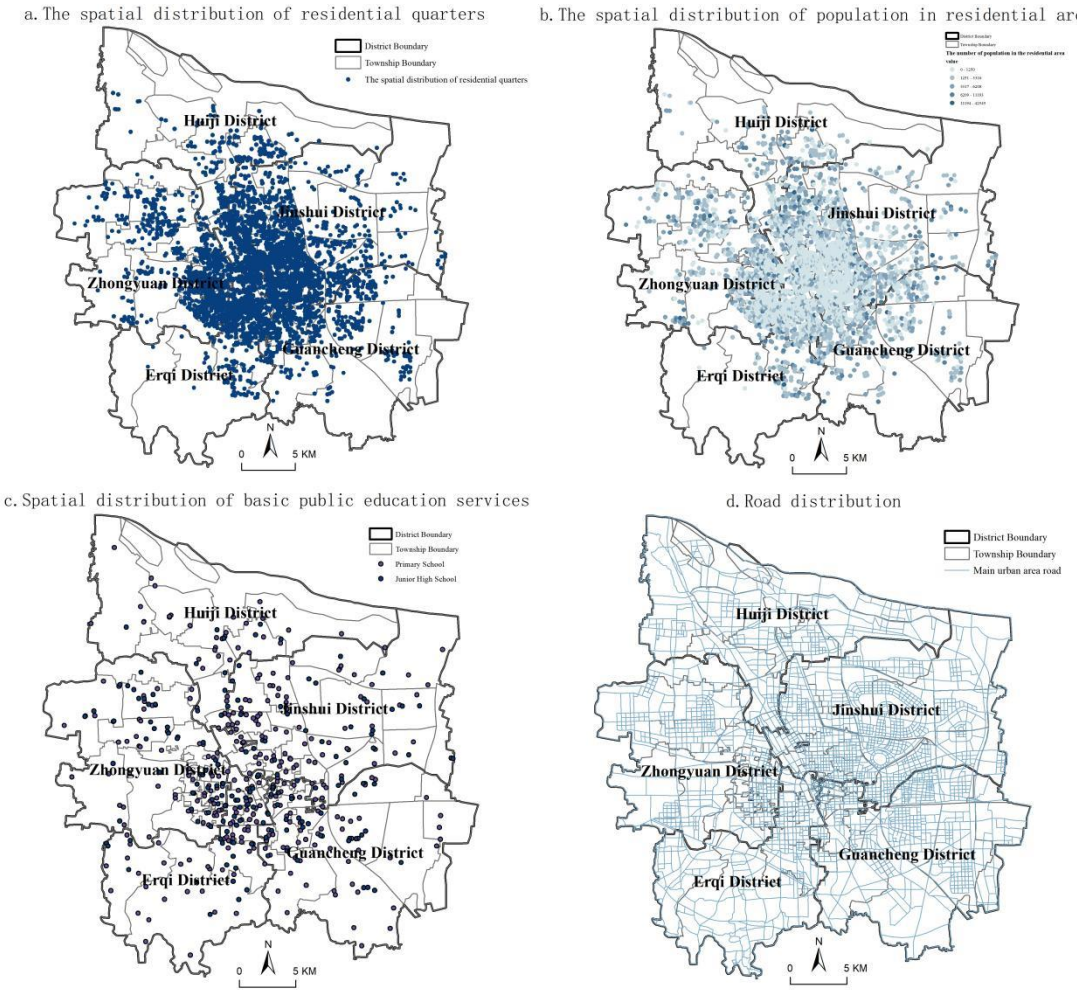

Figure 2. Basic Public Education Service Supply and Demand in the Main Urban Area of Zhengzhou and Road Data

3. Research Method

3.1 Nuclear Density Analysis

Kernel density analysis is a spatial analysis method commonly used in geographic information system (GIS), which is mainly used to calculate the distribution density of point or line elements in geographic space. This method calculates the density contribution of each point to the surrounding area by setting a smooth surface defined by the kernel function around each feature point, taking the point as the center and according to the principle of distance attenuation. When implemented in GIS, kernel density analysis uses the specified search radius to determine the influence range, and superimposes the contribution value of each point on each grid. The core is that the closer the grid element is to the point element, the higher the density value is obtained, and the density value of the grid element exceeding the search radius is zero. If the kernel surfaces of multiple point elements overlap at some grids, the density values of these grids will be accumulated, and finally the density distribution map of the entire study area will be formed. This process can convert discrete data into continuous spatial density

expression, which is convenient for visual presentation and further analysis. The calculation formula of nuclear density is

$$f_n = \frac{1}{nh} \sum_{i=1}^{n} k(\frac{x - x_i}{h}) \quad (1)$$

In the formula: for $k(\frac{x - x_i}{h})$ the kernel function; n the number of factor points in the study area; h is bandwidth parameter; $x - x_i$ is the distance from the center point of the grid to the element point.

3.2 OD Cost Matrix Analysis

OD cost matrix analysis is a spatial analysis method used to calculate the network distance between origin and destination in GIS. In the two-step floating catchment area, the travel cost between the supply point and the demand point is the key variable. It is more practical to select the road network distance as the travel cost. This paper uses the OD cost distance to calculate the shortest path network distance from the residential area to each school. Because the service radius of primary school is not more than 500 meters in principle, and the service radius of junior high school is not more than 1000 meters in principle, the travel distance threshold of primary school is 500 meters, and the travel distance threshold of junior high school and 9-year consistent school is 1000 meters. According to the analysis results of this step, it is concluded that the basic public education service facilities can be reached in the residential area within the travel distance threshold.

3.3 Gauss Two-step Mobile Search Method

The Gaussian two-step floating catchment area is based on the supply point and the demand point respectively, and sets a maximum travel distance or time as the critical value, that is, the search radius (set as the actual road network distance threshold in this paper). The mobile search is performed twice, and the resources available in the residential area within the threshold are compared. The higher the value, the better the accessibility. Considering the availability of data and drawing on relevant research, this paper selects the number of school degrees as a measure of basic public education services. The specific calculation steps are as follows.

First, the center of gravity j of each school is selected, and the actual road network distance threshold d_0 is selected as the search range, calculate the number k of each demand point falling in the region, obtain the number j of demanders that the supply point can meet, then divide the number of degrees of the supply point j by the total number of demanders, and calculate the supply and demand ratio R_j of the service provided by the school.

$$R_j = \frac{S_j}{\sum k \in \left\{ d_{kj} \le d_0 \right\} P_k} \tag{2}$$

In the formula, S_j represents the degree supply of the supply point school j; d_{kj} represents the travel distance between the residential area k and the school j; P_k denotes the total population of the residential area in the search area.

Secondly, for the center of gravity of each residential area i, the actual road network distance threshold d_0 from it to each school j is set as the demand range. The supply and demand ratio R_j of school j falling in this area is calculated, and the weight is given by Gauss equation. Finally, the weighted ratio is summed to obtain the spatial accessibility Ai of point i to obtain educational resources service.

$$G\left(d_{kj}, d_0\right) = \begin{cases} \dfrac{e^{-\frac{1}{2}\times\left(\frac{d_{kj}}{d_0}\right)^2} - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}}, d_{kj} \le d_0 \\ 0, d_{kj} > d_0 \end{cases} \tag{3}$$

$G\left(d_{kj}, d_0\right)$ is a Gaussian equation function that adds a distance decay function.

$$A_i = \sum i \in \left\{ d_{ij} \le d_0 \right\} G\left(d_{kj}, d_0\right) R_j \tag{4}$$

In the formula, d_{ij} is the road network distance between the residential area i and the supply school j; the greater the value of Ai, the better the accessibility of the services obtained by the residential area, and the closer the distance between the residents and the actual road network of the school ; the smaller the value, the worse the accessibility.

4. Results and Analysis

4.1 Spatial Distribution Analysis of Supply and Demand of Educational Resources

4.1.1 The Spatial Distribution of Educational Resources Demand Side

As the demand side of basic public education services, the residential area and its resident population in the main urban area of Zhengzhou show a strong agglomeration state in the central area of the main urban area and weaken outward, forming a small-scale residential and population agglomeration center

in other areas of each administrative region. The residential density in the central area is higher, and with the increase of the distance from the central area, the residential density gradually decreases. It may be because the central area belongs to the old urban area of the main urban area of Zhengzhou. It is the earliest area of urban development. It has a relatively mature urban infrastructure and social service system. Because of its superior location, convenient transportation and rich resources, it has become the preferred place to live. With the increase of distance from the core area, the attractiveness of the residential area gradually weakened. With the passage of time, urban expansion, new urban areas have gradually developed. In the process of urban expansion, some specific areas have developed into secondary residential centers because of certain location advantages or planning orientation. However, due to the historical accumulation and functional completeness of the old city, it still maintains a high population density.

4.1.2 The Spatial Distribution of Educational Resource Suppliers

The spatial distribution of primary and secondary schools in the main urban area of Zhengzhou shows a pattern of strong center and weak edge. In terms of spatial distribution, Jinshui District, Zhongyuan District, Erqi District and Guancheng District are the areas with the largest number of primary and secondary schools in the main urban area of Zhengzhou. The center formed by the four districts in the location is the area with the highest distribution density of primary and secondary schools in Zhengzhou. The spatial distribution of primary and secondary schools in the marginal areas of other main urban areas is relatively scattered. Although multiple sub-centers are formed, the overall concentration is low. It may be due to the high population density in the central region, the residents' demand for education is greater, while the population in the marginal area is relatively sparse, the demand for schools is naturally lower, and because of the development history and traditional comprehensive advantages of the central region, it has more school resources, while the marginal area is due to the limited level of development and other reasons, the distribution of schools is more dispersed.

On the whole, the spatial distribution of primary and secondary education resources in the main urban area of Zhengzhou is generally consistent with the population density distribution of residential areas and residential areas.

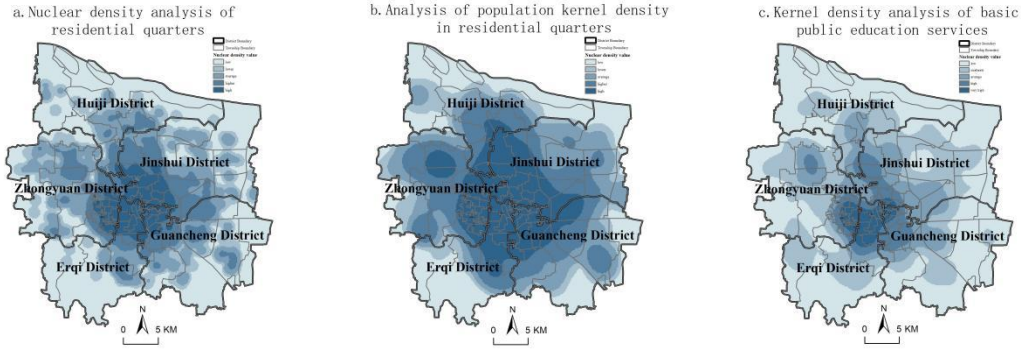

Figure 3. Spatial Distribution of Supply and Demand of Educational Resources

4.2 Analysis of Matching between Supply and Demand of Educational Resources

More than half of the residential areas in the main urban area of Zhengzhou have low accessibility to basic public education services, more than 20 % of the residential areas have poor accessibility, less than a quarter of the general residential areas have poor accessibility, and less than 2 % of the residential areas have high and high accessibility. The areas with better matching of supply and demand are only the southwest of Erqi District, the north of Huiji District, the northeast of Jinshui District and a small part of each administrative district. The reason for the better matching of supply and demand in the southwest of Erqi District and the northeast of Jinshui District is that there are fewer residential areas in these areas, but there is a certain amount of educational resources supply, which can just meet the needs of local residents. The northern part of the Huiji District may be because the northern part of the Huiji District is close to the Yellow River area. Due to geographical location and natural conditions, there are fewer residential areas and fewer educational resources. The reason for the good matching of supply and demand in a small part of each administrative region is that although these residential areas have a large demand for educational resources, they also have a large supply of educational resources. Most of the main urban area of Zhengzhou City, especially the central area of the main urban area, has a poor matching of supply and demand, because these areas have a large residential area and a large residential population. Although the supply of educational resources is also large, it still cannot meet the demand.

Table 1. The Supply of Basic Public Education Services in Each Administrative Region

Counties	Number of townships	Number of primary schools	Supply of primary school places	Number of junior high schools	Supply of lower secondary school places
Erqi District	14	68	66420	36	52600
Zhongyuan District	17	80	119020	43	67125
Guancheng District	16	76	103860	32	48350

Jinshui District	25	103	164160	36	62250
Huiji District	8	42	43560	12	19500
Total	80	369	497020	159	249825

Table 2. The Accessibility of Residential Quarters in Each Administrative Region

Counties	Number of residential quarters	Number and proportion of residential community accessibility									
		Low	Ratio	Lower	Ratio	Average	Ratio	Higher	Ratio	High	Ratio
Erqi District	780	280	35.90 %	294	37.69 %	205	26.28 %	0	0.00 %	1	0.13 %
Zhong yuan District	879	438	49.83 %	168	19.11 %	256	29.12 %	16	1.82 %	1	0.11 %
Guan cheng District	874	400	45.77 %	178	20.37 %	263	30.09 %	32	3.66 %	1	0.11 %
Jinshui District	1724	1089	63.17 %	287	16.65 %	315	18.27 %	32	1.86 %	1	0.06 %
Huiji District	231	142	61.47 %	36	15.58 %	47	20.35 %	6	2.60 %	0	0.00 %
Total	4488	2349	52.34 %	963	21.46 %	1086	24.20 %	86	1.92 %	4	0.09 %

4.3 Analysis of the Mismatch between Supply and Demand of Educational Resources

Some streets in the Erqi District, such as Dehua Street Street, Jiefang Road Street and Yima Road Street, do not have primary and secondary education resources, which may be related to the nature of land use, but there are individual residential areas; the residential areas of Huaihe Road Street and Jianzhong Street are the most, but the supply of educational resources is general, which belongs to the general area of high demand supply; Songshan Road Street has the most sufficient supply of educational resources, but the number of residential areas is also large, which belongs to the high supply and high demand area. There are a large number of residential communities in Tongbai Road Street, Central Plains District, but the supply of secondary school education resources is insufficient; the matching of supply and demand in most areas of Xiliuhu Street and Xushui Street is poor. It may be because the new development areas in these areas have formed a small-scale agglomeration center to generate certain demand for educational resources, but the allocation of educational resources has a certain lag, which can not meet the demand for educational resources for the time being. Longhai Road Street, East Street Street, West Street Street and Chengdong Road Street in Guancheng District have

less supply of educational resources, which belongs to the area of medium demand and low supply. There are many residential communities in Fengchan Road Street of Jinshui District, but the supply of educational resources is very small, which belongs to the area of high demand and low supply. The accessibility of Longhu Street, Longzihu Street, Boxue Road Street and Jinguang Road Street in the east of Jinshui District is poor. It is because it is still in the early stage of construction and the nature of regional land is different. Most of them are higher education land, but they have formed a strong aggregation effect. Local residents and teachers' children also form a certain scale of education demand, while the supply of educational resources is lagging behind. The number of primary and secondary schools is still insufficient, and the imbalance between supply and demand is more obvious. The residential area of Guoji Road Street in the northern part of Jinshui District has formed a scale, but the supply of secondary school education resources is insufficient. It may be because it belongs to the urban expansion area, and the supply of education resources cannot keep up with the demand. The matching of supply and demand in the southern part of Huiji District is general, because it is closer to the center of Zhengzhou City and other important economic zones, has better infrastructure, has more residential areas, and the number of primary and secondary schools and the number of degrees are limited.

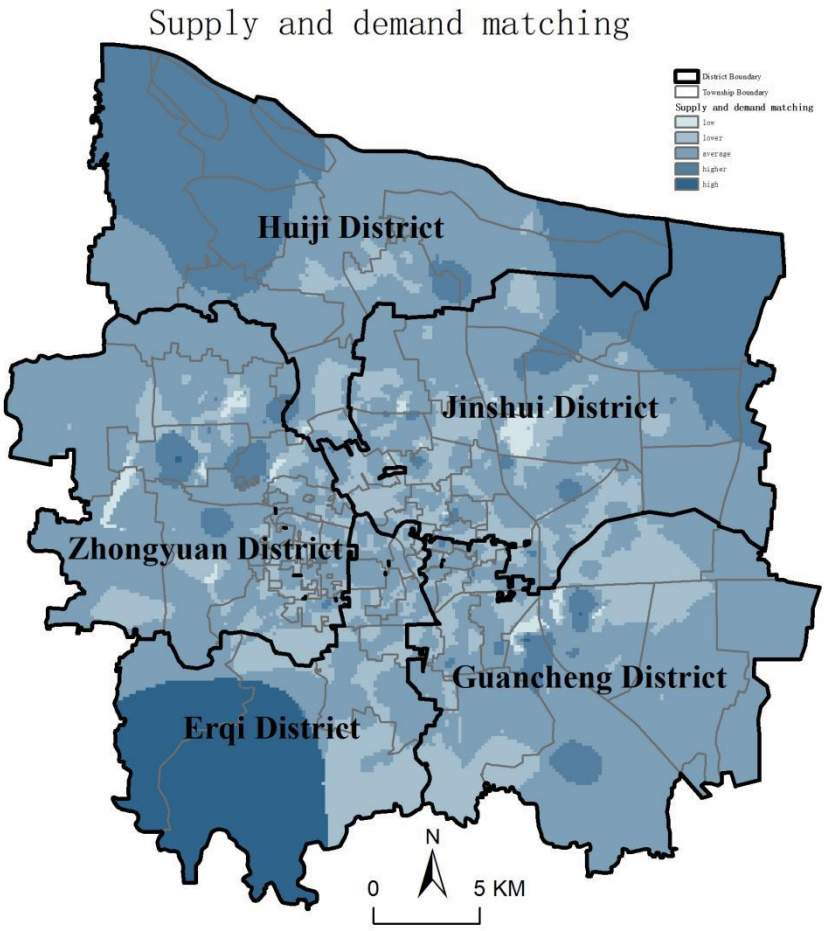

Figure 4. Supply and Demand Matching Analysis

5. Conclusions and Suggestions

5.1 Conclusion

The accessibility of basic public education services in more than half of the residential areas in the main urban area of Zhengzhou is low, more than 20% of the residential areas have poor accessibility, the accessibility of general residential areas is less than one quarter, and the accessibility of higher and higher residential areas is less than 2%. The areas with good matching between supply and demand of basic public education services are only the southwest of Erqi District, the north of Huiji District, the northeast of Jinshui District and a small part of each administrative region. Most of the areas have poor matching between supply and demand, and there are many areas with high demand and low supply, medium demand and low supply.

5.2 Proposal

The competent authorities need to pay close attention to the development trend of the city and the resident population, regularly carry out detailed statistical data collection and analysis, understand the actual changes in educational needs in different regions, and timely adjust the layout of educational resources. Although the current school district policy and the lock-up admission policy are aimed at

achieving a balanced distribution of educational resources, they also bring some challenges, such as the phenomenon of "giant schools" and "large classes." More scientific and reasonable allocation rules can be explored in the following ways: regularly reassessing and adjusting the boundaries of school districts according to population changes and urban development, and ensuring that the number of students in each school district is moderate. Carry out multi-school enrollment policy, disperse the number of students, and reduce the pressure of a single school. Through the teacher rotation system, we ensure that excellent teachers can flow between different schools, thereby improving the quality of teaching in all schools, rather than focusing on only a few schools. Encourage social organizations, enterprises and other third-party forces to participate in the distribution of educational resources, through public-private cooperation and other ways to supplement the lack of educational resources.

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Note

In this paper, basic public education services only refer to 9-year compulsory education.