

A Multidimensional Study on the Spatial Allocation of Pre-school Education Resources in River Valley Cities: Case study of Lanzhou

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Abstract: As the initial stage for children to receive knowledge systematically, pre-school education not only affects the quality of family life and happiness index, but also is an important indicator to measure the level of urban education development. Kindergarten is the main facility carrier of pre-school education. This study uses population census data and kindergarten degree and other multi-source data, based on the street scale, presents a systematic analysis of the spatial distribution of kindergarten, the relationship between the supply and demand of educational resources, accessibility, fairness in 51 streets in the central city of Lanzhou. The research is of great significance for optimizing the spatial distribution of preschool resources and adjusting the supply and equitable allocation of street-scale preschool resources. The results show that: 1) the spatial distribution of kindergartens is relatively uniform, showing the characteristics of 'one core, four centres' and east-west belt-shaped distribution. 2) The spatial distribution of school-age children roughly coincides with kindergartens, the overall mismatch between the supply of kindergarten places and the demand for the number of school-age children. with 13 streets are under supply of pre-school education resources and 38 streets are oversupply of pre-school education resources. 3) Within 300m, the number of streets with accessibility index of 0 accounted for 84.31%, and within 500m, the number of streets with accessibility index of 0 accounted for 58.82%. Along with the expansion of the search distance, the opportunity of enrolment increases, and the value of accessibility increases as well. 4) Lanzhou City preschool education resources in the range of 300-500m show inter-district overall equity and intra-district local imbalance, and in the range of 1000-1500m show inter-district overall imbalance and intra-district local equity. Finally, due to the limitations of data sources and precision, we have only discussed the allocation of preschool education resources at the street scale, and we have not been able to further analyses the differences in the access to preschool education resources, opportunities for enrolment in kindergartens, and the quality of education enjoyed by children of families from different strata at the residential scale. In the future, we will combine family income and other socio-economic factors to study social stratification and equal opportunities in preschool education resources, with a view to providing reference for strengthening the rational spatial distribution and coordinated development of preschool education resources in Lanzhou City.

Keywords: Preschool Education Resources; Spatial Distribution; Accessibility; Lanzhou City Center.

1. Introduction

The 'unit system' represents a social organisation and management system that formed during the planned-economy period. Under the unit system, every member of the society was integrated into a specific unit, with the unit having control the distribution of resources [1]. In order to strengthen the grass-roots social management in the city, the street and neighbourhood system was gradually established, 'street' refers to the street office, as the government's dispatching organ, which undertakes the function of grass-roots administration. 'Neighbourhood' refers to the residents' committee, which is responsible for organizing the residents to carry out activities such as self-management, self-education and self-service [2]. Preschool education is a concept in the context of institutionalised education in China, and its scope is defined by the age phasing of the modern school system [3-4], specifically referring to the care and education of children aged 3-6 years [5]. The development of kindergarten education configuration after the founding of New China is manifested as follows, it changed from the 'unit system' and 'street system' dominated by the unit welfare public garden configuration mode to the socialisation of the social transition period after the configuration mode change. Under the framework of the 'unit system' in the planned

economy, the unit controlled the power of resource allocation, and preschool education, as the welfare of the unit, was under the sole responsibility of the 'unit' and the 'collective', presenting a distinctive unit-affiliated characteristic [6]. However, with the profound changes in China's social and economic structure since the 1990s, the separation of 'government and enterprise' and 'government and society' has led to the gradual disintegration of the 'unit system', and the market and individual forces have come to the fore in the allocation of preschool education resources, with the vigorous emergence of privately-run kindergartens [7]. In 2004, the number of private kindergartens exceeded the number of public kindergartens for the first time, the number of private kindergartens is 52.76%. Kindergarten education has also become the field with the highest degree of privatisation and marketisation in the whole national education system [8]. The rapid expansion of private kindergartens under the market mechanism will inevitably bring problems such as management can't keep up, teachers are not guaranteed, and the quality of education is declining, etc. [9], while the public kindergartens remaining under the unit welfare system are in the position of 'exemplary' by virtue of their strong ability to obtain resources and relatively standardised kindergarten norms, and the huge 'welfare gap' between the two is very large. The 'welfare gap' between the two has become a major

contradiction in the education public service system [10]. Along with the social and economic development and improvement of people's livelihood, parents' concern for kindergarten education is no longer 'have an enrollment opportunity' of fair opportunities and balanced distribution, but the pursuit of 'a chance to go to a good school' of fair results and balanced quality [11]. Public kindergartens are usually enrolled in strict accordance with the enrolment standards and class sizes stipulated by the education department, while some inclusive private kindergartens accept as many children as possible in order to improve economic efficiency, which further triggers 'difficult' and 'expensive' enrolment in different types of kindergartens. This has further led to the problem of 'difficult' and 'expensive' access to different types of kindergartens [12]. Kindergarten education is an important aspect of urban public management and public services, and the rationality and balance of its spatial configuration directly affects the accessibility and convenience of children's education [13]. In 2021, the National Development and Reform Commission (NDRC) in conjunction with the Ministry of Civil Affairs and other 23 departments issued the 'Guiding Opinions on Promoting the Construction of Child-Friendly Cities' [Development and Reform of the Society [2021] No. 1380], which states: 'Adhere to the priority planning of public utilities, priority allocation of public resources, and priority guarantee of public services, and promote the integration of the principle of children's priority into social policies.' 'Improve the guarantee mechanism for inclusive preschool education, further increase the level of universal and inclusive, strictly implement the policy of supporting kindergartens in urban districts, make up for the short board of resources, and improve the quality of childcare and education.' Focusing on the spatial allocation of kindergarten resources, as well as their accessibility and fairness is not only a way to make up for the shortcomings and weaknesses of the city, but also a necessary path to realise the construction of a livable, green, safe, resilient, intelligent and humanistic city.

The concept of accessibility has a profound historical origin and was implicitly revealed in classical location theories. It was Hansen [14] who first clarified the concept of accessibility and defined it as the magnitude of opportunities for nodes in a transport network to interact with each other, reflecting the number of potential opportunities for residents to access facility services. Early childhood accessibility focuses on the characterisation of the ease with which young children can overcome barriers to kindergarten learning in the spatio-temporal dimension [15], and measures not only the ease with which young children can access kindergarten education resources, but also focuses on the spatial layout and accessibility of resource allocation [16]. Accessibility methods are voluminous and common: proportional modelling method, shortest distance method, potential modelling method, two-step mobile search method, and so on. Among them: the proportional model method lacks the consideration of intra-regional variability [17], the shortest distance method ignores the impact of supply and demand on accessibility [18], the potential model method and the two-step moving method (2SFCA) both consider the scale of supply and demand, as well as the impact of distance on accessibility [19], the difference lies in the treatment of the distance, and the potential model method does not limit the maximum radius of the facility service [20]. 2SFCA is a dichotomous method for distance processing, which can

effectively identify areas with low values of accessibility. In order to simulate the actual situation, many scholars have introduced 'gravity-type', 'Gaussian' and other distance attenuation functions [21]. There were scholars compared the potential model method with the 2SFCA, and found that both can effectively measure accessibility, and the results are similar. Current research on kindergarten resources focuses on the contradiction between supply and demand, fairness, and spatial distribution [22-23]. Li Jing et al. analysed the spatial distribution of kindergartens in Xicheng District, Beijing, and found that there is a problem of local concentration of quality educational resources [24]. Huang Xun studied the spatial balance of kindergarten resources from two spatial scales of streets and communities in Panyu District of Guangzhou City as a case study, and found that in the narrow and developed areas of the urban area, high-quality educational resources are concentrated, while in the vast and underdeveloped areas on the edge of the city, the density of the resources is low and the quality is poor [25]. Although the research on kindergarten education resources is getting deeper and deeper, there are still limitations in the research object, data source and research content. First of all, the research object mostly focuses on the resources of compulsory education in primary schools, junior high schools, senior high schools and university education resources, and pays less attention to the resources of preschool education. School-age children are the future of the motherland and the hope of the nation, and preschool education is the base of the national education system, which is not only related to the quality of life and happiness index of a family, but also an important indicator of the level of development of urban education; second, the data source replaces the number of school-age children of 3-6 years old with the number of the age group of 0-4 years old or 0-6 years old, which is insufficiently responsive to the characteristics of the demographic data, and it focuses on the spatial and temporal matching of the demand and supply points. And only focuses on the suitability of the spatial location of the supply and demand points to match, ignoring the matching relationship between the capacity of the facility supply and the characteristic demand population. Finally, in terms of research content, due to the lack of two key control variables, one is the estimation of the number of school-age children, and the other is the lack of data on the number of kindergarten places (i.e., reasonable enrollment scale), which leads to the study of the supply-demand issues are often inaccurate, invalid, or ambiguous, and the relationship between supply and demand cannot be analysed in a realistic manner.

Based on this, this study takes Lanzhou city centre as a case study, and explores the distribution pattern of kindergartens in urban space through kernel density analysis and standard deviation ellipse method, and analyses whether there exists the phenomenon of dense distribution in the core area and sparse distribution in the peripheral area, so as to reveal the characteristics of the agglomeration and diffusion of kindergarten resources in geospatial space. The Gaussian two-step movement method is used to study the spatial differentiation of the accessibility of kindergarten within different search distances. The matching relationship between the enrolment size and the number of school-age children in each kindergarten within the street area is examined in detail by means of the supply-demand difference method. Through accurate quantitative analysis, we can determine whether there is an imbalance between the enrolment scale and the

number of school-age children, and then explore the resulting resource tension or waste, so as to provide data support for the rational regulation of kindergarten enrolment scale and resource allocation planning. Through spatial equity indicators and other related methods, the study examines whether there are significant differences in the quantity and quality of preschool education resources among the four jurisdictions in the central city. The results of the study are intended to provide a scientific and targeted basis for the optimal allocation of preschool education resources in Lanzhou City, to help improve the level and quality of preschool education services in the city, and to promote the balanced development and sustainability in the field of preschool education.

2. Data Sources and Methods

2.1. Overview of the Study Area

China is currently in a stage of rapid urbanization, with large numbers of people moving from rural to urban areas, which has led to enormous pressure on urban kindergartens for school places; Gansu is a key area for the implementation of national policies on education poverty alleviation and balanced development of education, and compared with the eastern provinces, there is a huge difference in the distribution of total education resources, teacher strength and financial expenditure on education. Accompanied by the accelerated pace of urbanisation and the transfer of the rural population to the cities, the majority of urban school places are tight, and some students are faced with the problem of difficult and expensive school enrolment, which needs to be solved by seeking to choose schools across regions. Lanzhou City is an important industrial base in Northwest China and the capital city of Gansu Province, and the allocation of public facilities has the typical characteristics of a unitary system. Due to the limitations of socio-economic conditions, the problem of inequitable and insufficient distribution of preschool

education resources in the region is prominent, and accessibility is poor due to the profound influence of the belt-shaped urban form. By the end of 2021, the city's resident population is 4,384,300 people, kindergarten children are 135,400 people, the population density is 7,486 people/km² (Lanzhou City Statistical Yearbook 2021). With the accelerated process of urbanisation, changes in population fertility policy, the conditions for settlement in the city to be liberalised, the number of school-age children aged 3–6-year-old has increased year by year, and children of all ages who settle in the city and work in the city attend school for 153,000 people, and the valley region is small and dense, traffic congestion, and planning land constraints (Special Plan for Eliminating Large Class Sizes in Compulsory Education in Lanzhou City. http://jyj.lanzhou.gov.cn/art/2019/2/14/art_353_544416.html). In addition, the river valley is densely populated with little land, traffic congestion, and tight planning land, which brings great challenges to the spatial planning of preschool education and the government's macro-control.

Based on this context, this study takes the central urban area (26 streets in Chengguan District, 7 streets in Xigu District, 8 streets in Anning District, 9 streets and 1 town in Qilihe District) as the object of study, in which the Yanyuan Street under the jurisdiction of Chengguan District was deliberated and agreed to be added by the municipal executive meeting in 2017 by the splitting of the new street from the Yanbei Street, but the .shp surface data corresponding to it have not been updated. Therefore, based on the allocated boundaries belonging to the street office, the original base map has been corrected and preprocessed (Fig. 1). By studying the spatial distribution and accessibility of preschool education resources in Lanzhou City, it is of great significance to optimise the spatial allocation of preschool education resources, enhance the spatial quality of preschool education resources, and promote the high-quality development of preschool education.

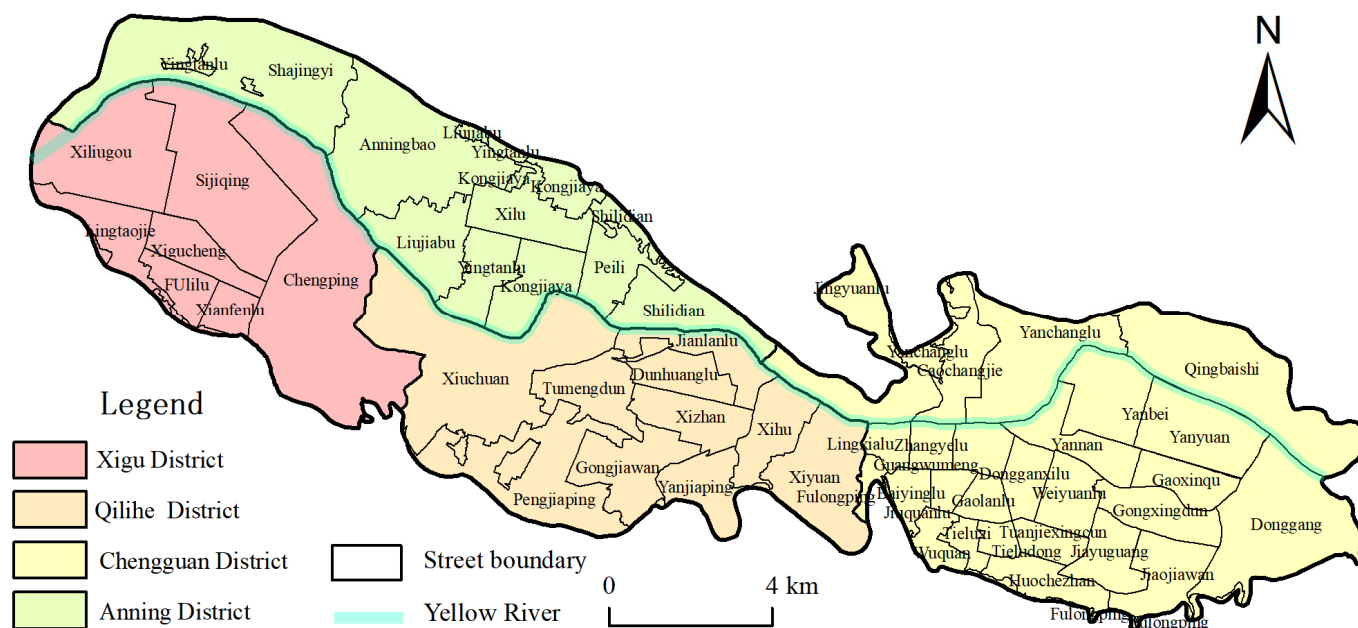


Fig 1. Overview of study area

2.2. Data Sources

The data sources are composed three aspects (Tab 1): the first is the surface data, traffic road network data, and point

data of street offices of Lanzhou city centre crawled from Gaode Map in 2024; the second is the data of 3-6 year-old children in the streets in 2024, which is an important period for children to receive preschool education, and the study of

3-6 year-old children's education from the spatial perspective helps to assess the regional. This study is based on the population data of 0-14 year-old in the streets from China's seventh population census data, combined with the total population and birth rate data from the 2020-2023 Lanzhou Yearbook, and fitted the data of preschool-age children aged 3-6 year-old in the streets using the population proportion model; thirdly, it is the kindergarten point data of 2024, which is crawled through the Gaode map, including the school address, school name and other Related attributes, the number

of kindergarten places refers to the maximum number of school-age children that can be enrolled in kindergartens, which is an important supply indicator in educational resources. This study replaces the number of kindergarten places with the exact number of school-age children that can be enrolled in each kindergarten approved in the Lanzhou Municipal Education Special Plan, and investigates the relationship between the matching of demand and supply, accessibility and other issues of preschool education.

Table 1. Sources of data for the study

Data category	Data source	Data pre-processing	Data role	Data volume
Kindergarten point data	By using Python Write a programme to batch capture the data from the Gaode Open Platform.	Define the projection coordinate system: CGCS2000_3_Degree_GK_CM_105E	Determine the spatial location of supply points	481 (units)
Street centre of gravity data	By using Python Write a programme to batch capture the data from the Gaode Open Platform.	Define the projection coordinate system: CGCS2000_3_Degree_GK_CM_105E	Determine the spatial location of demand points	51 (units)
Administrative Boundary Data	Lanzhou Municipal Bureau of Natural Resources	Define the projection coordinate system: CGCS2000_3_Degree_GK_CM_105E	Determination of the extent of administrative boundaries	51 Street Administrative Boundary Data
Road Network Data	Lanzhou Municipal Bureau of Natural Resources	Define projection coordinate system: CGCS2000_3_Degree_GK_CM_105E;	Basic data for accessibility distance calculation	—
Number of Kindergarten Places	Lanzhou Municipal Education Special Programme	The number of places is approximated to be equal to the number of children enrolled, with replacement.	Determining the supply of resources for pre-school education	481*Number of places in each kindergarten
Number of children of school age in the street	Seventh population census, Gansu Development Yearbook 2020-2023	Approximate modelling based on proportions	Determination of resource requirements for pre-primary education	51* Number of children of school age in each street

2.3. Research Methods

2.3.1. Spatial Distribution Evaluation Method.

(1) Kernel density estimation

Kernel density estimation: 1) Research concept: to study the spatial agglomeration and distribution characteristics of preschool education resources; 2) Research type: quantitative spatial analysis research type; 3) Research strategy: firstly, pre-processing the range and boundary of the main urban area of Lanzhou city and kindergarten point data; secondly, applying the kernel density analysis method to transform the kindergarten discrete point data into the continuous density surface, and processing the results with descriptive statistics to reveal the status quo and law of resource allocation [26]; 4) Time scale: the collection time of the surface data and kindergarten point data in Lanzhou City is 2024, during which the urban construction and preschool education development of Lanzhou City are in a relatively stable stage, which can accurately reflect the normal configuration and development of street-scale preschool education resources in Lanzhou City; 5) Sampling strategy: since it is a sample of all kindergartens within the scope of the main urban area of Lanzhou City Sampling strategy: Since it is an overall study of all kindergartens in the main urban area of Lanzhou City, it does not involve stratified sampling, random sampling and other strategies; 6) Data collection method: the surface data of Lanzhou City central city streets, the traffic network data, and the point data of the street offices are crawled from the Gaode map; 7) Data analysis technology: With the help of GIS software, the spatial clustering of elements of the preschool resources point data is analysed and effective analysis can be carried out by assigning different weights to the point data of preschool resources. assigning different weights for effective visualisation; 8) Methodological limitations: one of the major

defects of the kernel density analysis method is that at the boundary of the study area, due to the limited sample information, it is easy to underestimate the actual density near the boundary, which leads to the distortion of the distribution pattern. The calculation formula is:

$$K_{(x)} = \frac{1}{nd} \sum_{i=1}^n a \left(\frac{x-x_i}{d} \right) \quad (1)$$

In the formula: $K_{(x)}$ is the kernel density estimation value, d is the threshold of distance attenuation, n is the number of elements whose distance from x is less than or equal to d , a is the function of spatial weight, and $x-x_i$ is the Euclidean distance between two points. The use of nuclear density analysis can intuitively express the density and concentration of preschool education resources in space.

(2) Standard deviation ellipse

standard deviation ellipse: 1) research concept: study the spatial distribution range and concentration trend of preschool education resources; 2) research type: quantitative spatial morphology analysis; 3) research strategy: first of all, the complex dispersed kindergarten spatial location data, condensed into a simple ellipse graph, through the observation of the ellipse's morphology, location, direction of the long and short axes, the size of the evolution, the analysis of kindergarten's dynamic evolution law, accurate The time scale: the collection time of Lanzhou city's surface data and kindergarten point data is 2024, during which Lanzhou city's urban construction and preschool education development are in a relatively stable stage, which can accurately reflect the normal configuration and development of Lanzhou city's street-scale preschool education resources; 5) Sampling strategy: since it is a holistic study of all kindergartens within the scope of the main urban area of Lanzhou, the same study

is also carried out in the same way. Sampling strategy: Since it is an overall study of all kindergartens in the main urban area of Lanzhou City, stratified sampling and random sampling are not involved; 6) Data collection method: the surface data of Lanzhou City central city streets, traffic network data and point data of street offices are crawled from the Gaode map; 7) Data analysis technique: With the help of GIS software, the acquired point data of preschool education resources are analysed for the dominant direction of the spatial distribution and the degree of dispersion of the various directions, and the spatial characteristics are identified and effectively visualised; 8) The data collection method is based on the data collection method. Methodological limitations: the main limitation of the standard deviation ellipse is that it is very easy to be affected by outliers, if there are a small number of extreme outliers, the standard deviation ellipse in the calculation of the standard deviation will seriously interfere with the calculation of the centre, axis length and other parameters [28]. The calculation formula is:

$$SDE_x = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{X})^2}{n}}; SDE_y = \sqrt{\frac{\sum_{i=1}^n (y_i - \bar{Y})^2}{n}} \quad (2)$$

$$\tan \theta = \frac{A+B}{C} \quad (3)$$

Where:

$$A = (\sum_{i=1}^n \tilde{x}_i^2 - \sum_{i=1}^n \tilde{y}_i^2);$$

$$B = \sqrt{(\sum_{i=1}^n \tilde{x}_i^2 - \sum_{i=1}^n \tilde{y}_i^2)^2 + 4(\sum_{i=1}^n \tilde{x}_i \tilde{y}_i)^2}; C = 2\sum_{i=1}^n \tilde{x}_i \tilde{y}_i$$

$$\alpha_x = \sqrt{2} \sqrt{\frac{\sum_{i=1}^n (\tilde{x}_i \cos \theta - \tilde{y}_i \sin \theta)^2}{n}};$$

$$\alpha_y = \sqrt{2} \sqrt{\frac{\sum_{i=1}^n (\tilde{x}_i \sin \theta + \tilde{y}_i \cos \theta)^2}{n}} \quad (4)$$

In the formula: x_i and y_i are the spatial position coordinates of the elements, $\bar{X}$ and $\bar{Y}$ are the arithmetic average centers; SDE_x and SDE_y are the center of the ellipse. Equation 3 calculates the direction of the standard deviation ellipse, which is based on the X axis, 0 degrees in the north, and rotates clockwise. where $\tilde{x}_i$ and $\tilde{y}_i$ are the difference between the mean center and the XY coordinate. Equation 4 is used to determine the length of the X-axis and Y-axis of the standard deviation ellipse.

2.3.2. Spatial Suitability Evaluation Method.

1) the difference between supply and demand: 1) research concept: through the difference between supply and demand method, that is, the supply (the number of places) and demand (the number of children of the right age) subtracted, can visually reflect the matching difference between supply and demand and the trend of change, to provide a quantitative basis for decision-making; 2) the type of research: quantitative analysis; 3) the research strategy: first of all, first of all, all kindergarten places within the jurisdiction of the street, and then use the population ratio model to count all the 3 ~ 6-year-old children within the jurisdiction of the street; 4) time frame: number of places, school-age children data collection time is 2024; sample (iii) Research strategy: firstly, count the number of places in all kindergartens within the jurisdiction of each street, then use the population proportion model to count the number of school-age children aged 3-6 within the jurisdiction of each street, and finally do the

subtraction operation; (iv) Time frame: the number of school places and school-age children will be collected in the year of 2024; 5) Sampling strategy: since it is a holistic research on all kindergartens within the main urban area of Lanzhou City, stratified sampling, random sampling and other strategies will not be involved; 6) Data collection method: the number of school places is collected from the 'Lanzhou City Education Special Plan'. The number of places is collected from the exact number of school-age children that each kindergarten and nursery school can enroll as approved in the Lanzhou Municipal Education Special Plan, and the number of school-age children aged 3-6 years is simulated by the population ratio model based on the population aged 0-14 years in the streets in the data from the Seventh Population Census of China, and data on the total population and the birth rate of the population in the 2020-2023 Lanzhou Yearbook; 7) Data analysis techniques: the data are collected through the supply and birth rate models. Data analysis technology: the results of the difference between supply and demand are obtained by subtracting the supply and demand, and the difference between the supply and demand of preschool education resources in each street is spatially visualised with the help of GIS software; 8) Methodological limitations: although the method of the difference between supply and demand can intuitively calculate the results of the supply and demand of preschool education resources, it does not explain the relationship between supply and demand any further, i.e., the relationship of the supply exceeds the demand, the supply is lower than the demand, and the demand and supply is in equilibrium. The calculation formula is:

$$SDD = S_j - P_k \quad (5)$$

In the formula: SDD is the difference between supply and demand, S_j is the number of degrees in k street j kindergarten, and P_k is the number of school-age children in k street. If the number of degrees is greater than the number of school-age children, it indicates that supply exceeds demand; if the number of degrees is less than the number of school-age children, it indicates that the demand is greater than the supply.

(2) Z-score standard deviation method: 1) Research concept: the calculation method of the difference between supply and demand can not accurately portray the balance of pre-school education resources, in order to further characterise the spatial suitability of pre-school education, the Z-score standard deviation method is adopted. The Z-score standard deviation method eliminates the differences in data due to the differences in the scale of measurement and size by standardising the number of school places with the number of children of school age. Research type: quantitative analysis method; 3) Research strategy: the Z-score standard deviation method [29], divided into four quadrants, the X-axis represents the supply of school places, and the Y-axis represents the demand for school-age children. The first quadrant represents high supply - high demand, the second quadrant represents low supply - high demand, the third quadrant represents low supply - low demand, and the fourth quadrant represents high supply - low demand, where 'high supply - high demand' and 'high supply - high demand' are the same as 'high supply - high demand' and 'high supply - high demand'. The state of 'high supply - high demand' and 'low supply - low demand' is a state in which the supply of school places and the number of students match each other to achieve a balance and stability, which is recognised in this paper as the balance of supply and

demand of pre-primary education resources. This paper identifies it as the balance between supply and demand of pre-school education resources; 4) Time frame: the number of school places and the number of school-age children will be collected in 2024; 5) Sampling strategy: when using the Z-score standard deviation method, the sampling strategy needs to be determined in accordance with the characteristics of the study population. Since this is an overall study of all kindergartens in the main urban area of Lanzhou City, all kinds of sampling methods are not involved; 6) Data collection method: the number of school places is collected from the number of school-age children that each kindergarten and nursery can enroll as approved in the Lanzhou Municipal Education Special Programme, and the number of school-age children aged 3-6 is based on the data of 0-14 year-olds in the streets in the seventh population census of China, the data of the Lanzhou Yearbook of 2020-2023, and the data of the school-age children in the streets in the seventh population census of China. The number of school-age children aged 3~6 is simulated by using the population ratio model based on the population data of 0~14 years old in the seventh population census of China, the total population and the birth rate data in the Lanzhou Yearbook of 2020-2023; 7) Data analysis technique: after standardising the number of school places and the number of school-age children using the Z-score standard deviation formula, we can obtain the positive and negative values of the number of school places and the number of school-age children, with the positive value representing a high supply or a high demand, and the negative value representing a low supply or a low demand. 8) Methodological limitations: the analysis is based only on the numerical characteristics of the data, without considering the background and practical significance of the data. Since the standardisation process of the number of school-age children is similar to that of the number of school places, the same formula is used for the standardisation of the two data. The formula is:

$$Z = \frac{(X-\mu)}{\sigma} \quad (6)$$

In the formula : Z is the standardised value of the number of school-age children or places, X is the original value of the number of school-age children or places, μ is the mean of the number of school-age children or places, and σ is the standard deviation of the number of school-age children or places.

2.3.3. Spatial Accessibility Evaluation Method.

Gaussian two-step mobile search method (referred to as Gaussian 2SFCA): 1) Research concept: Gaussian 2SFCA method breaks through the traditional method's simple consideration of distance and resource distribution, and incorporates the distance decay effect. Young children enrolling in school generally choose kindergartens closer to their homes, the further the distance the less attractive to young children, and its gravitational change just fits with the Gaussian function with the increase in distance, the decline speed first accelerates and then slows down the characteristics of the Gaussian function, so the Gaussian 2SFCA is used for the accessibility measurements [30]; 2) Research type: quantitative analysis; 3) Research strategy: the Gaussian 2SFCA method integrates the relationship between demand and supply and the distance attenuation, and the computation process is mainly divided into two steps, the first step is to calculate the supply-demand ratio, and the second step is to aggregate the supply-demand ratio to calculate the accessibility of kindergartens for young children; 4) Time

frame: the number of school places, the data of school-age children, and the data of the road network are collected in the year of 2024; 5) Sampling strategy: the point of the centre of gravity of the street is taken as the starting point of the accessibility measurements, which not only reflects the differences in the characteristics of different streets, but also reduces the workload of data collection and processing; 6) Data collection Methods: The number of school places is collected from the exact number of school-age children that each kindergarten and nursery school can enroll as approved in the Lanzhou Municipal Education Special Plan, and the number of school-age children aged 3 to 6 is based on the population data of 0-14 years old in the streets in the data of the seventh population census of China, and the data of the total population and the birth rate of the population in the 2020-2023 Lanzhou Yearbook, and simulated by using the Population Ratio model simulation, and the road network data are crawled from Gaode map; 7) Data analysis technology: construct geospatial database, calculate the accessibility value of preschool education resources according to the two-step search step, and with the help of GIS software, spatial visualisation of the accessibility value of preschool education resources of each street; 8) Methodological constraints: the Gaussian 2SFCA method relies on the Gaussian function to describe the distance attenuation effect, and assumes that the utilization of resources increases with the distance in a specific way, which is the same as the distance. The assumption that people's use of resources increases with distance in the form of a specific Gaussian distribution attenuation, but in reality, people's behavioural patterns and choice of resources are affected by a variety of factors, which may not be fully consistent with this assumption, leading to bias in the assessment of accessibility. The calculation formula is:

$$R_j = \frac{s_j}{\sum_{k \in \{d_{kj} \leq d_0\}} G(d_{kj}, d_0) p_k} \quad (7)$$

$$G(d_{kj}, d_0) = \begin{cases} \frac{e^{-\frac{1}{2} \times \left(\frac{d_{kj}}{d_0}\right)^2} - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}}, & d_{kj} \leq d_0 \\ 0, & d_{kj} > d_0 \end{cases} \quad (8)$$

$$A_i^F = \sum_{k \in \{d_{il} \leq d_0\}} G(d_{kj}, d_0) R_l \quad (9)$$

Equation (7) is used to calculate the supply and demand ratio of preschool education resources, where d_{kj} is the spatial distance from the center of mass of k street to j kindergarten, and d_0 is the spatial distance threshold of search radius (that is, the reasonable radius of kindergarten entrance, which is set to 300m, 500m, 100m and 1500m respectively). p_k is the number of school-age children in k street, s_j is the number of degrees in j kindergarten in k street, and is the distance attenuation function, that is, Gaussian function. Equation (9) is used to calculate the spatial accessibility b of all kindergartens in k street, and the larger the A_i^F , the better the accessibility. d_{il} is the distance between the center of mass of k street and j kindergarten, and R_l is the supply and demand ratio of k street.

2.3.4. Spatial Equity Evaluation Method.

(1) Gini coefficient: 1) Research concept: accessibility-based equity measurement is used to measure the balanced distribution of preschool education resources in space and among groups of people; the Gini coefficient can intuitively reflect whether accessibility is fair or not by calculating the

degree of difference in the distribution of resources. If the Gini coefficient tends to be close to 0, it means that the difference in the accessibility of resources among regions or groups is extremely small, and the fairness of accessibility is high; if the Gini coefficient tends to be close to 1, it means that the difference in accessibility is extremely large, and the fairness is low; 2) Research type: quantitative analysis; 3) Research strategy: based on the calculated values of accessibility, according to the formula of the Gini coefficient, the Gini coefficient of the accessibility in the study area is calculated. Through the numerical analysis of the Gini coefficient, the fairness of accessibility is judged; 4) Time frame: the number of school places, data of school-age children, and data of the road network are collected in the year 2024; 5) Sampling strategy: since the study is carried out on all the streets within the scope of the main urban area of Lanzhou City, it does not involve the strategies of stratified sampling, random sampling, etc.; 6) Methods of data collection: the Gaussian 2SFCA is applied, the values of the accessibility are calculated and The calculated accessibility value is used as the basis for the fairness calculation; 7) Data analysis technique: based on the results of the accessibility calculation, the formula of the Gini coefficient is applied; 8) Methodological limitations: the Gini coefficient indicates the gap between the actual state and the state of complete equality, and the number of intermediate strata in the actual state is the most sensitive to the impact of the Gini coefficient value, so its biggest defect is that it is not enough to focus on high and low strata, which makes it difficult to get the overall results of the Gini coefficient. The biggest defect is that it does not pay enough attention to the high and low tiers, which makes it difficult to get the difference between the groups within the whole. The calculation formula is shown in Table 2.

(2) Palma Ratio: 1) Research Idea: Palma Ratio focuses on the difference between the top and bottom of the accessibility level of a specific proportion of streets, by comparing the

degree of access to resources of high accessibility groups and low accessibility groups, visually presenting the degree of inequality of accessibility among different groups. The core idea is that when the Palma ratio is low, it means that the gap between the high accessibility group and the low accessibility group is small and the fairness is high; on the contrary, the higher the ratio indicates that the gap between the two is bigger and the fairness is lower; 2) Type of research: quantitative analysis; 3) Research strategy: according to the accessibility value of each street in descending order, the top 20% of the streets are selected as the high-accessibility streets, and the bottom 40% as the low-accessibility streets. as low accessibility streets. Then, the ratio of the average accessibility of the high accessibility group to the average accessibility of the low accessibility group is calculated to obtain the Palma ratio; 4) Time frame: the number of school places, school-age children data, and road network data are collected in 2024; 5) Sampling strategy: since the study is conducted on all streets within the main urban area of Lanzhou City, it does not involve the strategies of stratified sampling, random sampling, etc.; 6) Data collection method: Gaussian 2SFCA is used to calculate the average accessibility value of each street, which is the most important factor in the study. Gaussian 2SFCA, calculating the value of accessibility, and using the calculated accessibility value as the basis of fairness calculation; 7) Data analysis technique: according to the results of the accessibility calculation, using the formula of the Parma ratio; 8) Methodological limitations: the Parma ratio mainly focuses on the differences between high accessibility groups and low accessibility groups, ignoring the situation of the intermediate groups. In reality, the accessibility status of the intermediate groups may also have an important impact on the overall fairness, and this omission may lead to an incomplete assessment of the fairness of accessibility. The calculation formula is shown in Table 2.

Table 2. Spatial equity measurement index

Index	formula	Index	formula
Gini coefficient (Gini)	$\frac{\sum_{i,j}^n A_i - A_j }{2n^2 \bar{A}}$	Palma ratio (Palma)	$\frac{\text{The accessibility share of the top 10 \% of streets}}{\text{The accessibility share of the last 10 \% of the streets}}$

Note: A_i and A_j are the reachability of demand points i and j ; $\bar{A}$ is the population weighted average of accessibility, which is equal to the ratio of total supply to total demand in a specific scale range; n is the number of demand points.

3. Results Analysis

3.1. Analysis of the Spatial Distribution of Preschool Education Resources

On the street scale, the spatial distribution density of preschool education resources is distributed in Chengguan District > Qilihe District > Anning District > Xigu District, with a high distribution density in the city centre and a low distribution density in the peripheral districts. The characteristics of 'one core and four centres' are obvious (Fig 2). The core of the distribution is distributed in Chengguan District, and the centre is distributed in all four districts. Under the kernel density analysis, 'one core and four centers' is usually used to describe the key aggregation nodes in a specific spatial distribution pattern, and 'one core' often refers to the point of aggregation of preschool education resources with the highest degree of aggregation in the central area of the city. The 'four centres' are the four secondary preschool education resource centres distributed in different parts of the

city around the core area. The 'core' and the 'heart' echo each other, jointly constructing the spatial skeleton of urban preschool education resources, so that the distribution of education resources in the overall distribution of both primary and secondary, but also relatively balanced coverage of the city's various major boards, to meet the needs of residents in different regions of the preschool education in the vicinity, to ensure fair educational opportunities.

According to the nuclear density estimation map of preschool education resource distribution, it can be found that the peak area appears in Chengguan District, and the spatial polarization phenomenon is obvious. A typical 'one core' is formed around Yannan Street, Yanbei Street and high-tech zone in Chengguan District. There are 44,16 and 13 kindergartens respectively, a total of 73, accounting for 30 % of the total number of kindergartens in Chengguan District, and the concentration is much higher than other areas. The formation of the 'core area' is the result of many factors. The predecessor of the high-tech zone is one of the old urban areas

of Lanzhou City. It has gathered a large number of scientific research institutions such as Lanzhou University, Lanzhou Institute of Modern Physics of the Chinese Academy of Sciences, Institute of Chemical Physics of the Chinese Academy of Sciences, Northwest Institute of Ecological Environment of the Chinese Academy of Sciences, and Gansu Provincial People 's Hospital. There are 19 residential communities in the area. The district is also one of the first 27 national high-tech industrial development parks of the State Council, attracting a number of well-known enterprises and a large number of researchers. The high-tech zone is science and technology-oriented, and the economic development industry chain is mature and complete. It has increasingly become a new economic growth pole in Lanzhou City, thus attracting many preschool education resources. Yannan Street and Yanbei Street are new residential areas formed in the process of spatial expansion of Lanzhou City. There are a large number of commercial residential areas in the area. Yannan Street has large residential areas such as Jindi Garden, Jinhe Community, Civil Air Defense Building, Minbai Community, Huating Garden and Rongda Garden, with a total population of 53,230 people (in 2011) and 24 kindergartens. Yanbei Street has large residential areas such as Tianqing Lishe and Hongyun Runyuan. With a total population of 56201 (in 2011) and 40 kindergartens. Due to the significant population aggregation, the demand for preschool education resources is strong, which has become one of the highly intensive areas of kindergartens.

The district is centered on ' Jiuquan Road Street (7) ', surrounded by Railway West Village Street (4), Railway East Village Street (5), Gaolan Road Street (6), Zhangye Road Street (3), Wuquan Street (10), Guangwumen Street (8), Baiyin Road Street (4). The preschool education resources in this area account for 19 % of the total in Chengguan District. Zhangye Road Street and Jiuquan Road Street are the real old urban areas of Lanzhou City, with complex functions and dense population (population density up to 50,000 people / km²). There is a strong demand for preschool education resources. In addition, Jiuquan Road Street gathers other high-quality educational resources such as Lanzhou Experimental Primary School and Lanzhou No.1 Middle School. Because of the close relationship between the

enrollment of schools at different levels in China, it also attracts many preschool education resources. The Zhangye Road Street and the Guangwumen Street are the seats of the provincial government and the municipal government. The government gives priority to the allocation of preschool education resources through administrative power.

Qilihe District is centered on ' Xiyuan Street (21) ', surrounded by West Lake Street (15), West Station Street (8) and Dunhuang Road Street (11). The preschool education resources in this area account for 40 % of the total in Qilihe District. The district has a small West Lake business district and a large commercial complex in the West Station business district. It is rich in business forms. It relies on urban complexes such as Lanzhou Center, Lanzhou Global Lane, and Zhongtianjian Square to attract a large population and provide sufficient demand for the allocation of preschool education resources. There is subway stations distributed in the streets of the west station, which is convenient for parents to go to and go to school. The subway station promotes the upgrading of regional value and attracts a large number of preschool education institutions to gather and develop here, with high distribution density.

The Anning District is centered on ' Yintan Road Street (8) ', surrounded by Kongjiaya Street (9), Liujiabao Street (5), and West Road Street (18). The preschool education resources in this area account for 65 % of the total Anning District. Yintan Road Street carries the central business district of Yingmentan Beach, and aggregates landmark commercial and commercial resources such as Wuyue Square and Zhonghai Square. As the core area of development, strong population siphon and regional prosperity drive the allocation of preschool education resources and the development of various education and training comprehensive formats.

Xigu District is centered on ' Xigucheng Street (10) ', surrounded by Sijiqing Street (8), Xianfeng Road Street (7), Fuli Road Street (7) and Lintao Street (9). The preschool education resources in this area account for 62 % of the total number of kindergartens in Xigu District. Xigu District is a typical industrial area in Lanzhou City. Lanlian, Lanhua and other large enterprises have a large number of employees and many school-age children, which also lays a foundation for the allocation of preschool education resources.

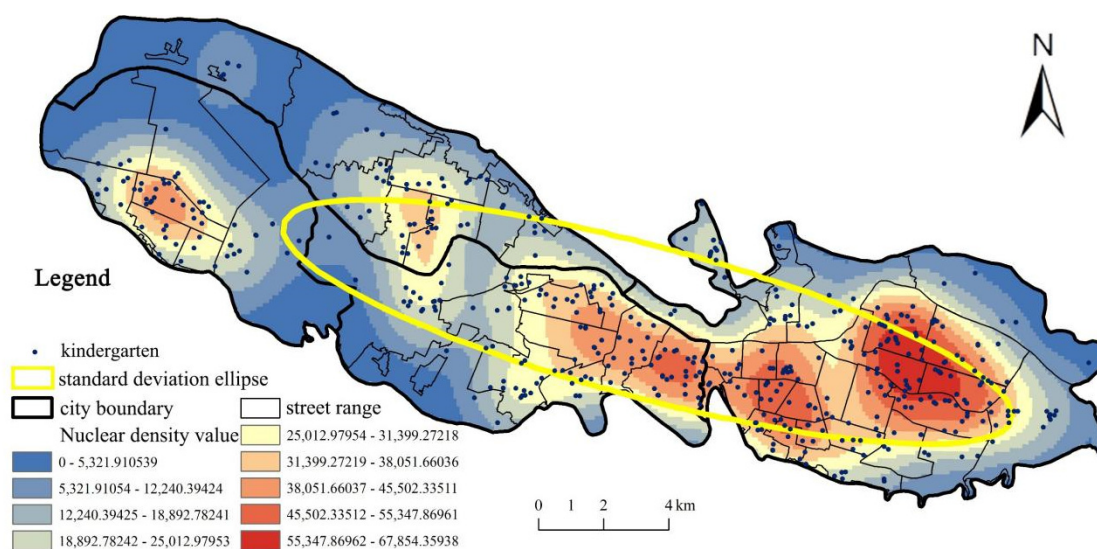


Fig 2. The kernel density distribution map of preschool education resources in Lanzhou City

From the results of the standard deviation ellipse analysis, the center of the circle (103.783365N, 36.06977E) is located

in the West Lake Street in Qilihe District, with a long axis of 0.132,009 and a short axis of 0.027,857. The long axis

direction is highly consistent with the distribution direction of the main urban area of Lanzhou City, which is in line with the morphological characteristics of the valley-shaped city. The standard deviation ellipse covers 336 preschool education institutions, accounting for nearly 70 % of the total number.

3.2. Analysis of Spatial Suitability of Preschool Education Resources

The appropriateness of preschool education resources reflects the accessibility and equity of resources to some extent. In streets with good adaptability, the ratio of supply and demand of preschool education resources is perfect, and child can enroll in schools near their homes, so accessibility is high. The better the suitability, the lower possibility of cross-district enrollment of child, the higher efficiency of educational resources' popularization within the street, the lower difficulty for child to enroll in kindergartens, the lower inequality of attainment to resources within the accessibility, and the better fairness. The appropriateness of preschool education resources focuses on both the 'supply of places' and the 'demand for school-age children'. The fitness of resources is portrayed through the quantitative relationship between the two above (including oversupply, under supply, and equilibrium of supply and demand). The appropriateness of resources is characterized by the quantitative relationship between the two (including oversupply, under supply and equilibrium). The idealized state of 'supply-demand equilibrium' is generally in the minority and is difficult to measure and define. Oversupply and 'under supply' are normalcy of supply-demand relationship in reality, which are reflected by 'supply-demand ratio' and 'supply-demand gap' accordingly.

At the street-level, the number of school places for school-age children is closely related to the density of population distribution. Streets with a large number of children and a high population density distribution have a high number of degrees. High-value areas with a high number of degrees are distributed in concentrated clusters (Figure 3-a): Chengguan District contains Yannan, Yanyuan, Yannbei, Gongxingdun, Donggang, Jingyuan Road, Qingbaishi Street. Qilihe District contains Xiuchuan, Gongjiawan, Pengjiaping, Xiyuan,

Dunhuang Road Street, Xigu District contains Chengping Street, Anning District includes West Road and Kongjiaya Street. Low-value areas with low numbers of places are located in Peili Street in Anning District.

The number of school-age children gradually decreases from the city center towards the periphery (Figure 3-b). The number of preschool-age children in the 3 to 6-year-old group is densely distributed within Chenping and Xigucheng streets in Xigu District, Yannan, Yanyuan, Yannbei, Donggang, Caochangjie, Jingyuanlu, and Gongxingdun streets in Chengguan District, and Xiuchuan, Xiyuan, Xihu, and Dunhuanglu streets in Qilihe District. These streets have high demand for preschool education resources and pressure on space allocation and high demand for pre-school education resources, with high pressure on spatial allocation. Conversely, the number of school-age children in each street in Anning District is relatively evenly distributed, without any densely areas.

The average number of kindergarten children is mostly between 100 and 200 (Figure 3-c). Kindergartens with an average number of children greater than 300 are mainly located in Donggangxi Road, Zhangye Road and Baiyin Road street in Chengguan District, which is closely related to the fact that the number of kindergartens within those streets is less while the number of school-age children is more, so they have no choice but to expand the enrollment scale; Kindergartens with an average of less than 100 children are mainly located in Chengguan District's Yanbei, Yanyuan Street, and Gaoxin District, and in Anning District's Yintan Road, Shajingyi, Kongjiaya, and Xi Lu Streets, which have a large number of kindergartens but a small number of school-age children.

By comparing the number of ' school-age children ' and 'degree' in each street, the adaptability of preschool education resources can be intuitively reflected (Fig 3-d). The results show that 13 streets are in short supply and 38 streets are in oversupply. If the supply-demand gap is controlled in the range of $[-200, +100]$, there are only 5 streets in this range. If the boundaries are expanded to $[-300, +300]$, the number of streets with supply-demand gap within this interval totals 10 streets. The overall spatial adequacy is poor.

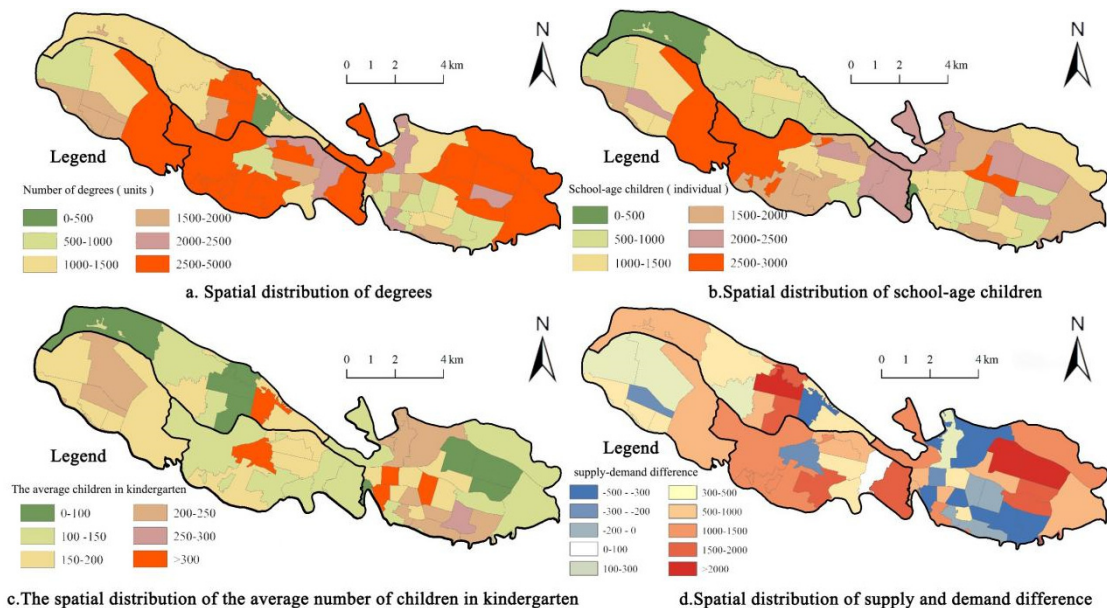


Fig 3. Spatial distribution of relationship between supply and demand for preschool education in Lanzhou City

There are 13 streets in short supply : Zhangye Road, Baiyin Road, Gaolan Road, Railway Station and Tuanjie New Village Street, the number of school-age children > 'degree ', up to 524, the supply is very tight, and school-age children are facing difficulties in entering the park. These streets are basically distributed in the Chengguan District. Due to the large population base and the large number of school-age children, although they are also the main allocation area of preschool education resources, they still show a tight dilemma in the face of huge demand. There are 38 streets, such as Yanbei, Yunnan and Yanyuan streets in the Luochengguan District, Gongjiawan and Dunhuang Road in the Qilihe District, where the supply exceeds the demand, and there is idle waste of resources.

On the whole, due to the mixed functions of the city center and the administrative center of each jurisdiction, these regions have a large population base, and there are many school-age children. However, due to the allocation of a large

number of pre-school education resources, it shows a trend of oversupply, which can meet the needs of school-age children, and even there is idle waste of resources. Nevertheless, the allocation of preschool education resources in remote streets, streets at the junction of jurisdictions and suburban towns is insufficient and in under supply.

There are obvious spatial differences in the fitness of preschool education. As shown in Tab 3 and Fig 4, among the 51 streets, the 'low supply-low demand' type is more prominent, accounting for 49% of the total. Most of these streets are concentrated in Anning District. The 'high supply-high demand' category accounts for 27% of the total, and is concentrated in Qilihe District. The 'high supply-low demand' category accounted for 12% of the total, distributed in Chengguan and Anning Districts. The 'low supply - high demand' category accounted for 12% of the total and was distributed in Chengguan and Xigu Districts.

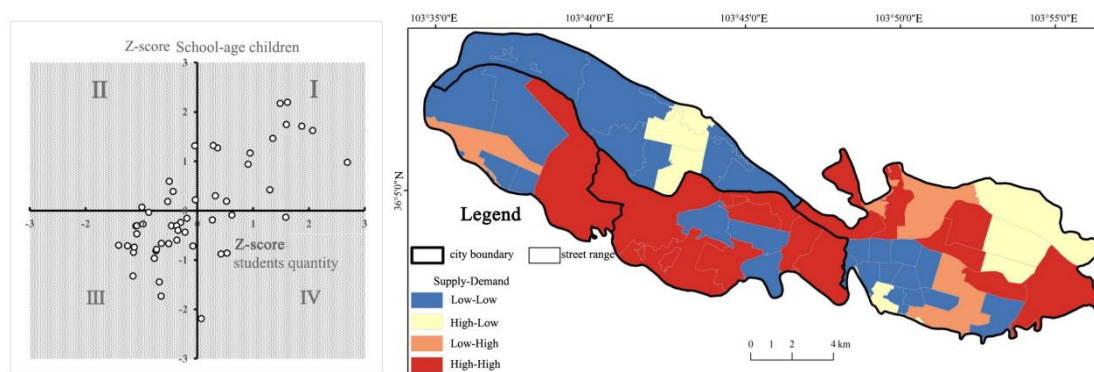


Fig 4. Spatial distribution map of supply and demand adaptation relationship of preschool education in Lanzhou

Table 3. The adaptation relationship of preschool education in each street of Lanzhou City

type	street name	Proportion (%)
Low supply-low demand	Jiaojiawan, Tuanjie New Village, Gaolan Road, Railway East Village, Railway West Village, Zhangye Road, Jiuquan Road, Linxia Road, Baiyin Road, Fulongping, West Railway Station, Yanjiaping, Tumendun, Xiliugou, Shilidian, Anningpu, Shajingyi, Peili, Donggang West Road, Sijiqing, Welfare Road, Pioneer Road, Yintan Road, Liujiapu, Guangwumen Street.	49
High supply-low demand	High-tech Zone, Qingbaishi, Wuquan, West Road, Kongjiaya, Yanyuan Street	12
Low supply-high demand	Jiayuguan Road, Weiyuan Road, Railway Station, Lintao Street, Xigu City, Yanchang Road Street	12
High Supply - High Demand	Pengjiaping Town (part of the urban built-up area), Caochang Street, Yanbei, Yunnan, Gongxingdun, Xiyuan, Xihu, Jianlan Road, Dunhuang Road, Gongjiawan, Xiuchuan, Chenping, Donggang, Jingyuan Road Street	27

3.3. Spatial Accessibility Analysis of Preschool Education Resources

The preschool education planning led by the education authorities is generally grounded in the number of school-age children within a block, the size of the kindergarten and the location of the kindergarten. Under the principle of 'nearby enrollment 'and ' Zoning based on schools ', estimated and judged the surplus of preschool education resources. Urban planning emphasizes ' reasonable service radius ', so as to break through the geographical boundaries of enrollment areas and school districts. The two do not coincide in space, that is to say, ' policy boundary ' and ' planning boundary ' are often not unified and do not coincide. Accessibility research is useful to find deficiencies and promoting the overall spatial allocation of preschool education resources to achieve the

optimal welfare level [31].

According to the ' Kindergarten Standard Design Sample ', the service radius of urban kindergartens should range from 300m to 500m. This study takes the center of mass of the street as the origin to calculate the accessibility of each preschool education resource. Because Lanzhou is a typical belt city and a district city, this study sets the spatial distance threshold of the Gaussian 2SFCA two-step mobile search method to four levels: 300m, 500m, 1000m, and 1500m.

The density of O-D road network is highly consistent with the ' one core ' and ' four center ' areas of preschool education distribution. Due to the dense road network in the core area and the central area, there are more O-D lines from the street centroid to the kindergarten, the spatial accessibility is high, and the service points corresponding to the facilities are more and concentrated (Fig 5). The O-D lines of peripheral streets

and urban suburbs are sparse, and their spatial accessibility is low or even unreachable., the service points corresponding to

the facilities are few and scattered.

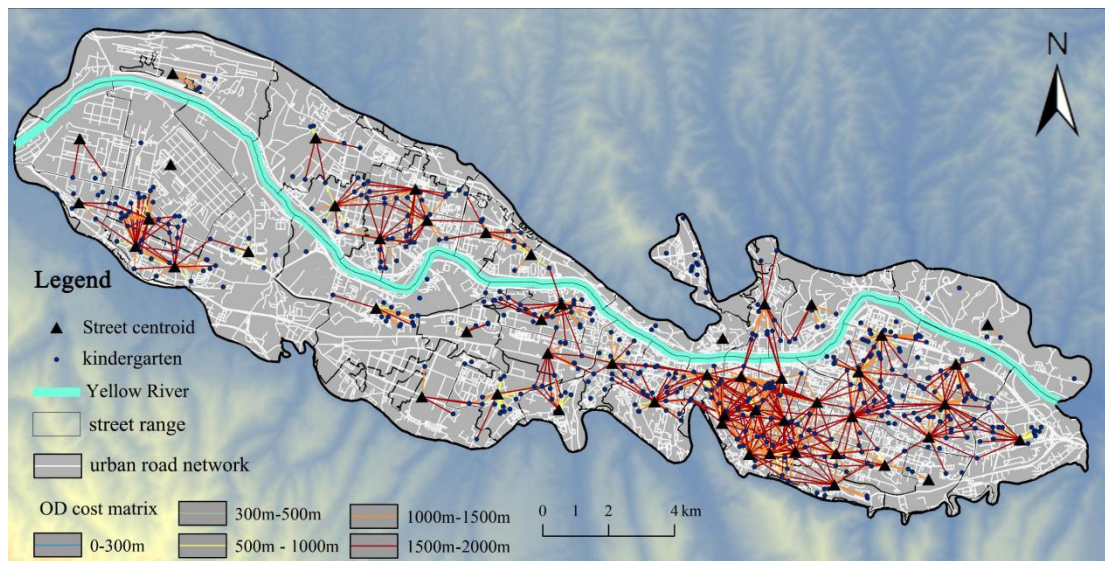


Fig 5. O-D cost matrix connection of preschool education resources in Lanzhou

With the increase of the search radius, the value of accessibility is increasing at the same time (Fig 6). Within an accessibility range of 300 m, 84.31 % of the street accessibility index is 0, in the accessibility range of 500 m, 58.82 % of the street accessibility index is 0, in the accessibility range of 1500 m, the street accessibility index is 0 accounted for 5.88 %. The streets with accessibility index between 0 and 1 account for 50.98 %, indicating that in the

range of 300m ~ 500m, children enjoy poor accessibility of preschool education resources and low convenience. In the range of 1000m ~ 1500m, children enjoy good accessibility of preschool education resources, but with the increase of space-time distance, the safety factor of children 's commute is indirectly reduced (Tab 3). This fits the characteristics of the belt city.

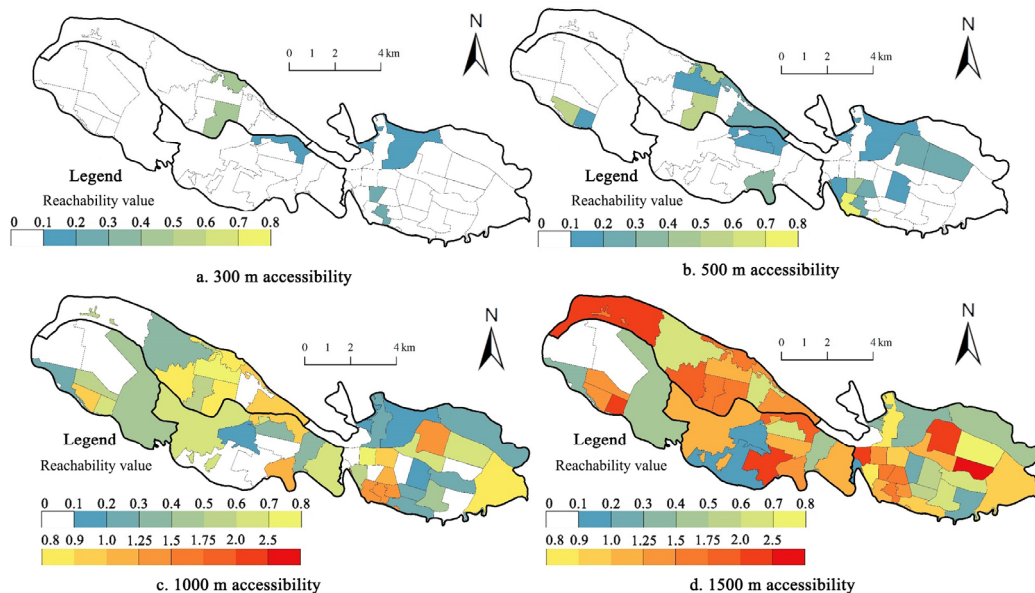


Fig 6. Accessibility distribution map of preschool education resources in Lanzhou City

As the search radius increases from that of a single street to that adjacent street, the reachability extension extends and the values increase (Tab 4). As the search radius increases, the accessibility extends from a single street to a nearby street, and the value increases. When the search radius increases from 500 m to 1000 m, the accessibility value changes significantly, especially for streets with accessibility values of 0 and greater than 0.5. The proportion of streets / towns with

accessibility values of 0 decreased from 58.82 % to 17.64 %, and the proportion of streets / towns with accessibility values greater than 0.5 increased from 5.88 % to 52.94 %. With the orderly expansion of the spatial-distance threshold, the high-value areas of accessibility move closer to high value areas and gradually shrink to the core urban areas. Concurrently, the proportion of low-value areas of accessibility decreases, from peripheral concentration to isolated existence.

Table 4. Numerical changes of accessibility at different distances in Lanzhou streets

	Street Name	300m Accessibility	500m Accessibility	1000m Accessibility	1500m Accessibility
Chengguan district	Qingbaishi	0	0	0.203415	0.458797
	Caochangjie	0	0.063888	0.251926	0.882193
	Gaoxinqu	0	0	1.75717	4.47805
	Yanbei	0.057369	0.274481	1.400593	2.3674
	Yannan	0	0	0.619734	1.185982
	Gongxindun	0	0	0.246377	0.681258
	Jiaojiawan	0	0	0	0.217844
	Jiayuguan	0	0	0.427782	0.602615
	Weiyuanlu	0	0.141261	0.141261	0.513812
	Tuanjiexincun	0	0	0.204776	0.578949
	Huochezhan	0	0.095267	0.283981	0.979577
	Gaolanlu	0	0.203642	1.063778	1.518585
	Tieludongcun	0	0	1.463264	1.385892
	Tieluxicun	0.263521	0.263521	1.484681	1.567519
	Zhangyelu	0	0	0.739614	1.266406
	Jiuquanlu	0.223602	0.402839	1.974373	1.671637
	Wuquan	0	0.764202	1.303803	1.073432
	Linxialu	0	0	1.929147	2.209973
	Baiyinlu	0.082713	0.189413	0.517953	0.873533
	Fulongping	0	0	0.072567	0.191388
	Donggang	0	0	0.838257	0.955433
	Donggangxilu	0	0	0	0.265958
	Yanchanglu	0.1018	0.1018	0.147357	0.380765
	Jingyuanlu	0	0	0	0
	Guangwumen	0	0	0.964934	0.922587
	Yanyuan	0	0	0.610305	0.785283
Qilihe district	Xiyuan	0	0	0.616399	1.093798
	Xihu	0	0.089445	0.322004	0.465116
	Jianlanlu	0.146801	0.146801	0.926021	1.981278
	Dunhuanglu	0	0.122955	0.330492	0.696046
	Xizhan	0	0	0	1.1736
	Yanjiaping	0	0.369663	1.079775	1.388374
	Gongjiawan	0	0	1.873653	2.27006
	Tumendun	0	0	0.133009	0.133009
	Xiuchuan	0	0	0.661612	1.171987
	Pengjiaping	0	0	0	0.192787
Xigu district	Chenping	0	0	0.440903	0.440903
	Lintaojie	0	0.055123	0.267185	0.399481
	Xiliugou	0	0	0	0
	Sijiqing	0	0	0	0
	Fulilu	0	0.531017	0.982795	1.328834
	Xigucheng	0.081057	0.081057	0.533811	1.405318
	Xianfenglu	0	0.137391	0.647653	2.010752
Anning district	Shilidian	0	0.229124	0.954175	1.308584
	Anningbao	0	0	0.31652	0.673392
	Shajingyi	0	0	0	2.195122
	Peili	0	0	0	0.655177
	Xizhan	0	0.181335	0.759484	1.136361
	Yingtianlu	0	0	0.55216	1.736806
	Liujiabao	0	0	0.868798	1.854212
	Kongjiaya	0.511034	0.511034	0.89547	1.696023

Comparative analysis shows that there exists significant differentiation in the accessibility values of different levels of streets. The spatial-distance threshold is within 500 m, which generally corresponds to the 5min life circle. It is generally difficult to coordinate the pre-school education facilities, and the actual layout distance is often inconsistent with the standard distance, resulting in the low accessibility of most streets [32-33]. The accessibility value calculated in the search radius of 1500 m streets, the central area and the surrounding area are quite different, the lowest value distributed in Jingyuan Road, Xiliugou, Sijiqing Street, and higher value area is distributed in Yanbei, High-tech Zone, Gongjiawan, Linxia Road, Pioneer Road, Shajingyi Street 6 streets. The uneven accessibility value is closely related to the supply and demand relationship between the number of degrees and the number of school-age children, the density of road network, the length of road network distance, and the spatial proximity of kindergartens and street offices. The peripheral area with low accessibility value is in the awkward location of ' low resource allocation and high location ' [34], the supply of degree resources is in short supply, the density of road network is low, the distance from school-age children to kindergartens is far, and the accessibility value is relatively low. Compared with the central area with high accessibility value, which the supply of degree resources exceeds the demand and the density of road network is high, the distance from street office to preschool education facilities is close, and the accessibility value is relatively high.

3.4. Spatial Equity Analysis of Preschool Education Resources

The Gini coefficient represents the gap between the actual state and the completely equal state. The proportion of the middle-level in the actual state is the most sensitive to the Gini coefficient value. Therefore, its biggest drawback is that it does not pay enough attention to the high and low levels, which makes it difficult to obtain the differences between the overall internal groups. Consequently, it is used as an estimated indicator for the overall level of inter-regional accessibility. The Palma ratio focuses on the relationship between the high-value areas and the low-value areas, reflecting the situation between the overall internal levels, making up for the shortcomings of the Gini coefficient, and policy makers pay more attention to the changes in the high

and low parts, so the Palma ratio gradually replaces the Gini coefficient.

Overall, the Gini coefficient does not change consistently with the Parmar ratio as the distance thresholds set for accessibility expand, with the Gini coefficient increases with distance, indicating a gradual widening of the overall level of variability in reachability (Tab 5). In particular, the change is more significant in Chengguan and Xigu Districts, with Chengguan District changing from 0.018 to 0.318, and Xigu District changing from 0.008 to 0.327, within 1500m, the degree of regional accessibility differentiation is more obvious. The Palma ratios of Chengguan District, Qilihe District, and Anning District decrease with increasing distance, indicating that along with the expansion of the distance threshold set for accessibility, the degree of accessibility differentiation between streets showed a gradual trend of decreasing. The change was more significant in Chengguan District and Qilihe District, with Chengguan District changing from 4.465 to 0.413 and Qilihe District changing from 4.118 to 1.527. The Parma ratio of Xigu District increased from 3.678 to 5.033, indicating that the degree of accessibility differentiation between streets was further widened. Within 1000 m, the Palmar ratio is greater than 3, indicating that the difference between the four streets is significant. The proportion of the first 10 % of the street accessibility values is more than three times that of the last 40 % of the street accessibility values.

In the 300-500 m range, the Gini coefficient is low and the high Palmar ratio is high. This indicates that children attend school within a close range, and in terms of spatial accessibility, it shows overall equity with localized imbalance. In the range of 1500 m, the Gini coefficient becomes larger, the Palma ratio shrinks, and children go to school remotely. Spatially manifested as a clear overall and local variability in accessibility (except for Xigu District). Within 1000 meters, the degree of inter-regional differentiation of accessibility expressed Chengguan District > Qilihe District > Xigu District > Anning District, and the degree of internal accessibility differentiation also manifest as Chengguan District > Qilihe District > Xigu District > Anning District. In the range of 1500 m, the degree of inter-regional accessibility differentiation is Xigu District > Chengguan District > Qilihe District > Anning District, and the degree of accessibility differentiation within the district is Xigu District > Qilihe District > Anning District > Chengguan District.

Table 5. Spatial equity measurement of preschool education resources accessibility in Lanzhou City

	300m Accessibility		500m Accessibility		1000m Accessibility		1500m Accessibility	
	Gini	Palma	Gini	Palma	Gini	Palma	Gini	Palma
Chengguan district	0.018		0.054		0.255	4.465	0.318	0.143
Qilihe district	0.009		0.037		0.205	4.118	0.261	1.527
Xigu district	0.008		0.067		0.151	3.678	0.327	5.033
Anning district	0.030		0.044		0.108	3.015	0.156	0.891

Note: because 300 m accessibility and 500 m accessibility in the process of spatial equity measurement, the latter 40 % of the street accessibility values are 0, so the Parmal ratio is vacant.

The main findings of this study focus on the following four points:

(1) The spatial distribution of preschool education resources is relatively uniform, balanced, and locally concentrated, presenting a 'one-core, four-centre' and east-west belt-shaped distribution characteristics. The density

of distribution decreases from the centre of the urban area to the periphery⁴⁸⁸, in line with the morphological characteristics of the river-valley type of city.⁴⁸⁹ High-density zones are distributed in the areas rich in resources such as commerce, culture, transport and education, while low-density districts ⁴⁹⁰ are distributed in economically

underdeveloped resource-poor areas, which is closely related to the historical development process of Lanzhou City 491.492

(2) The spatial distribution of school-age children and preschool education resources roughly matches the overall mismatch of spatial appropriateness of preschool education resources.493 Thirteen streets are in oversupply, and 38 are in undersupply.494 The type of 'low supply and low demand' is the most prominent among the 51 streets, accounting for 49 per cent of the total,495 and it is concentrated in Anning District. The 'low supply-low demand' type is most prominent among the 51 streets,496 accounting for 49 percent of the total and concentrated in the Anning District.497

(3) The spatial accessibility of preschool education resources is generally satisfactory. Within 300m and 500m,498 84.31% and 58.82% of the streets have an accessibility index of 0, indicating that early childhood preschool resources499 are less accessible and less convenient. Within the range of 1,000 to 1,500 metres, the accessibility of preschool 500 education resources is better. As the critical value of spatial distance is adjusted from 300m to 1500m, the areas with high 501 accessibility values shrink towards the inner-city core area, and the areas with low values shift from concentration to segregation, and 502 closes to 50.98 percent of the streets have accessibility values between 0-1.

(4) The spatial equity of preschool education resources is evidently imbalanced. As the distance threshold set for accessibility expands, the Gini coefficient increases while the Palma ratio decreases. In the range of 300 - 500m, overall inter - district equity and local imbalance within the district are demonstrated. In the range of 1000 - 1500m, overall inter - district imbalance and local equity within the district are manifested.

4. Discussion

Accessibility is a key indicator of how easy it is to travel from one place to another. In urban geography, accessibility refers to how easy it is for children to travel to kindergartens, and the results of accessibility measurement can assess the efficiency of spatial allocation between 'home' and 'kindergarten'. The result of accessibility measurement can assess the efficiency of spatial allocation between 'home' and 'kindergarten'. Through accurate measurement of accessibility, we can understand the difficulty of children travelling to kindergartens from their home locations, so as to further optimize the spatial distribution of urban education resources and improve the fairness and efficiency of education services. Young children generally choose kindergartens closer to their homes, and the farther the distance is, the less attractive it is to young children, and its gravitational change just matches with the Gaussian function that decreases faster and then slower as the distance increases, so the Gaussian 2SFCA is used for the measurement of accessibility, and the Gaussian 2SFCA method integrates the relationship between demand and supply and the distance attenuation, and covers the dual concepts of accessibility to the facility and the facility's accessibility, therefore The calculated accessibility value is not only an expression of the efficiency and convenience of travelling to the kindergarten for school-age children, but also a further indication of the opportunity for school-age children to access the kindergarten. In the study of the accessibility of kindergartens for young children, it is crucial to base calculations on real road network

distances in studies of accessibility to schools for young children. As the search distance gradually expands, the number of kindergartens that can be included in the provision of access opportunities increases, and the accessibility increases with distance. However, the core of accessibility focuses on convenience and efficiency, i.e., the simpler and shorter the process of enrolment, the higher the accessibility. However, when discussing accessibility, many scholars [35] often ignore the key condition of search range, and the accessibility mentioned is often an absolute value without distance grading, rather than a relative quantitative index within a specific search range. This makes it impossible to realistically reflect the actual accessibility of schooling for young children. The study of accessibility in this paper focuses on relative quantities within the search radius, which are relative values of accessibility within the search area. In addition, in terms of scale, scale is the hierarchy by which geographical events and processes are represented, experienced, and organised, making spatial scale difficult to identify, understand and analyse due to the diversity of research topics, the ambiguity of spatial and temporal boundaries, and the availability of data [36]. Spatial scale is as one of the important dimensions of geographic analyses, and in the study of educational resources, the emphasis is often more on the distribution and configuration of educational resources at different geospatial levels. The main scales for studying preschool education resources are the school district scale and the grid scale. Compared with the grid scale, the street is a naturally formed spatial unit of the city with complete social structure and function. In the study of preschool education resources, the street contains a complete social ecosystem from the family, community to preschool institutions. The grid scale, as an artificially divided spatial unit [37], obliterates the influence of different urban forms and functional zoning on the results, and severs the social connection between humans and nature. In addition, the distribution of preschool education resources at the street scale is more in line with the actual distribution of social demand. The formation of streets is often related to population distribution, accessibility and other factors. Therefore, preschool education resources are usually reasonably distributed along streets to meet the needs of neighbouring residents. However, resource statistics at the grid scale may be mechanically divided in a way that makes the distribution of resources within the same grid look fragmented and disconnected from the actual social service demand. Compared with the school district scale, the relatively smaller spatial extent and more flexible boundaries of streets enable the study to focus on preschool resources in more detail and examine the equity of preschool resource distribution more precisely. The school district scale, on the other hand, is usually divided around primary and secondary schools [38], has a relatively large spatial scope, and focuses mainly on the layout of schools in the compulsory education stage. As the basic unit of statistical data, the street scale is often easier to obtain data on education-related attributes, and the spatial allocation of educational resources and the corresponding aspects of supply and demand are often carried out within the street scale. In the context of using administrative districts as the spatial governance unit, it is also easier to study the allocation of pre-school education resources in combination with related education policies. Therefore, this paper is based on the street scale, with four levels of 300m, 500m, 1000m and 1500m to develop the study

of preschool education resources.

Secondly, the kindergarten system consists of two major branches: public and private, which are the same as the main body of preschool education service supply, but are very different in operation mechanism and enrolment allocation mode. Most of the public kindergartens rely on government funding and management, the implementation of the degree lock regulation, household registration, school district as the dominant criterion of the nearest area for enrolment, so that the enrolment scope is relatively limited, resulting in some of the family's access to the kindergarten demand is blocked. In stark contrast, private gardens are not subject to the shackles of school districts, and follow a more market-driven logic, with more flexible enrolment strategies. This divergence in enrolment attributes has led to stark differences in the accessibility of kindergartens for children from different family backgrounds. The kindergarten data collected by Gaode Maps only presents the spatial location attribute, without the intrinsic differentiation between public and private kindergartens, which makes the current accessibility analysis a prediction under the assumption that all kindergarten enrolments are beyond the restriction of zoning area. In view of this, it is necessary for subsequent studies to incorporate traditional statistical data to explore the different characteristics of public and private kindergartens in terms of accessibility in order to fill this research gap. Again, this study also reveals a phenomenon: as the distance threshold for accessibility setting gradually increases, the Gini coefficient shows an increasing trend and the Palma ratio decreases accordingly[36]. This trend suggests that at the level of county and district-level administrative units, which have a wider spatial scope and a larger scale of resource allocation compared to streets, the problem of unequal distribution of educational resources nevertheless becomes more prominent. In contrast, at the street level, as the distance threshold for accessibility increases, there are more choices of preschool education resources, which to a certain extent effectively mitigates the disparity between the rich and the poor due to the difference in accessibility, and results in a more balanced access to preschool education resources for children from families of different economic status.

Finally, regarding spatial equity indicator methods, scholars such as Wang Peiyu, Liao Neng Kun and others have primarily evaluated spatial equity from the perspective of the opportunity to use public service facilities, based on accessibility measures such as the 2SFCA, and using the Gini coefficient and Lorentz curve [39-40]. An important feature of spatial equity is the balance between supply and demand, typically showing a high supply-high demand fit in the urban centre and a low supply-low demand fit in the urban periphery [41]. Evaluating spatial equity based on the supply-demand ratio based on 2SFCA does not address the issue of the supply-demand fit in different regions, and it also lacks considerations of comparative analyses of the opportunities for access to resources between different regions. Therefore, this study develops the research on accessibility and equity based on prioritising the supply-demand relationship between degree capacity and population size. Furthermore, as space itself encompasses a rich concept of extension and transformation [42], spatial equity is influenced by the complex interplay of various factors, including the economy (e.g., housing polarization), the population (e.g., disadvantaged groups), and evolving supply and demand dynamics (e.g., the two-child policy). As such, spatial equity

cannot be confined to accessibility alone. Over time, population mobility and natural demographic changes require a dynamic measurement of spatial equity, emphasizing how to structure a comprehensive and evolving analysis of the relationship between resource access and population size. Therefore, spatial equity should be measured from a dynamic perspective, and how to structure dynamic and comprehensive evaluation indicators and methods needs to be explored in the future.

5. Conclusion

The development of preschool education affects the service quality and quality of urban education service facilities. This study takes the downtown of Lanzhou city, a river-valley type city, as a case study, and uses kindergarten point data, kindergarten degree number, 3~6 years old children and other multi-source data to explore and analyse the clustering characteristics and fitness relationship of preschool education in the urban space; based on the city road network data, it uses Gaussian two-step moving search method to reveal the accessibility characteristics of preschool education, and based on the accessibility value to explore the fairness of preschool education in Lanzhou city, which can provide a scientific basis for future rational planning and regulation of the space of preschool education. The study can provide a scientific basis for the future spatial rational planning and regulation of preschool education in Lanzhou city. The main conclusions are as follows:

The spatial distribution of preschool education resources shows the characteristics of 'one core, four centres' and an east-west belt, with the density of distribution decreasing from the centre of the urban area to the periphery, which is in line with the morphological characteristics of a river valley-type city. Overall, there is an overall mismatch between the supply of kindergarten places and the demand from school-age children. Specifically, 13 streets having an oversupply of preschool education resources and 38 streets having an oversupply of preschool education resources. All streets have the most prominent type of 'low supply-low demand'. The spatial accessibility of preschool education resources in the range of 300m and 500m, 84.31% and 58.82% of the streets have an accessibility index of 0, indicating that the accessibility of preschool education resources for young children is poor and the degree of convenience is low. Within the range of 1000m to 1500m, the accessibility of preschool education resources for young children is good. The spatial equity of preschool education resources is significantly imbalanced, with the Gini coefficient increasing and the Palma ratio decreasing as the distance threshold set for accessibility expands, showing overall inter-district equity and local imbalance within districts in the range of 300~500m, and overall inter-district imbalance and local equity within districts in the range of 1000~1500m.

This study can provide valuable reference for the spatial allocation of kindergarten education resources and the improvement of accessibility. For the 12 streets with a 'low supply - high demand' situation, such as Jiayuguan Road and Weiyuan Road, the government should increase financial investment and expand the supply of public kindergartens through new construction or expansion. For the 12 streets with a 'high supply - low demand' situation, such as Qingbaishi, Wuquan, Xi Lu, Kongjiaya, etc., the government should strengthen regulation to prevent further expansion and consolidate and improve the quality of current kindergarten

education. In addition, since the number of school-age children is changing dynamically, the supply and demand of pre-school education resources will also change according to the demand side. Therefore, it is necessary to set up a platform for accurate observation of school-age children, so that through the co-operation between the planning department and the education department, the exchange and sharing of information can make the fair allocation of pre-school education resources to benefit every school-age child, and to improve the spatial quality of pre-school education resources. Finally, due to the limitation of data, we were not able to analyse the correlation factors affecting accessibility and matching supply and demand, which will be explored in depth in the future research.

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