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Article

Spatial distribution and influencing factors of Shadow Education Enterprises in primary and secondary schools: A case study of Zhengzhou's main urban area

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Abstract: The Primary and secondary shadow education refers to a kind of unofficial education that exists outside the traditional mainstream primary and secondary education system in China, with both commercial and educational attributes. As the primary and secondary school stage is an important key stage for further education, existing research mainly focuses on the spatial distribution of primary and secondary school basic education facilities and non-subject training, with fewer studies targeting primary and secondary school subject tutoring shadow education. With the changes in China's education industry and the introduction of the Double Reduction Policy, there is an urgent need to conduct in-depth research on the spatial aggregation characteristics and influencing factors of Shadow Education Enterprises for primary and secondary school students. This paper takes the main urban area of Zhengzhou City as the study area, and takes primary and secondary school Shadow Education Enterprises as the research object, and applies spatial analysis methods such as kernel density, nearest-neighbor index, and geographic detector to quantitatively analyze the spatial distribution characteristics of primary and secondary school shadow education tutoring enterprises in Zhengzhou City and the factors affecting them The results show that: 1) The overall spatial pattern of primary and secondary school tutoring Shadow Education Enterprises in the main urban area of Zhengzhou City has largely formed a core-edge structural feature that spreads from the urban center to the periphery, and presents the spatial agglomeration feature of "double nuclei many times" distributed along both sides of the Beijing-Guangzhou Line. 2) The distribution of mentoring Shadow Education Enterprises in the main urban area of Zhengzhou City in relation to provincial model primary and secondary schools is significant and there is a significant difference between the distribution around secondary schools and primary schools. 3) The spatial distribution of Shadow Education Enterprises in the main urban area of Zhengzhou City is mainly influenced by factors such as the size of the school-age population, the level of commercial development, the location of school buildings and the accessibility of transport.

Keywords: Shadow Education Enterprises; primary and secondary schools; spatial agglomeration; influencing factors; Zhengzhou main urban area

1. Introduction

Education plays a crucial role in China's pursuit of modern talent development, making it a topic of great concern for society at large. As the economy rapidly advances and societal and cultural changes interact with market consumer behavior, educational activities have undergone a transformation. They are increasingly characterized by socialization, diversification, and complexity, deviating from the traditional model of education penetration. Gradually, a dualistic phenomenon has emerged, where the traditional model of public education coexists with a market-oriented, socially-driven educational model in the 21st century. This shift has intensified the competition in education, prompting students to seek additional avenues for enhancing their academic performance. Consequently, students have started to engage in various extracurricular training programs. In response to market demands, primary and secondary education and training organizations have emerged, often referred to as shadow education due to its close association with mainstream education (Bray and Qing, 2012; Bray, 2020). Since 2000, China's shadow education and training industry has continued to grow, by 2020, the scale of education and training close to 700 billion yuan, reflecting the current high degree of development of the socialized education and training industry, to a certain extent, education and training to make up for the current inadequacy of public education, but at the same time, it exacerbates problems such as education inequality, lack of regulation and effective supervision (Wang, 2023). However, it has exacerbated educational inequality, and the lack of regulation and effective supervision and other issues have aroused widespread concern in all walks of life (Lu et al., 2019). The report of the 20th National Congress of the Communist Party of China (CPC) highlights the importance of developing quality education and promoting equity in education as key components of building a strong educational nation. It recognizes that primary and secondary education, being the foundation of national education, should be pioneering, universal, and fundamental in nature. However, for a significant period of time, the issue of excessive academic burden on primary and secondary school students has become a widespread problem and a prominent social issue. This problem has greatly hindered the balanced development of education and has had a negative impact on the physical and mental well-being of minors. In 2021, the General Office of the State Council issued the Opinions on Further Reducing the Burden of Homework for Students in Compulsory Education and the Burden of Out-of-School Training (Chen and Li, 2021). This policy aims to regulate both online and offline forms of education and training and effectively alleviate the academic pressure on primary and secondary school students. Following this, the Ministry of Education and other departments introduced the Opinions of Thirteen Departments on Regulating the Out-of-School Training of Primary and Secondary School Students. These opinions outline a series of measures and approaches to implement the "double reduction" policy for students in compulsory education. These initiatives and methods aim to reduce the workload and academic burden on students at the compulsory education stage. Indeed, conducting a spatial study of shadow education counseling institutions in primary and secondary schools can provide valuable insights into the spatial distribution patterns of the targets for double reduction. This research can help policymakers understand the geographic concentration of these institutions and identify areas where the burden of out-of-school training is particularly high. By mapping the spatial distribution, decision-makers can make more informed and targeted interventions to regulate and govern the provision of out-of-school training. This spatial analysis can contribute to the development of precise measures to alleviate the burden on students and promote a more balanced and equitable education system.

Since the 1980s, foreign scholars have paid extensive attention to shadow education, mainly focusing on the social impact of shadow education (Kim, 2013), the global development trend of shadow education (Mori and Baker, 2010) and the influencing factors and driving mechanisms of shadow education (Baker et al., 2001). On the basis of foreign studies, domestic scholars have paid attention to the development process and social impact of shadow education (Li, 2017). and social impact of shadow education (Feng, 2018) and the relationship between shadow education organizations and schools (Ding et al., 2018) marketing strategy (Huang et al., 2018; Zhang et al., 2016) and influencing factors and effects (Li et al., 2016; Li, 2017) and normative governance (Song and Xue, 2018; Yang and Huang, 2020). However, from the perspective of spatial research, studies based on the main body of "primary and secondary school shadow education" (counseling institutions) are relatively weak. For example, Pan Zhang studied the influence of peers on students' shadowing activities and found that an increase in the percentage of peers receiving shadowing positively impacted students' shadowing participation, expenditures, and weekend hours (Zheng et al., 2022). Ran (2019) explored the optimal location for the siting of education and training institutions and concluded that the regional layout for establishing education and training institutions should match the optimal location for the development of the institutions. Xie (2018) used social media data to analyze differences in the accessibility of school-age children aged 3-12 years old to different educational tutoring institutions and came up with the suggestion that children's educational course tutoring institutions should consider a layout close to the source of students when selecting locations (Luo et al., 2020). In studying the spatial pattern and influencing factors of shadow education in Lanzhou City, it was concluded that the shadow education institutions in the category of tutoring and training are on the mainstream education layout (Liu, 2021). When studying the spatial differentiation of shadow education institutions and the relationship between shadow education and mainstream education in Nanjing, it was concluded that the course tutoring type of shadow education is easy to gather around famous schools; Dou (2022) analyzed the characteristics of the spatial pattern of educational tutoring institutions for children aged 5–14 in Beijing and came to the conclusion that subject tutoring-type shadow education institutions have obvious characteristics of clustering near school districts. which have been the focus of attention after the promulgation of the Double Reduction Policy, and their research is far less in-depth than that of mainstream education. Furthermore, when scholars study the influencing factors of school distribution, they usually consider factors such as population size, residential distribution (Wang et al., 2019), the level of economic development of the city (Wang et al., 2019), the disposable income of residents, the cost of travelling to school, the school environment, and government policies (Ji et al., 2020). Regarding the placement of training institutions, Ran Hui assessed the suitability of school locations based on factors like transportation costs, population size, and other considerations (Ran, 2019). Qu (2013) argued that when establishing education and training institutions, the location should prioritize convenient transportation, a sufficient student population, and student's family income, thus promoting concentration in specific areas. Dou's research (2022) on the distribution of children's educational counseling institutions in Beijing concluded that factors such as school districts, housing prices, accessibility, and demographic conditions play a significant role in determining the spatial distribution of such institutions. Ye's study (2022) on the spatial arrangement of educational training institutions in Fuzhou City proposed that the main factors influencing their layout are the location environment, transportation conditions, and student population status.

In general, prevailing research on primary and secondary education and training primarily centers around educational institutions, parents, and students as research subjects. It places emphasis on the psychological aspects of students and parents, students' learning conditions, and the spatial patterns of various forms of clandestine education. Concerning the scope of the investigation, current research predominantly revolves around examining the spatial distribution of clandestine education at the municipal level. As for research methodologies, a majority of existing studies employ pedagogical and sociological analytical approaches, including case analysis, interviews, and questionnaire surveys, thus hindering a comprehensive and systematic analysis of the spatial and temporal distribution characteristics and the primary influencing factors of clandestine educational institutions catering to primary and secondary school students in China. Consequently, it is evident that there is a dearth of spatial research specifically dedicated to clandestine educational institutions offering curriculum counseling for primary and secondary school students. In particular, research pertaining to clandestine educational tutoring institutions for primary and secondary school students, which has garnered attention following the implementation of the Double Reduction Policy, remains comparatively less extensive and in-depth than mainstream education research.

This study uses POI data to study the shadow educational institutions of primary and secondary education counseling. With the development of geographic information technology, the collection and acquisition technology of POI data has become quite mature nowadays, and due to the fact that the number of POI individuals is large and the scale is small, it is especially suitable for the study of the spatial distribution of urban phenomena on a microscopic and small scale, POI data has already been widely used in spatial research, and the study has carried out the study of the urban commerce, education infrastructure and facilities (Wang et al., 2015). The urban commercial, basic education resource facilities, and transport facilities have been studied (Wang et al., 2019) transport facilities (Liu and Xue, 2019), public services and infrastructures (Diao et al., 2017). The widespread use of POI data provides a reliable and credible data source for geospatial research and strong data support for shadow education spatial research. This study takes the main urban area of Zhengzhou City as the research scope, takes primary and secondary education tutoring shadow education institutions as the research object and obtains the POI data of 1516 primary and secondary shadow education institutions through the web crawler software, and applies the spatial analysis methods such as nearest-neighbour index, kernel density, standard deviation ellipse, etc., in order to achieve the following research objectives 1) to analyse the spatial pattern characteristics of primary and secondary school shadow education 2) to explore the spatial layout pattern of primary and secondary school Explore the spatial layout pattern of shadow education in primary and secondary schools 3) Understand the spatial relationship between model primary and secondary schools and shadow education 4) Explore the factors affecting primary and secondary schools' shadow education institutions. This study can provide scientific basis and theoretical reference for the precise spatial management of primary and secondary school shadow education and the implementation of double reduction policy in Zhengzhou City.

2. Overview of study area

Zhengzhou is situated in central China and serves as the capital city of Henan Province. It is located in the north-central part of the province, where the middle and lower reaches of the Yellow River meet. Geographically positioned between 112°42′–114°14′ East longitude and 34°16′–34°58′ North latitude, Zhengzhou is a typical plain city in the northern region of China. As a national central city and a significant growth pole within the Central Plains City Cluster, Zhengzhou boasts a strategically advantageous geographic location and excellent transportation infrastructure. It serves as a comprehensive transportation hub, connecting railways, highways, airlines, and communication networks throughout China. Not only is Zhengzhou a comprehensive transportation hub, but it also holds importance as a major city in the Central Plains region, characterized by a sizable educational population.For this study, the main urban areas selected include five municipal districts: Jinshui, Erqi, Zhongyuan, Huiji, and Guancheng Huiyuan. These districts encompass a total of 80 streets and townships, covering an area of 1033.51 km^2 (**Figure 1**). According to data from the seventh national census, the resident population in the study area amounts to 5,028,500, with a primary and secondary school-age population (5–19 years old) of 795,400. As of 2022, there are 426 primary schools, 303 secondary schools, and 1516 shadow educational institutions within the study area.

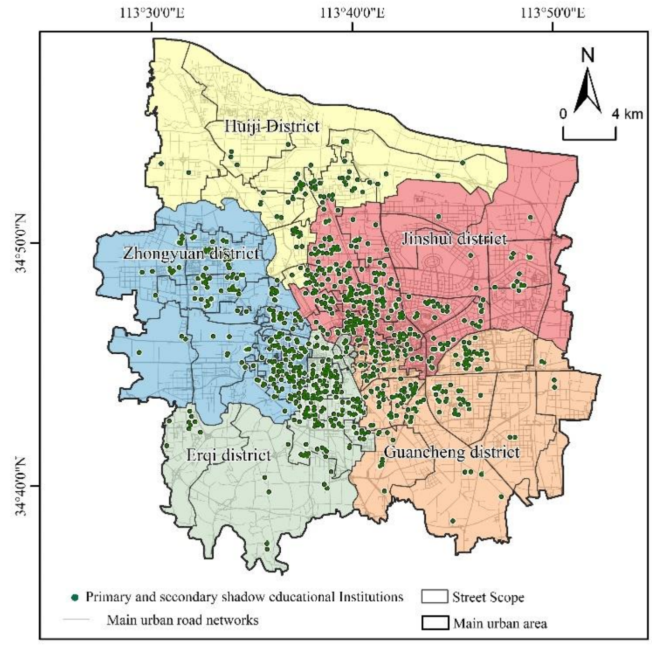


Figure 1. The spatial distribution of Shadow Education Enterprises Zhengzhou.

3. Data sources and research methods

3.1. Data sources and technological route

The data needed for this study include POI data of primary and secondary schools and primary and secondary school extracurricular tutoring institutions. This data was obtained by web crawling on the Gaode Map open platform. A total of 426 primary schools and 303 secondary schools (including high schools) were obtained. The shadow institutions targeting primary and secondary school students' extracurricular tutoring were filtered by deleting non-college or vaguely defined parts such as early childhood education, vocational training, and art training from 6943 shadow institutions. The data was collected in October 2021 and identified using Dianping and Tianyancha websites. POI data of residential districts and district house price information. This data was crawled from the official website of Anjuke (https://zhengzhou.anjuke.com). A total of 5194 residential districts were obtained in December 2021.Primary and secondary school-age population data of each street. This data was obtained by converting the street-scale data from the 7th National Population Census. The population data for the age group of 5 to 19 years old was selected for analysis to correspond to the age of the service subjects of primary and secondary school counseling Shadow Education Enterprises. The formula used for conversion is the number of primary and secondary school students in each township (street) = the resident population of each street × the proportion of primary and secondary school students in the municipal area to the total population of the municipal area. Urban road network data of the main urban area of Zhengzhou City. This data was downloaded from OpenStreet. Administrative division data. This data was obtained from the National Geographic Information Service platform. The above data will provide the necessary foundation for this study. The research technology roadmap is as follows (**Figure 2**).

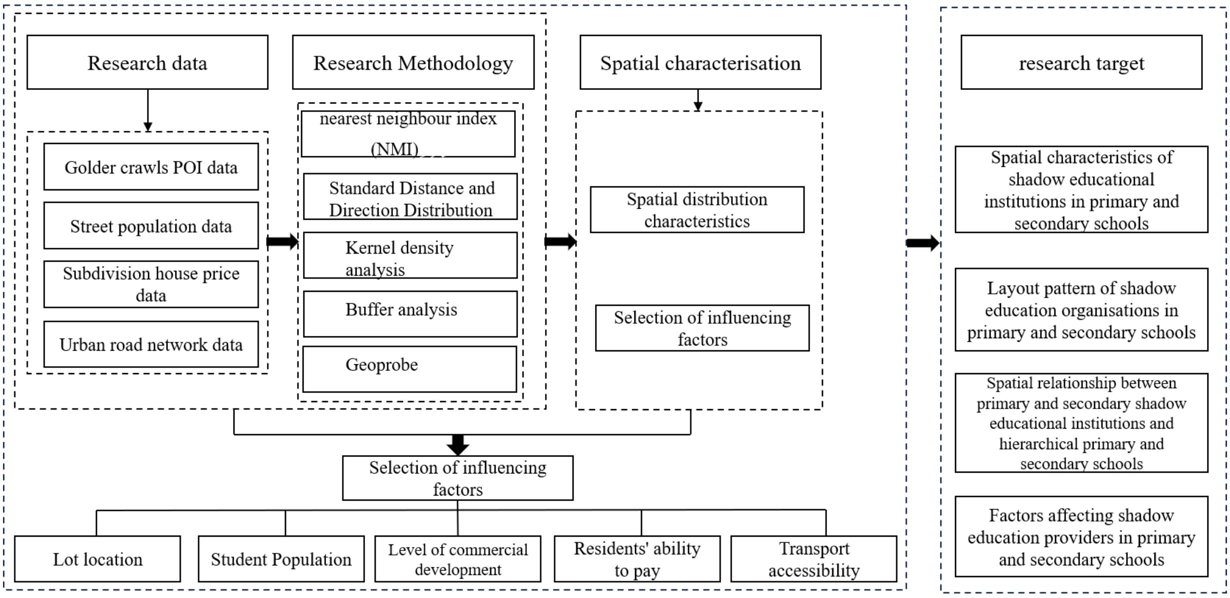


Figure 2. Technology roadmap.

3.2. Research methods

The study aims to characterize the spatial distribution pattern of shadow educational institutions in the main urban area of Zhengzhou City. The researchers utilize various spatial statistical tools in ArcGIS to analyze the distribution of point of interest (POI) data related to these institutions. The nearest-neighbor index, standard distance and direction distribution, and kernel density estimation methods are applied to understand the clustering or dispersion of these institutions within the city. Additionally, the study employs a geoprobe to investigate the factors that contribute to the spatial distribution of shadow educational institutions. The geoprobe allows for further exploration and understanding of the influencing factors that play a role in determining the locations of these institutions within the city. Overall, this research combines spatial statistical analysis and geoprobe exploration to gain insights into the spatial distribution pattern of shadow educational institutions in Zhengzhou City and the factors that influence their locations.

3.2.1. The Nearest Neighbour Index (NNI)

The nearest neighbor index (NNI) is a measure used to assess the spatial distribution pattern of point objects in a geospatial space. Specifically, the average nearest neighbor (ANN) index calculates the average distance between points and their nearest neighbors. This index provides insights into the level of clustering or dispersion of point elements in the study area. The NNI is calculated by dividing the observed average distance (r1) by the expected average distance (rE). The observed average distance is obtained by averaging the distances between each point and its nearest neighbors. On the other hand, the expected average distance refers to the average distance between neighboring regions in a hypothetical random distribution. By comparing the observed and expected average distances, the NNI can indicate whether the point objects are clustered, dispersed, or randomly distributed. A value of NNI less than 1 suggests clustering, while a value greater than 1 indicates dispersion. A value close to 1 suggests a random distribution. In the context of the study on shadow educational institutions in Zhengzhou City, the NNI can help determine the degree of clustering or dispersion of these institutions in the urban area. This information provides insights into the spatial distribution characteristics of shadow educational institutions and contributes to understanding their overall pattern within the city (Clark and Evans, 1954). The specific formula is:

$$r_E = {}^{1}\!/_{2}\sqrt{{}^{n}\!/_{D}}, R = {}^{r_1}\!/_{r_E} \tag{1}$$

In Equation (1), D represents the area of the study area, and n is the total number of elements being analyzed. The nearest neighbor index (R) is calculated using the average nearest neighbor tool in ArcGIS. When $R = 1$, it indicates a random distribution of the elements being studied. When $R > 1$, it suggests a dispersed or discrete distribution, meaning that the elements are more spread out than would be expected in a random distribution (Wang et al., 2018). When $R < 1$, it indicates a clustered distribution, implying that the elements are closer together than would be expected in a random distribution. In this study, the average nearest neighbor tool in ArcGIS is employed to measure the nearest neighbor index. This tool allows for the visualization and analysis of the spatial distribution characteristics of primary and secondary Shadow Education Enterprises within the main urban area of Zhengzhou City. It also helps determine the degree of clustering of these institutions.

3.2.2. Kernel density analysis

The kernel density analysis tool is commonly used to calculate the density of elements within a spatial neighborhood. This analysis helps to reveal the spatial clustering or agglomeration of the research object. In the case of this study, the kernel density tool is employed to analyze the overall agglomeration characteristics of shadow education tutoring institutions in Zhengzhou City. The kernel density analysis method works by taking an individual point as the center and then calculating the data aggregation status for the entire region based on the input element data (Mitchell, 2005; Xue et al., 2018). It estimates the probability density function (f) and uses it to assess the spatial distribution pattern. The equation for kernel density estimation can be expressed as follows:

$$f_h(x) = \frac{1}{nh}\sum_{i=1}^{n} k\left(\frac{x - x_i}{h}\right) \tag{2}$$

In the context of kernel density estimation, the function $f_h(x)$ represents the kernel function, which defines the shape of the density estimation. A larger value of the kernel function indicates a denser distribution of elements. The spatial weight function is represented by k, and it determines how neighboring points contribute to the density estimation. The bandwidth h is a parameter that controls the degree of smoothing in the estimation process. It defines the size of the spatial neighborhood over which the density is calculated. Finally, n represents the number of points within the analyzed range, which is the total number of elements being considered for the density estimation.

3.2.3. Standard distance and directional distribution

Distribution Standard Distance (SD) is a geographic tool for measuring distributions by creating a circular plane to measure the discrete or aggregation of elements at the center of a geometric mean. Calculating Standard Distance using ArcGIS tools gives you a circular plane containing the xy coordinates of the mean center point, and the radius of the circle is the Standard Distance. The specific calculation formula is:

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{X})^2}{n} + \frac{\sum_{i=1}^{n}(y_i - \bar{Y})^2}{n} + \frac{\sum_{i=1}^{n}(z_i - \bar{Z})^2}{n}}. \tag{3}$$

In the equation x_i, y_i, and z_i represent the coordinates of element i, and n represents the total number of elements being analyzed (Zhao and Zhao, 2014). By plotting and generating the standard distance circle surface within the main city of Zhengzhou and its districts, you can obtain the average center of the distribution of training institutions in the region. This average center represents the centroid or the point of highest density of the training institutions. In addition to determining the average center, you can also measure and compare the centripetal force of each center on the points of training institutions in the region. The centripetal force represents the attraction or influence that each center has on the surrounding training institutions. To measure and compare the centripetal force, you can consider factors such as the distance between each center and the training institutions, the density of training institutions around each center, and any other relevant factors that indicate the strength of attraction. By analyzing and comparing the centripetal force of each center, you can gain insights into the spatial dynamics of the training institutions in Zhengzhou. This information can be useful for understanding the distribution patterns, accessibility, and potential concentration areas of training institutions within the city and its districts.

The Standard Deviational Ellipse (SDE) is an analytical tool used to quantitatively describe the overall spatial distribution of point elements. It provides information about the center of the ellipse, the long and short axes, and the azimuthal angle, which are the basic parameters of the SDE. The center point of the Standard Deviational Ellipse indicates the relative position of the spatial distribution of geographical elements. It represents the point of highest density or concentration within the distribution. The azimuthal angle of the SDE indicates the direction of the main trend of development or the major axis of the distribution. It shows the orientation or direction in which the elements are most concentrated or dispersed. The long semiaxis of the SDE represents the degree of concentrated influence of geographic elements in the direction of the main trend. It illustrates the extent or magnitude of concentration or dispersion along the major axis or trend. The short semiaxis of the SDE represents the degree of concentrated influence of geographic elements in the secondary direction. It indicates the extent or magnitude of concentration or dispersion along the minor axis or secondary trend. Overall, the Standard Deviational Ellipse provides a comprehensive view of the spatial distribution of point elements. It helps to understand the relative position, orientation, and degree of concentration or dispersion of the geographic elements within the study area. By analyzing the SDE, researchers can gain insights into the overall pattern and characteristics of the distribution, which can be useful for various spatial analysis and planning applications. The specific calculation formula is:

$$\delta_x = \sqrt{\frac{\sum_{i=1}^{n}[(x_i - \bar{X})cos\theta - (y_i - \bar{Y})sin\theta]^2}{n}} \tag{4}$$

$$\delta_y = \sqrt{\frac{\sum_{i=1}^{n}[(x_i - \bar{X})sin\theta - (y_i - \bar{Y})cos\theta]^2}{n}} \tag{5}$$

This tool calculates the standard deviation ellipse, which provides information about the difference in direction and distribution of the facility points. The standard deviation ellipse is generated based on the spatial locations (x_i, y_i) of the teaching and learning institutions. It captures the variability and spread of the facility points along the x-axis (represented by δ_x) and along the y-axis (represented by δ_y) (Shi et al., 2019). The standard deviation ellipse provides insights into the direction and size of the distribution pattern. By comparing different ellipses, researchers can understand the differences in the direction and size of the teaching and learning institutions in different areas. This comparison helps identify any variations or patterns in the distribution of these institutions across the main urban area and its districts. Additionally, the standard distance ellipse can be combined with the standard deviation ellipse to further analyze the distribution trend and closeness of the main teaching and learning institutions in each area. The standard distance ellipse represents the density or concentration of the facility points. By analyzing the distribution characteristics of the training institutions in each district of the main urban area of Zhengzhou City and the entire area, researchers can gain a deeper understanding of the spatial patterns and relationships between the institutions. This analysis can provide valuable insights for urban planning, resource allocation, and decision making related to education and training facilities. It is important to note that in this study, the default first and second-level standard deviations are used for calculations, i.e., for standard deviation ellipses and standard distances, and one standard deviation range, the default range, encompasses the center of mass of about 68% and 95% of the total number of input elements when the elements have a spatial normal distribution.

3.2.4. Geographic detector

The Geographic Detector is a tool used to detect spatial dissimilarity and analyze the causes of spatial patterns in a given element. It is widely used in studies of spatial layout and can help determine whether a specific geographic factor is responsible for differences in the spatial distribution of a particular index value (Xu et al., 2019). In this study, the Factor Detector is utilized to analyze the influencing factors of shadow educational institutions in the main urban area of Zhengzhou City. The Factor Detector is specifically designed to examine whether a geographic factor contributes to variations in the spatial distribution of a specific indicator value. By applying the Factor Detector, researchers can identify and analyze the potential factors that may influence the distribution of shadow educational institutions in Zhengzhou City's main urban area. This analysis can help understand the spatial patterns and drivers behind the presence or concentration of these institutions. The Factor Detector allows for a systematic examination of various geographic factors, such as proximity to transportation hubs, population density, land use patterns, and socioeconomic characteristics, among others. By evaluating the relationship between these factors and the spatial distribution of shadow educational institutions, researchers can gain insights into the underlying causes and drivers shaping their distribution in the study area. Overall, the Geographic Detector, specifically the Factor Detector, provides a valuable tool to investigate the influencing factors of shadow educational institutions in Zhengzhou City's main urban area. the detection formula is as follows:

$$q_{D,H} = 1 - \frac{1}{n\sigma^2} \sum_{H_{i=1}}^{m} n_{D,i}\, \sigma^2_{H_{D,i}} \tag{6}$$

where: $q_{D,H}$ represents the explanatory potency of factor D on factor H; n and $n\sigma^2$ the total sample size and variance of shadow education teaching and learning institutions, respectively; m indicates the count of a specific factor, and$n_{D,i}$ signifies the sample count of indicator D within class i. The value of $q_{D,H}$ falls within the interval of [0, 1], and as its magnitude increases, so does the impact of the factor on the spatial arrangement of shadow education teaching and learning institutions.

4. Characterizing the spatial pattern of shadow education

4.1. Spatial distribution characteristics

(1) Shadow Education Enterprises exhibit notable variations in spatial distribution across districts, with Jinshui and Zhongyuan districts serving as the central hubs for the arrangement of Shadow Education Enterprises. Based on the obtained point of interest (POI) data for shadow education tutorial institutions in the main urban area of Zhengzhou City, quantity statistics (**Table 1**) and geographic information visualization (**Figure 3**) were conducted on a district level. The data points represent the geographical locations of shadow education tutorial institutions, while the darkness of the background color in each district indicates the number of Shadow Education Enterprises present. Regarding the number of Shadow Education Enterprises in the

five districts of the main urban area, Jinshui, Zhongyuan, Erqi, Guancheng Huiyuan Autonomous Region, and Huiji districts accounted for 419, 402, 315, 260, and 120 institutions, respectively. These figures correspond to 28%, 27%, 21%, 17%, and 8% of the total number of Shadow Education Enterprises. Notably, the Jinshui district exhibited the highest concentration, while the Huiji district had the lowest number of Shadow Education Enterprises.

Table 1. Quantitative characteristics of Shadow Education Enterprises in the main urban area of Zhengzhou.

Area name	Number of shadow educational institutions	Percentage
Zhongyuan District	402	27%
Jinshui District	419	28%
Erqi District	315	21%
Guancheng District	260	17%
Huiji District	120	8%

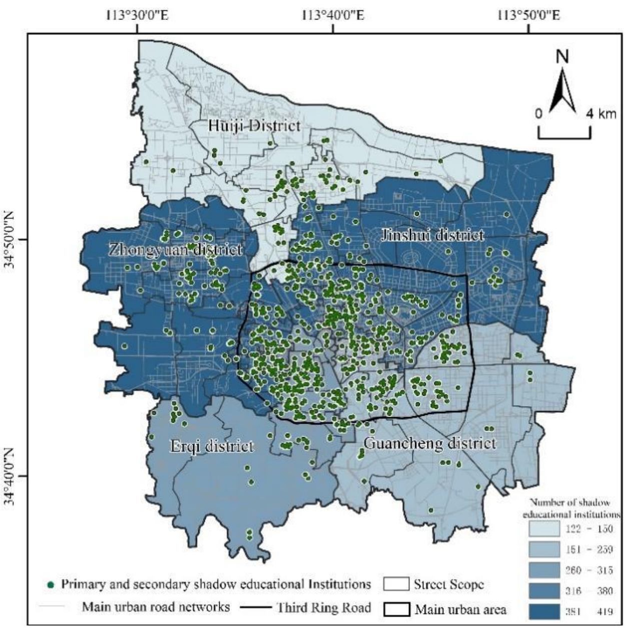


Figure 3. Distribution map of Shadow Education Enterprises in the main urban area of Zhengzhou.

(2) The spatial arrangement of Shadow Education Enterprises exhibits a notable characteristic in relation to the distribution of urban centers within the boundaries of the third ring road. There is a significant overlap between the areas where shadow education teaching and learning institutions are concentrated and the regions housing vital transportation hubs with extensive road networks. It has been calculated that the number of Shadow Education Enterprises within the Third Ring Road reaches a staggering 1083, accounting for 72% of the total number of such establishments. This concentration is primarily observed in areas characterized by dense urban road networks, which typically correspond to higher population densities and relatively stronger economic conditions. Consequently, there is a greater presence of educational institutions catering to the needs of primary and secondary school students in these

areas.

(3) Shadow Education Enterprises exhibit a noteworthy concentration around the spatial distribution of primary and secondary schools. Specifically, these institutions are predominantly clustered within the buffer zones surrounding primary and secondary schools located within the three ring road (refer to **Figure 4**). Using ArcGIS, a buffer zone of 1000 m was created around secondary schools, while a buffer zone of 500 m was established around primary schools. The selection of buffer zone sizes adhered to the principles governing the layout of primary and secondary schools in our country. Upon conducting statistical analysis, it was discovered that within a 500m radius around primary schools in Zhengzhou, there were 1098 teaching-aiding Shadow Education Enterprises. This figure accounts for 72.24% of the total number of Shadow Education Enterprises. Similarly, within a 1000m radius around secondary schools, there were 1320 teaching-aiding Shadow Education Enterprises, representing 87.07% of the total number of Shadow Education Enterprises. Hence, the number of Shadow Education Enterprises with teaching aids surrounding secondary schools is significantly higher than that surrounding primary schools.

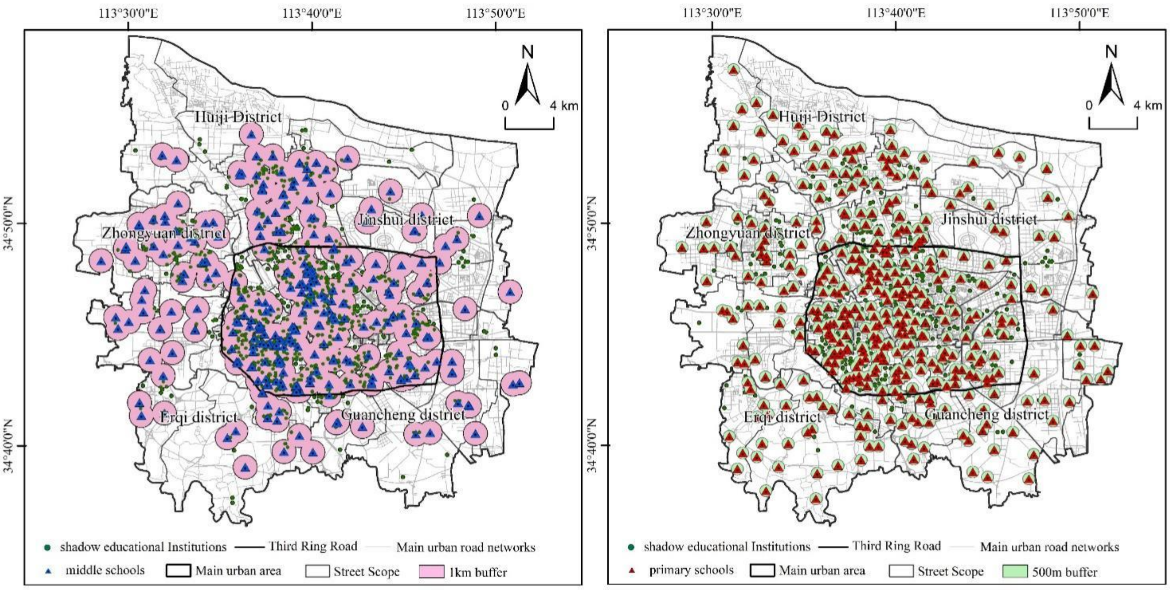


Figure 4. Distribution map of Shadow Education Enterprises in Zhengzhou Primary and secondary school Buffer zone.

(4) The distribution of Shadow Education Enterprises in relation to the layout of primary and secondary schools showcases remarkable patterns, particularly in areas where provincial exemplary primary and secondary schools are concentrated within the third ring road (refer to **Figure 5**). Using ArcGIS, a 1000 m buffer zone was created for 30 demonstrative secondary schools, and a 500 m buffer zone was established for 50 demonstrative primary schools. The selection of buffer zone sizes adhered to China’s principles governing the layout of primary and secondary schools. Upon conducting statistical analysis, it was found that the number of demonstrative secondary schools distributed within the third ring road in Zhengzhou accounted for 70% of the total number, while the number of demonstrative primary schools accounted for 80% of the total. This distribution aligns with the concentration of

Shadow Education Enterprises, which is primarily observed in Jinshui District and Zhongyuan District. Notably, these two districts also host the highest number of model primary and secondary schools. On average, there are 30 Shadow Education Enterprises within a 500m radius of a single model primary school in Zhengzhou, significantly surpassing the average of 8 Shadow Education Enterprises within the same distance of an ordinary primary school. Similarly, the average number of teaching-aid Shadow Education Enterprises within a 1000 m radius of a single model secondary school is 23, far exceeding the average of 10 Shadow Education Enterprises within a 500 m radius of an ordinary secondary school.

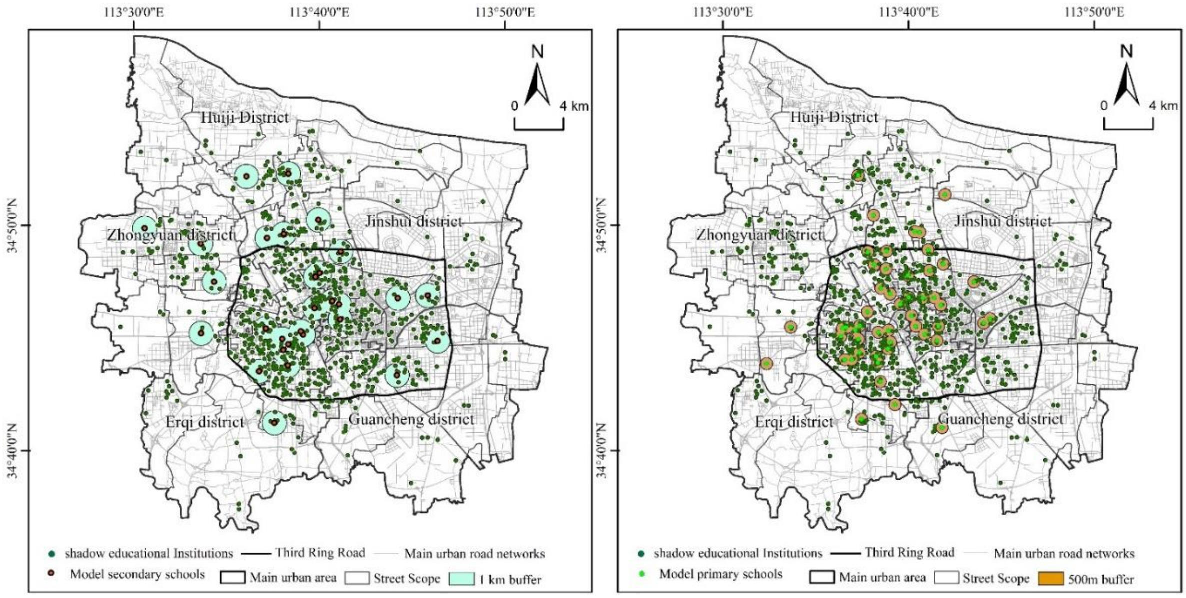


Figure 5. Distribution map of buffer zones for demonstration of primary and secondary schools of Zhengzhou city.

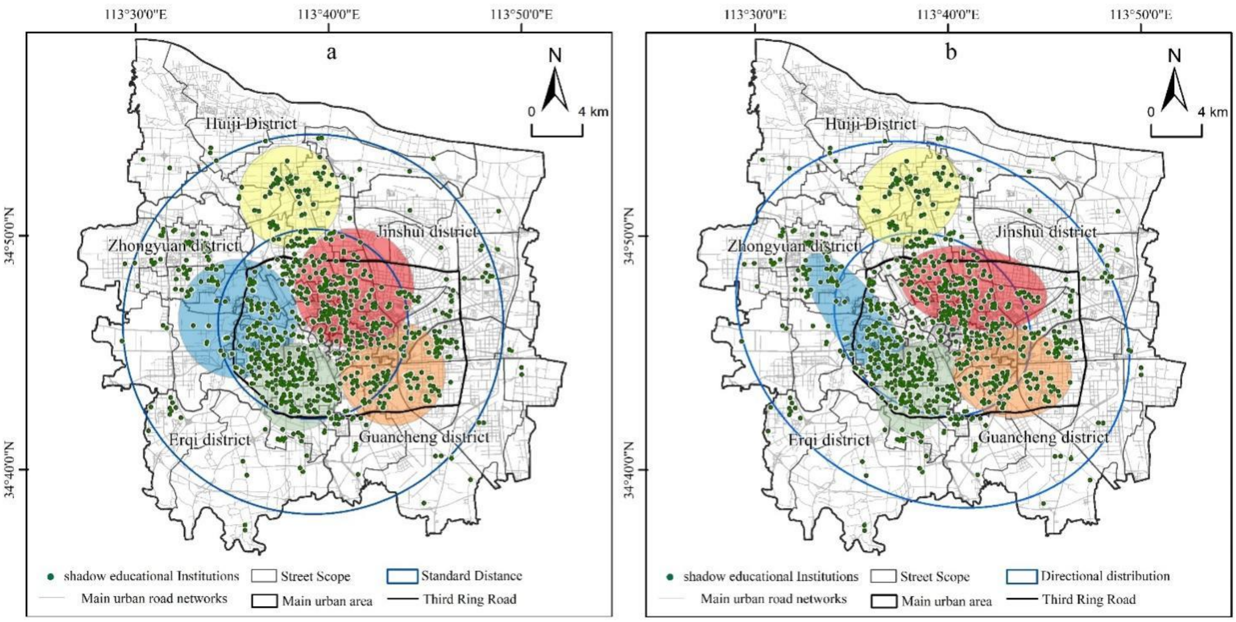
4.2. Spatial agglomeration characteristics

In this study, the spatial agglomeration characteristics of shadow education in primary and secondary schools in Zhengzhou City were investigated using various analytical tools. The nearest-neighbor index was employed to examine the spatial clustering status of both shadow education teaching institutions and teaching aids. Additionally, the standard distance and direction distribution tool was used to explore the spatial distribution center and direction of these institutions in the main city of Zhengzhou and its five districts. Furthermore, kernel density estimation was applied to analyze the spatial agglomeration characteristics of shadow education teaching and teaching aids.

The standard distance tool was utilized to generate a standard distance circle within Zhengzhou city and its surrounding areas (counties and municipalities), as depicted in **Figure 6a**. This allowed for the determination of the average center of regional distribution for Shadow Education Enterprises. The size of the circle reflects the level of proximity in the distribution of these facilities, enabling comparisons of the centripetal force exerted by each center on the Shadow Education Enterprises in the region. Furthermore, the directional distribution tool was employed to investigate the distribution pattern of shadow education teaching and learning institutions in the main urban area of Zhengzhou City and its subordinate districts. This tool generates a standard deviation ellipse, as shown in **Figure 6b**. The long axis of the ellipse represents the direction of the distribution of shadow education teaching and learning institutions in the region, while the short axis characterizes the range of distribution of the facility points. The center of the ellipse coincides with the center of the circle representing the standard distance surface. Overall, these analytical tools provide insights into the spatial agglomeration characteristics of shadow education in primary and secondary schools in Zhengzhou City, highlighting the clustering patterns, distribution centers, and directional trends of these institutions.

(1) The center of concentration for both primary and secondary Shadow Education Enterprises and teaching-aid institutions in the main urban area of Zhengzhou City is located in the geometric center of the city. The overall spatial expansion pattern follows a "center-periphery" trend, as shown in **Figure 6a**. By comparing the standard distance circles of each district, it is observed that the distribution center of institutions in Zhongyuan District is located in the east, Huiji District in the south, Jingshui District in the west, Guancheng District in the northwest, and Erqi District in the northeast. Interestingly, the major Shadow Education Enterprises in these districts are not concentrated in the internal centers of their respective districts, but rather cluster towards the junction of Jinshui, Zhongyuan, Erqi, and Guancheng districts. Overall, the distribution centers in each district exhibit similar characteristics, converging towards the average center of institution distribution in the main urban area of Zhengzhou City. These distribution centers also tend to overlap with the geometric center of the main urban area.

(2) In the main urban area of Zhengzhou, the primary and secondary shadow education teaching and learning institutions exhibit a northwest-southeast distribution pattern, which aligns with the direction of the Beijing-Guangzhou line that runs through the city (refer to **Figure 6b**). As a national transportation hub, Zhengzhou's urban geographic space is significantly shaped by its extensive road network. The distribution direction of Shadow Education Enterprises in the five districts under the jurisdiction of Zhengzhou City is particularly notable in Zhongyuan District, Jinshui District, Erqi District, and Guancheng District. Zhongyuan District shows a northwest-southeast distribution direction. Jinshui District presents a west-east distribution direction. Erqi District exhibits a northeast-southwest distribution direction. Guancheng District displays a west-east distribution direction. Overall, the distribution of shadow institutions spreads from the center of the main city towards the outskirts. This is because the zone of concentration for shadow education coincides with the city center, specifically the junction of the four districts. This area represents the location of Zhengzhou's city center, with the densest road network and the most prosperous commercial zone.



a **b**

Figure 6. Standard distance and direction distribution map of Shadow Education Enterprises in the main urban area of Zhengzhou.

Using the ArcGIS tool, the nearest-neighbor index for Shadow Education Enterprises in Zhengzhou City was calculated to be approximately 0.366, which is less than 1 (refer to **Figure 7**). The result passed the significance test at a level of 0.01, indicating that the shadow education teaching and learning institutions in the main urban area of Zhengzhou City exhibit significant spatial agglomeration characteristics. This suggests that these institutions are not randomly distributed, but rather cluster together in certain areas within the city. The presence of spatial agglomeration indicates the concentration of Shadow Education Enterprises in specific locations, which can have implications for educational access and competition in those areas.

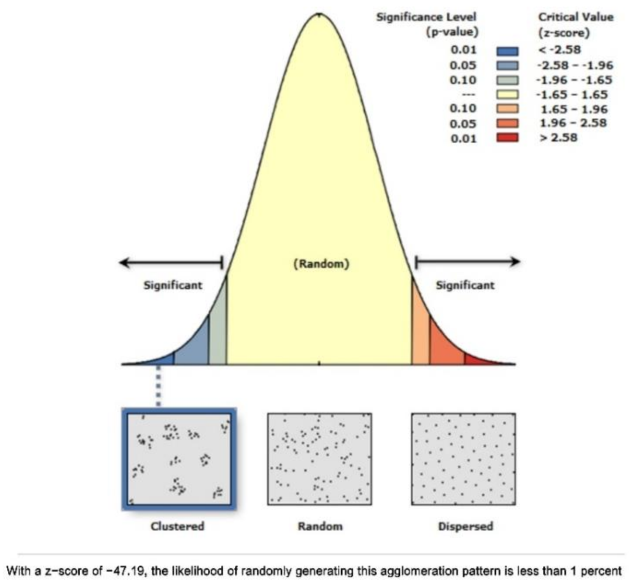


Figure 7. Report on the nearest neighbor index of Shadow Education Enterprises in Zhengzhou city.

(3) Shadow Education Enterprises in the main urban area of Zhengzhou City exhibit a spatial agglomeration pattern characterized by a “center-edge” group distribution (refer to **Figure 8**). The results of kernel density analysis indicate that the density of Shadow Education Enterprises in the central area of the main urban area of Zhengzhou City is significantly higher than that in the peripheral areas. Within the third ring road, the distribution of Shadow Education Enterprises is denser, while outside the third ring road, they are more scattered. The concentration of institutions spreads outward from the junction of the Erqi and Zhongyuan districts, as well as the junction of the Erqi, Guancheng Huizu, and Jinshui districts. Small clusters of Shadow Education Enterprises can be found in the central and northern parts of Zhongyuan District, central and northern parts of Erqi District, central, southern, and northeastern parts of Guancheng Huizu District, central and southern parts of Jinshui District, and the western part of Huiji District. This distribution pattern suggests that the central areas of the main urban area of Zhengzhou City have a higher density of Shadow Education Enterprises, while the peripheral areas have a more dispersed distribution.

(4) Shadow Education Enterprises in the main urban area of Zhengzhou City exhibit a multi-space agglomeration pattern characterized by “double nuclei, multiple times” distribution along both sides of the Beijing-Guangzhou Line. Within the main city of Zhengzhou, there are two large-scale high agglomeration cores, as well as several secondary agglomeration cores. These two large-scale groups have a spatial layout in a southeast-northwest direction (refer to **Figure 8**). This distribution pattern indicates that Shadow Education Enterprises are concentrated in specific areas along the Beijing-Guangzhou Line, with two major clusters forming the main agglomeration cores. Additionally, there are several smaller agglomeration cores scattered throughout the city. The spatial layout of these agglomeration cores contributes to the overall multi-space agglomeration characteristics of Shadow Education Enterprises in Zhengzhou City.

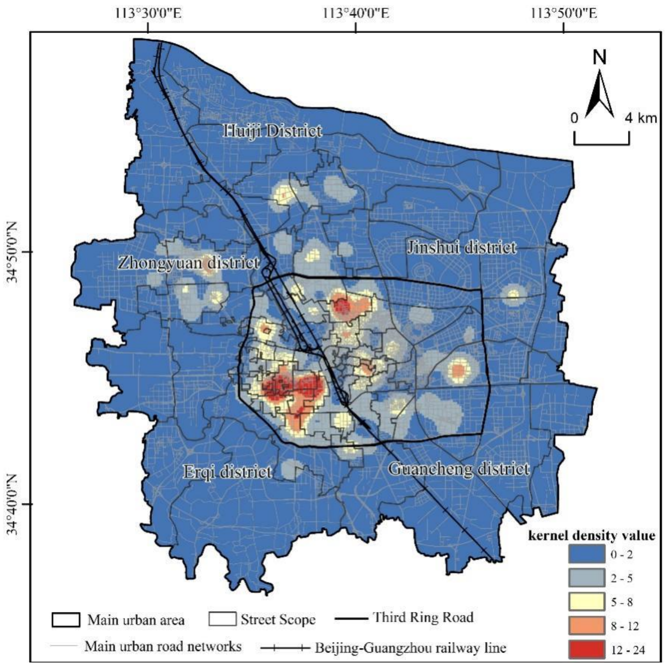


Figure 8. The core density map of shadow education enterprises in Zhengzhou.

Among these agglomeration cores, the high agglomeration core in Jinshui District is located on Culture Road Street, in Zhongyuan District on Linshanzhai Street, in Erqi District on University Road Street and Jianzhong Street. These areas represent the formation of the main agglomeration cores for shadow education teaching and learning institutions in the city. The secondary agglomeration cores are mainly found in areas with high population flow and developed commercial areas. In Zhongyuan District, the secondary agglomeration core is mainly located in Poly Culture Plaza on Fengle Street and Tungpai Road on Chemical Fertilizer East Road, forming the Zhongyuan District group. In Guancheng District, the secondary agglomeration cores are mainly located on Dongda Street and East Chengdu Road Street, New Times Square, Changjiang Plaza, and Shopping Mall Road, forming the Guancheng District group. In Jinshui District, the secondary agglomeration cores are mainly on Culture Road Street, Keyuan Road, Jingkai Road Street, Culture Road, Jingqilu, and Jingbaji Road, forming the Jinshui District group. In Huiji District, the secondary agglomeration cores are mainly on New City Streets, Kaiyuan Road, Yingbin Road Street, and Yueji Street, forming the Huiji District group. In Erqi District, the secondary agglomeration cores are mainly on Jingguang Street, Biyun Road, and Xiangyun Road, forming the Erqi District group. These agglomeration areas are generally consistent with the distribution of district-level centers and commercial centers in the main urban area of Zhengzhou City. Low-density areas are mainly found in Shushui Street and Zhaogou Township in Zhongyuan District, Mazhai Township and Houzhai Township in Erqi District, Longhu Street, Yangjin Road Street, and Xingda Road Street in Jingshui District, as well as the neighborhoods outside the Third Ring Road in Huiji District and the streets and townships outside the Third Ring Road in Guancheng District. These areas can be considered as urban-rural transition zones. This distribution pattern indicates that shadow education tutorial institutions in Zhengzhou City tend to choose areas in the city center with frequent economic activities. These areas have high population mobility, frequent exchange of information, intensive commercial activities, and well-developed transportation, which meet the requirements for the layout of the service industry. At the same time, they can maximize their influence, obtain sources of students, and generate operating income.

5. Analysis of factors influencing the spatial distribution of shadow education in primary and secondary schools

5.1. Selection of impact factor indicators

To ensure data accessibility and computational feasibility, this study considered the number of shadow education teaching and learning institutions in the street unit of the main urban area of Zhengzhou City as the dependent variable. Five level 1 indicators were primarily selected as independent variables, namely, the status of the student population, the level of accessibility, the location of the lot, the degree of commercial development, and the resident's ability to pay. These indicators were chosen by drawing upon the influencing factors of basic education in primary and secondary schools, along with relevant research on education and training institutions (**Table 2**). 1) Location: Educational counseling activities exhibit a unique dependence when compared to other commercial economic activities. This is primarily due to the concentration of the consumer group within mainstream educational institutions and residential areas. Consequently, when selecting a suitable location, it is essential to take into account the proximity to mainstream institutions and residential areas. The location layout should be strategically chosen to be in close proximity to the target consumers, thereby attracting students effectively. Therefore, in this study, the number of primary and secondary schools, as well as the number of residential neighborhoods, are utilized as representative indicators for determining the location of the lot. 2) Student population: While educational counseling institutions share certain characteristics with commercial economic activities, their location layout should prioritize proximity to a significant consumer population to meet market demand. In the case of educational counseling institutions catering to primary and secondary students, the consumer population primarily consists of students aged 5–19. To capture the status of the student population, this study utilizes the number of school-age individuals as an indicator. By considering this factor, the study aims to better understand the dynamics of the student population and its impact on the location selection of educational counseling institutions. 3) Residents’ ability to pay: House price is selected as an indicator to represent the residents’ ability to pay. It is believed that higher house prices correlate with higher levels of disposable income, better living environments, and improved educational conditions. As a result, parents residing in areas with higher house prices are more likely to have greater willingness and capacity to invest in their children’s education. By considering house prices, this study aims to capture the residents’ ability to pay and its influence on the demand for educational counseling services. 4) degree of commercial development: As a knowledge-based service industry, educational counseling falls within the commercial sector and shares its commercial nature. Similar to the layout of commercial districts, parents also consider the convenience of life and shopping when selecting counseling institutions for their children. The presence of large shopping malls in the vicinity can enhance the diversity of consumption options for parents and children, making it a multi-purpose and multi-targeted layout. Therefore, the number of large shopping malls serves as an indicator to measure the level of development of commercial services. By considering this indicator, this study aims to capture the influence of commercial development on the location selection of educational counseling institutions. 5) The level of accessibility: To effectively attract consumers and reduce consumer travel costs, educational counseling institutions often prioritize locations with convenient transportation access. The degree of accessibility is primarily influenced by the density of the transport road network. Therefore, in this study, road density is utilized as an indicator to represent the degree of accessibility. By considering road density, the study aims to capture the impact of transportation infrastructure on the location selection of educational counseling institutions.

Table 2. The detection index system of influencing factors.

Primary Indicator	Secondary Indicator	Variable Explanation:
Lot location	Number of primary and secondary schools X1	Number of primary and secondary schools on the street
	Number of residential neighborhoods X2	Number of residential neighborhoods on the street
Student Population	Population of school age X3	Population density (5–19 years old) in the street
Level of commercial development	Number of large shopping centers X4	Number of large shopping centers on the street
Residents' ability to pay	The average price of housing X5	Average price of housing on the street
Transport accessibility	Road density X6	Road density in the street

5.2. Analysis of factor results

In this study, the main urban area of Zhengzhou City is selected as the study area, and the number of shadow educational institutions is counted as the unit of analysis. The geoprobe tool is utilized to explore the factors influencing the distribution of shadow educational institutions in the main urban area. To conduct the analysis, the spatial connection tool in ArcGIS software is employed. The number of primary and secondary schools (X1), the number of residential districts (X2), the number of school-age students (X3), the number of large shopping malls (X4), the average price of housing (X5), and road density (X6) are connected with the streets in the study area. To facilitate the analysis, the data is divided into five levels using the natural breakpoint method. This division allows for a more detailed examination of the relationships between the variables. The data is then processed into discretized data, which is the required format for the geodetector tool. This tool enables the identification of the relative importance and interactions of the factors influencing the distribution of shadow educational institutions. By utilizing these analytical techniques, the study aims to gain insights into the factors that contribute to the location selection of shadow educational institutions in the main urban area of Zhengzhou City.

Firstly, the number of primary and secondary Shadow Education Enterprises in 80 street units in the main urban area of Zhengzhou City was counted with the ArcGIS spatial connection tool, and the number of primary and secondary shadow education counseling institutions in the street units was taken as the dependent variable, and the selected independent variables were connected to the street units, and the factor probing and the interaction probing of the detector were used to explore the spatial distribution of the primary and secondary shadow education counseling institutions. The explanatory power of the influencing factors, in the geodetection results, the q value indicates the degree of explanation of the independent variable X on the attribute Y, and the p value corresponding to the q value indicates the degree of credibility, the larger the q value indicates that the X variable has a stronger explanatory power on Y, and the lower the p value indicates that the X variable has a more credible explanation on Y, the results of the geodetection are shown in **Table 3**.

Table 3. The explanatory power of the impact factors on the distribution of shadow education enterprises in Zhengzhou.

	X1	X2	X3	X4	X5	X6
q	0.629	0.571	0.687	0.585	0.305	0.351
p	0.014	0.036	0.000	0.060	0.078	0.032

Note: The q-values for each indicator's factor detection are significant at the 0.1 test level.

The results show that:

The geographical placement, the demographic composition of the student population, and the level of commercial prosperity are the primary determinants impacting the spatial dispersion of primary and secondary school shadow education pedagogical and support establishments. Conversely, the financial capacity of residents and the level of transportation convenience exert a more modest influence on these entities. 1) The primary determinant shaping the spatial distribution of Shadow Education Enterprises is the size of the school-age population, accounting for a substantial explanatory power of 68.70%. This underscores the significance of considering the target demographic, namely primary and secondary school students when strategically selecting the locations for shadow education teaching and learning establishments. Ensuring a sufficient population base is crucial, as the population of the catchment area significantly impacts the spatial distribution of Shadow Education Enterprises. 2) The geographical placement of lots emerges as the predominant factor shaping the spatial arrangement of shadow education teaching and learning institutions, accounting for a substantial explanatory power of 62.9% and 58.5% respectively. This underscores the interdependence between Shadow Education Enterprises and the student pool originating from mainstream education. Consequently, their proximity to primary and secondary schools should be duly considered when designing their layout. 3) The level of commercial development emerges as a significant factor impacting the spatial arrangement of shadow educational institutions, with a substantial explanatory power of 58.5%. This suggests that these institutions are characterized by their commercial nature, emphasizing the importance of considering the convenience of commercial promotion and information exchange, as well as the presence of complementary industries in the surrounding area, when designing their layout.

The significant explanatory power of the degree of commercial development also suggests that the distribution of Shadow Education Enterprises tends to be concentrated in urban areas with thriving commercial centers. This indicates that shadow education and teaching, with its market-oriented services, possess distinct commercial and economic characteristics. This is a result of commercial institutions driven by economic interests seeking profit, and it serves as a complementary component of the traditional education industry. 4) The average price of housing and the density of the road network also exert a modest influence on the spatial distribution of shadow education tutoring institutions, with explanatory powers of 30.50% and 35.10% respectively. This suggests that the spatial layout of shadow education is influenced by factors such as transportation convenience, the time cost for students to commute to school, and the residents' ability to afford housing. These factors, in turn, affect the investment families make in education tutoring. 5) The results of the interaction factor detection in shadow education tutoring institutions indicate that the interaction between factors is primarily driven by non-linear enhancement (Refer to **Table 4**). The interaction force between factors is significantly stronger than the individual factors themselves. Notably, the interaction between location and degree of commercial development exhibits a two-factor enhancement, while the interaction with the distribution of the school-age population demonstrates the highest explanatory power. This reveals the close association between the commercial characteristics of Shadow Education Enterprises and the distribution of students' places of origin. Based on the analysis of influencing factors in shadow education, the spatial layout of Shadow Education Enterprises can be broadly categorized into three types: layout in residential areas, layout in commercially developed areas, and layout in proximity to primary and secondary schools. This is in contrast to the balanced layout mode typically found in traditional primary and secondary schools.

Table 4. Interactive detection results of shadow education influencing factors.

	X1	**X2**	**X3**	**X4**	**X5**	**X6**
X1	0.629					
X2	0.602	0.571				
X3	0.531	0.625	0.687			
X4	0.507	0.437	0.501	0.585		
X5	0.551	0.628	0.610	0.406	0.305	
X6	0.666	0.574	0.419	0.540	0.295	0.351

6. Characterization of the spatial pattern of shadow education

6.1. Conclusion

This study focuses on the main urban area of Zhengzhou City and applies various spatial analysis methods, such as standard distance and standard deviation ellipse, kernel density analysis, and nearest-neighbor index, to examine the spatial pattern of primary and secondary shadow education institutions. The study aims to analyze the spatial distribution pattern of these institutions in Zhengzhou City and explore the factors influencing their spatial clustering. The results of the study indicate that:

(1) The study reveals that in Zhengzhou City, the main urban area, the spatial distribution pattern of primary and secondary shadow education institutions follows a core-periphery distribution, spreading from the urban center towards the periphery. This distribution pattern aligns with the direction of urbanization expansion in Zhengzhou City and is closely related to local economic and social development. The districts with the most prominent concentration of shadow education institutions include Jinshui District, Zhongyuan District, Erqi District, and Guancheng District. Additionally, the distribution of primary and secondary shadow education institutions is closely tied to the distribution of primary and secondary schools, with a noticeable concentration of shadow education institutions around renowned schools and demonstration schools.

(2) In the main urban area of Zhengzhou City, there are clear clustering characteristics of primary and secondary school shadow education institutions. Within

the three-ring road boundary of Zhengzhou City, the distribution of shadow education institutions is dense, particularly within the three-ring road area. Outside of the three-ring road, the distribution becomes more dispersed, mainly concentrated in the junction area of Erqi District and Central Plains District. From this central region, which includes Erqi District, Guancheng Hui nationality District, and Jinshui District, there is a diffusion trend outward. In specific areas, there are small clusters of shadow education institutions located in the north-central part of Zhongyuan District, the north-central part of Erqi District, the south-central and northeast part of Guancheng Huizu District, the south-central part of Jinshui District, and the western part of Huiji District.

(3) The shadow education institutions in the main urban area of Zhengzhou City exhibit a spatial structure characterized by "double-core multiple" multi-center spatial agglomeration, distributed along both sides of the Beijing-Guangzhou Line. In Zhengzhou's main city, there are two large-scale high agglomeration cores and several secondary agglomeration cores. These two large-scale clusters are spatially clustered in a southeast-to-northwest direction on both sides of the Beijing-Guangzhou Line. The high concentration core is primarily located in Zhongyuan District and Jinshui District, with notable streets such as Culture Road Street in Jinshui District, Linshanzhai Street in Zhongyuan District, University Road Street, and Jianzhong Street in Erqi District serving as representative areas. These areas form high-concentration cores at the district level. The secondary concentration cores are distributed in districts such as Erqi District, Guancheng District, and Huiji District, around areas with dense population flow and commercial centers with a concentration of service industries.

(4) The factors that influence the spatial layout of primary and secondary shadow education institutions in the main urban area of Zhengzhou City can be ranked in terms of their explanatory power as follows: the size of the school-age population factor > the location environment factor > the degree of commercial development factor > the traffic factor. The size of the school-age population, the location environment, and the degree of commercial development are the main factors that affect the overall spatial layout of shadow educational institutions in the main urban area of Zhengzhou City. Among these factors, the size of the school-age population, the distribution of primary and secondary schools, and residential areas have the most significant influence. Additionally, the typical urban form of the city, expanding from the center to the periphery, and the extensive system of traffic arteries also play a role in the functional zoning and layout of shadow educational institutions. Based on the degree of influence, the spatial layout of primary and secondary shadow education institutions in Zhengzhou can be broadly divided into three distribution patterns: based on the origin of students (residential area), based on commercially developed areas, and based on the distribution patterns of primary and secondary schools. This indicates that the spatial layout of shadow education institutions differs from the traditional balanced spatial layout of primary and secondary education. It also reflects that the layout of primary and secondary shadow education institutions is influenced by multiple socio-economic factors, which align with the general characteristics of the service industry under the market economy. From the perspective of commercial behavior, the spatial layout of these institutions demonstrates rationality.

6.2. Discussion

Based on the data related to shadow education institutions for primary and secondary school counseling groups in Zhengzhou City in 2021, this study aims to investigate the spatial characteristics and factors influencing these institutions in the main urban area of Zhengzhou City. The study aims to gain insights into the spatial distribution of primary and secondary school counseling and training industries in the main urban area of Zhengzhou City. This research will contribute to the spatial analysis of the shadow education and training industry in Zhengzhou City, and expand the scope of research on shadow education among primary and secondary school groups in urban case studies in China. By analyzing the spatial patterns and factors influencing primary and secondary school counseling shadow education institutions, this study aims to provide a better understanding of the spatial distribution characteristics of the shadow education and training industry in Zhengzhou City. The findings will contribute to the spatial study of the shadow education industry in Zhengzhou City and further enhance our understanding of the factors that shape the distribution of primary and secondary school counseling services. This research will also contribute to the broader research on shadow education in China, particularly in urban settings. This study utilizes POI data to analyze the social phenomenon of shadow education in primary and secondary school students' curriculum tutorials from a geospatial perspective. By examining the spatial distribution of shadow education institutions, the study aims to shed light on the spatial patterns and characteristics of this phenomenon. This research contributes to the field of spatial pattern research by addressing the relative lack of studies on shadow education at the primary and secondary school levels. By exploring the spatial aspects of shadow education, the study provides valuable insights into the spatial dynamics and implications of this educational phenomenon:

(1) The spatial distribution of shadow education institutions in primary and secondary schools, as well as their concentration, development, and evolution, is a complex process influenced by multiple factors. On one hand, the spatial distribution is influenced by geographical environmental conditions, the size and shape of different cities, and transportation infrastructure. On the other hand, it is influenced by social and cultural factors, socio-economic conditions, educational systems, and ideological factors, which vary across different cities and at different developmental stages. This leads to both similarities and heterogeneity in the spatial distribution patterns of shadow education institutions among cities. The results of the study indicate that the spatial structure of shadow education institutions in Zhengzhou City follows a center-periphery pattern, similar to the concentric circle model of urban expansion in central place theory. This reflects the influence of the city's plain topography on the spatial distribution of shadow education institutions. Additionally, the agglomeration of these institutions along the Beijing-Guangzhou line suggests that transportation routes also play a significant role in shaping their spatial distribution. Overall, the spatial distribution of shadow education institutions in primary and secondary schools is influenced by a combination of geographical, social, and cultural factors. Understanding these factors and their impact on the spatial patterns of shadow education institutions can provide valuable insights into the dynamics of this

educational phenomenon.

(2) The excessive commercialization of primary and secondary education contributes to an unequal spatial distribution of educational resources, leading to educational inequity. Primary and secondary education are crucial stages characterized by high academic pressure for students and concentrated investment in education by families. State policies such as the Double Reduction Policy and the Code for the Management of Out-of-School Training Institutions primarily focus on primary and secondary school students and the education and training industry. This study contributes to the research on the shadow education and training industry for primary and secondary schools, as well as expands the investigation of the spatial layout of shadow education institutions in different types of cities. However, the study's findings indicate that the spatial distribution of primary and secondary school shadow education and training institutions is heavily influenced by marketization and commercial behavior. As a result, their distribution is not balanced like mainstream primary and secondary schools. Instead, these institutions tend to cluster in urbanized and highly commercialized areas. This lack of consideration for educational equity in their location choices increases the academic pressure on primary and secondary school students and exacerbates the imbalance in the spatial distribution of educational resources between different regions within the city. This ultimately widens the gap between social classes and gives rise to social conflicts. Overall, the over-commercialization of primary and secondary education and the concentration of shadow education institutions in certain areas contribute to educational inequity and exacerbate the spatial disparity of educational resources within cities. These issues highlight the need for policies and measures to address these imbalances and promote a more equitable distribution of educational resources.

(3) There is a strong connection between primary and secondary shadow education counseling organizations and mainstream primary and secondary schools. The study's findings indicate that when choosing locations, shadow education tends to cluster around mainstream primary and secondary schools, particularly those considered model schools. However, this study only provides a preliminary recognition of the spatial distribution relationship between primary and secondary schools and shadow education institutions. Further research is needed to explore the complex human, social, and economic links between the two. Additionally, more investigation is required to understand the spatial differences between primary and secondary schools and shadow education institutions in cities with varying economic levels and scales. The distribution of primary and secondary education and training industries not only impacts the spatial structure of urban industries but also changes the relatively balanced spatial distribution of mainstream educational resources. Therefore, future research should expand studies on the influence of primary and secondary school shadow education on mainstream teaching resources and the role it plays in enhancing students' academic performance. Case studies of cities with different urban classifications and expansion patterns should also be conducted to gain a clearer understanding of the landscape of the primary and secondary school shadow education and training industry.

This study has certain limitations that need to be acknowledged. Firstly, the POI data used in the study lacks attributes related to primary and secondary shadow education organizations, such as student population, teacher strength, registered capital, etc. This limitation restricts the depth of analysis that can be conducted. Additionally, the data used in the study is static, which limits the ability to capture dynamic changes in the spatial patterns of shadow education. Secondly, the study does not consider the impact of online education and training services, which have become increasingly prevalent with advancements in network technology. Online education and training in primary and secondary schools often involve cross-regional education, which presents different spatial dynamics. However, these aspects have not been explored in this study due to the difficulty in obtaining relevant data. Lastly, the study does not measure the influence of parents' educational philosophies on students' participation in shadow education and training institutions for primary and secondary school students. This aspect would require data beyond the scope of the study. Further research is needed to address these limitations and provide a more comprehensive understanding of the spatial patterns and dynamics of primary and secondary school shadow education. This would provide a theoretical basis for regulating shadow education institutions in light of policies such as the double-decrease policy, and contribute to the management of the education and training market in Zhengzhou City.

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