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RESEARCH ON THE SPATIAL DISTRIBUTION OF PUBLIC SERVICE FACILITIES IN NANCHANG OLD CITY, CHINA BASED ON POINT OF INTEREST (POI) DATA

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Abstract

In recent years, Nanchang City has focused on urban renewal, including the transformation of old residential areas. The spatial layout of various public service facilities in the city has also undergone significant changes. To improve the public service facility system, it is essential to analyse the spatial layout of various service facilities in the old city area. The Geographic Information System (GIS) technology combined with Point of Interest (POI) data was to analyse the spatial distribution characteristics, thereby drawing the following conclusions: Nanchang's old urban area has less public service facilities in the edge area, and the spatial layout presents an imbalanced trend of "central aggregation - edge dispersion." The density of various facilities around the subway is good, educational, and cultural facilities is highly correlated with other types of facilities. However, medical facilities and other infrastructure are in a state of obvious differentiation, especially in the edge areas. The above analysis proposed for relevant strategies and recommendations, thus providing a basis for future scientific arrangement of urban facilities.

***Keywords**:* GIS, Public Service Facilities, Spatial Layout, POI Data

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INTRODUCTION

According to the 2022 "14th Five-Year Plan for Public Service" in China, it is indicated that the National Development and Reform Commission and several other related departments clarified the goals, tasks, paths, and measures for the development of public service systems for the new era. Urban public service facilities are the basic guarantee for citizens' daily lives, covering various purposes of facilities such as education, culture, medical, fitness, transportation, and commercial services. Scientific, rational planning and arrangement of urban public service facilities contribute to the improvement and perfection of the public service system, as well as promote high-quality developments of urban facilities, further enhancing the sense of gain, happiness, and security of the people. To improve the layout defects of facilities in Nanchang and to compare it with an international renowned city, as well as to learn from its urban construction, this research undertakes a comparative study by investigating the spatial distribution characteristics of public service facilities in Hong Kong.

RESEARCH BACKGROUND

Research on Urban Public Service Facilities Based on Data Analysis

Cheng Shunqi et al. (2016) have shown that research on urban public service facilities began in the 1950s when international scholars focused on the location selection of residential public service facilities using modern location theory with more emphasis on pursuing social benefits. In recent years, data analysis has been increasingly applied in the analysis of urban public service facilities. In the study of public facilities in urban communities, Osumanu I. K. (2013) conducted an analytical study to assess the accessibility and utilisation of public toilet facilities in Wa, Ghana, which showed that there is a deficiency in the spatial distribution of public toilets in the city, as these facilities are concentrated only in the central areas of the town. In addition, the study revealed that such public facilities should not be resource-intensive but should consider urban sanitation needs. Ballester, Nicholas et al. (2014) used actual shopping data to explore whether the layout of urban retail commercial facilities is influenced by traffic density and travel distance which showed that sectors with a high proportion of purchases do not necessarily need to be in locations with a high concentration of foot traffic. Retail layout can also be profit-driven and not just dependent on walking distance. Rim Meziani et al. (2017) investigated the link between the spatial layout and configuration of urban shopping centres and pedestrian movement behaviour in Abu Dhabi city, UAE by using structural equation modelling (SEM) techniques. The study led to the conclusion that the popularity of shopping centres is positively related to both satisfaction with way finding and the location of mall facilities. Kiyashko G. A. (2017) described that the application of GIS technology in urban planning, including various methods of using vector data and raster data which are useful in solving applicability tasks for better decision-making, especially for detailed planning of urban public facilities in developing areas. Yang (2017) used index models and spatial auto-correlation analysis to find significant differences in the spatial distribution of urban public service facilities in Guangzhou. Ge P. et al. (2019) extracted outflow, inflow, net flow, and net flow ratio features from big data of human activities in terms of urban land use and urban planning to improve the accuracy and utilisation of urban spatial distribution. Chen and Li (2022) selected Dongying District as an example to explore the configuration level and compliance rate of public facilities within the "15-minute life circle."

Research on POI Data

Point of Interest is abbreviated as POI; in geographic information systems, it refers to any meaningful point on a map that is not geographically significant. A POI can be a house, a store, a mailbox, a bus stop, shops, bars, gas stations, hospitals, stations, and others (Haofei Long, 2018). Wang and Shijun (2012) reported that the spatial agglomeration and location characteristics of commercial facilities in Changchun can be explained based on the POI data analysed. Liu K, Qiu P, et al. (2020) proposed a new framework for extracting and understanding subway stations as cognitive areas in urban public service facilities based on POI, Investigating urban subway stations as spatial cognitive places in cities, based on Geographic Information System (GIS) technology, 166 subway stations and more than 1 million POI data sources in Shenzhen, China, were studied to analyse the spatial location characteristics of urban subway stations and provide a human-centred perspective for the construction of urban public facilities. Currently, big data is prevalent, and GIS technology is widely used in urban spatial layout planning, and GIS provides new ways for spatial analysis and editing of urban data, as well as data management. Jang（2020）conducted a global comparative study on urban compactness using night-time lights data and POI (Points of Interest) big data. Various open-source datasets were utilised, including OSM's (Open Street Map), NTL (Night-time Lights), and POI data to identify the boundaries and cores of individual metropolitan areas, estimate net density, and measure the network distance (i.e., proximity to the nearest core). The findings suggest that densely populated cities in developed countries appear to have better proximity, while cities in developing countries exhibit the opposite trend.

However, at the current stage of urban renewal and transformation, there is relatively less research on the spatial distribution of public facilities in old urban areas. Therefore, taking Nanchang's old city as an example, based on POI data and using GS-related technology, this study analyses the current status of the spatial distribution of public service facilities in Nanchang's old city, clarifies the existing problems, provides a scientific reference for the future transformation and development of urban areas, as well as optimises the spatial distribution pattern of public service facilities in the old city.

Research Object

Nanchang City is an important provincial capital city in the middle and lower reaches of the Yangtze River, located in the northern part of Jiangxi Province. It is a famous historical and cultural city, with a total area of approximately 7,195 square kilometres. This study selects the old city of Nanchang (Figure 1) as the research area, which is mainly composed of the intersecting regions of Xihu District, Donghu District, Qingshanhu District, and Qingyunpu District. The area's boundaries extend from the Ganjiang River in the west, along River Avenue, to Hongcheng Road in the south, Hero Bridge in the north, and Hongdu Avenue in the east. According to the urban master plan data released by the urban planning management department of Nanchang City, it is evident that there have been significant changes in the spatial layout of various urban public service facilities in Nanchang City. These changes can be attributed to the continuous adjustments made to the city's administrative boundaries, as well as the rapid economic development witnessed in the past two decades. These transformations have had a profound impact on the distribution and arrangement of urban public service facilities, reflecting the dynamic nature of urban development in Nanchang City.

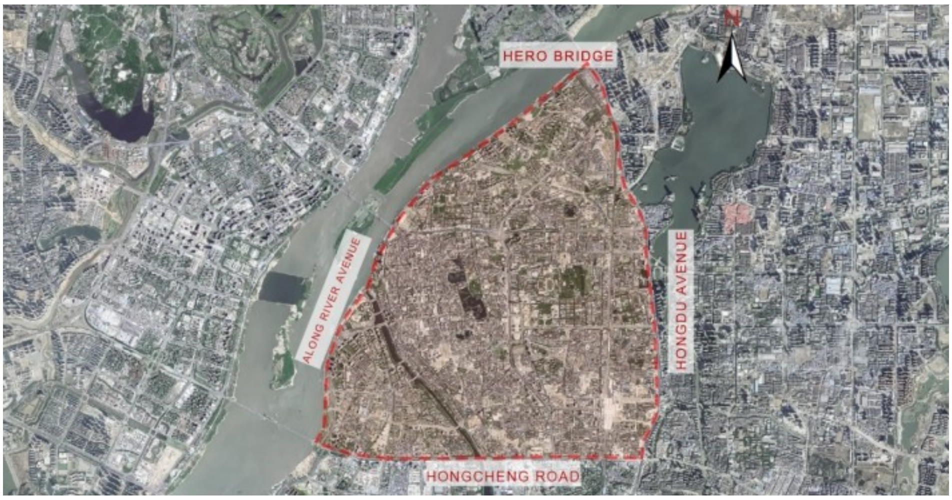


Figure 1: Map of the old city area of Nanchang
Source: Chinese Google Earth (2022)

Data Sources

The basic data for this study come from the open-source POI network data of public service facilities in the old city of Nanchang on Baidu Maps, where each POI data point corresponds to information such as the location and attribute category of the point of interest. According to the requirements of the "Urban Land Classification and Planning Construction Land Standards" the obtained data are organised into six major categories: commercial service facilities, administrative management facilities, medical and health facilities, financial service facilities, community public facilities, and educational and cultural facilities, as detailed in Table 1 (Wang Kai, 2012). A total of 20,392 points of interest were counted in the old city area, including 9,547 in Xihu District, 9,903 in Donghu District, 887 in Qingshanhu District, and 55 in Qingyunpu District, as shown in Table 2.

In ArcGIS software, the obtained POI data are visually analysed, using the WGS1984 coordinate system uniformly. The coordinate system of point attributes is made consistent with the map coordinates of the old city area of Nanchang, and the distribution maps of different categories of facility POI data are drawn (Figure 2).

Table 1: Classification of Public Service Facilities

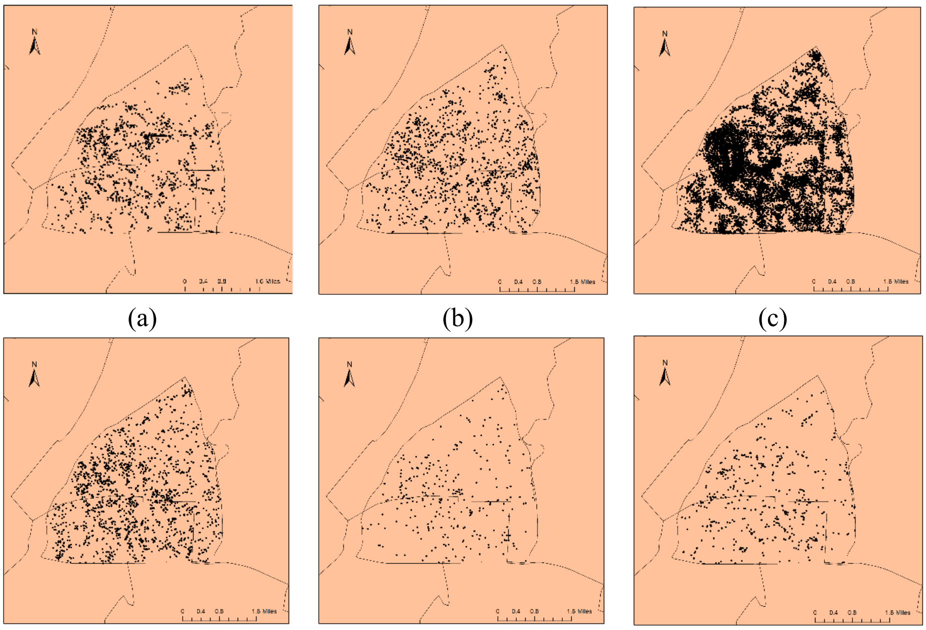
No	Category	Classification
1	Medical and Health Facilities	Hospitals, clinics, pharmacies, health centres, etc.
2	Educational and Cultural Facilities	Research institutions, schools, educational training, cultural centres, etc.
3	Commercial Service Facilities	Malls, convenience stores, wholesale markets, home appliance markets, etc.
4	Administrative Management Facilities	Government agencies, administrative departments, social organisations, etc.
5	Community Public Facilities	Newspaper halls, public toilets, etc.
6	Financial Service Facilities	Securities exchanges, financial insurance, major banks, etc.

Source: Author

Table 2: Distribution of Public Facilities POI in the Old City of Nanchang

Place	**Medical & Health Facilities**	**Educational & Cultural Facilities**	**Commercial Service Facilities**	**Administrative Management Facilities**	**Community Public Facilities**	**Financial Service Facilities**	**Total**
Xihu District	536	602	7030	956	134	289	9547
Donghu District	724	811	6804	1125	156	283	9903
Qingshanhu District	49	89	621	93	12	25	887
Qingyunpu District	2	3	48	1	0	1	55
Total	1311	1503	14503	2175	302	598	20392

Source: Author



(a) (b) (c)

(d) (e) (f)

Figure 2: Map of the old city area of Nanchang: (a) Medical and Health Facilities; (b) Educational and Cultural Facilities ;(c) Commercial Service Facilities; (d) Administrative Management Facilities; (e) Community Public Facilities; and (f) Financial Service Facilities
Source: Author

Research Methods

In the field of spatial analysis, "Average Nearest Neighbour" denotes the mean of the minimal inter-point distances within a given dataset. The methodology underlying this metric involves assessing spatial structure by juxtaposing the computed mean distance among proximate neighbour pairs against the corresponding mean distance as exhibited within a theoretical randomly distributed pattern. This comparative analysis facilitates an understanding of the real-world spatial distribution, as it allows for discerning whether the configuration of points is dispersed, clustered, or essentially random in nature.

Kernel Density Estimation (KDE) constitutes an analytical tool designed to scrutinise the spatial agglomeration of objects of interest. By applying a smoothing process to point-based data, KDE computes the density of pertinent attributes within their immediate vicinities. This technique is particularly instrumental when employed to dissect the density of amenities within a specified geographical area, thereby providing insightful perspectives on spatial patterns and distributions.

Average Nearest Neighbour Analysis Method

The nearest neighbour analysis represents the random distribution characteristics of features within a region (Yunlong, 2012). The aggregation characteristics of public service facilities in the old city area of Nanchang can be obtained through the average distance ratio of the average nearest neighbour method. By calculating the centroid distance between each element and its nearest neighbour element, the spatial pattern can be determined, and the P-value can be obtained. Comparing the Z-score with the critical value can determine the probability of random distribution, thereby judging the characteristics of the aggregation and dispersion of public facilities. The calculation formula is as follows:

$$D_O = \frac{1}{2}\sqrt{\frac{N}{A}} \quad (1)$$

In the formula, D_o represents the average distance of point features under random distribution, N is the number of selected features within the range, and A represents the area of the research region.

Kernel Density Analysis Method

Kernel density analysis is used to reflect the relative concentration of features in spatial distribution (Jiang Shiguo, 2009). The kernel density analysis calculates the density expansion value of facility points of interest in their surrounding neighbourhoods. The closer the distance between the elements, the higher the degree of mutual correlation, and the closer to the core element, the greater the density expansion value. The calculation formula is as follows:

$$F_{\mathrm{i}} = \frac{1}{n\pi R^2} \times \sum_{j}^{n} K_j (1 - \frac{D_{ij}^2}{R^2})^2 \quad (2)$$

F_{i} represents the kernel density of the *i-Th* facility point in the research area, R is the bandwidth of the selected regular area, and the K function is the spatial weight function; D_{ij} is the distance between facility point i and research object j ($D_{ij} < R$, when D_{ij} reaches a certain value, $R = 0$); n is the number of research objects j within the bandwidth R range.

RESULTS AND ANALYSIS

Spatial Agglomeration and Dispersion Characteristics of Public Service Facilities in Nanchang Old City Area

The POI data of various types is imported into ArcGIS to calculate the average nearest neighbour ratio parameter results for various types of public service facilities in Nanchang City. The agglomeration and dispersion pattern characteristics of urban public service facilities can be determined through the relevant results data. By importing the POI (Point of Interest) data of various facilities into ARCGIS for analysis, relevant index values of Average Nearest Neighbour zare obtained (Table 3). Based on the distribution characteristics of Average Nearest Neighbour, feature values can be categorised into three forms: Clustered, Random, and Dispersed. By comparing the data values from this study with the standard values (Figure 3), it can be concluded that the nearest neighbour ratios of these six types of public service facilities are all less than 1, and the p values are all 0, indicating that various service facilities are agglomerated in Nanchang City. The z scores are all less than the critical value of -2.58, indicating that the random distribution probability of various facilities is less than 1% and the degree of agglomeration of financial service facilities is much higher than that of other service facilities. According to the inverse relationship between the size of the nearest neighbour ratio and the degree of agglomeration, the smaller the ratio value, the greater the degree of aggregation. Comparing the nearest-neighbour ratios of the six types of public service facilities in Table 3, the degrees of agglomeration and dispersion from small to large are community public facilities, educational and cultural facilities, medical and health facilities, commercial service facilities, administrative management facilities, and financial service facilities.

Table 3: The Average Nearest Neighbour of Public Service Facilities in the Old City of Nanchang

Facilities	**Average observation distance**	**Expected average distance**	**Nearest neighbour ratio**	***Z* score**	***P* value**
Medical and Health Facilities	46.7054	73.4516	0.635866	–25.222819	0
Educational and Cultural Facilities	48.4945	73.9325	0.655929	–25.51871	0
Commercial Service Facilities	14.0619	24.3677	0.577070	–97.438028	0
Administrative Management Facilities	33.0897	62.5389	0.529105	–42.013051	0
Community Public Facilities	129.4887	163.8744	0.790171	–6.97591	0
Financial Service Facilities	51.4043	114.2548	0.449909	–25.734519	0

Source: Author

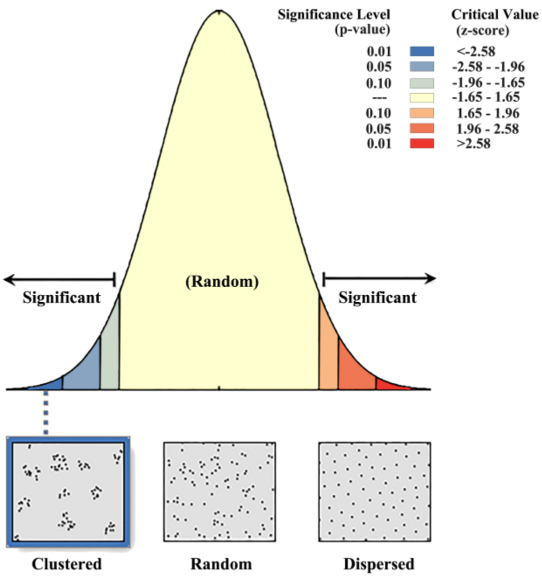


Figure 3: Map of Average Nearest Neighbour Distribution Characteristic Index
Source: Author

Kernel Density Analysis of Public Service Facilities in Nanchang Old City

To reflect more intuitively the spatial configuration characteristics of various types of public service facilities in Nanchang Old City, the kernel density analysis method is used to analyse the six types of public service facilities. The darker the regional colour, the larger the kernel density value, and the more concentrated the distribution. The results are shown in figure 4.

（1）Kernel Density Analysis of Medical and Health Facilities: As an important part of a healthy city's construction and an increasingly needed infrastructure for people's livelihood, the distribution characteristics of medical facilities in Nanchang Old City are shown in Fig 4a. The distribution features are clearly clustered in the old city area, with high facility density in the north-central part of the city. However, the clustering degree is low in the relatively marginal areas, and the medical service area in the marginal areas is too wide, causing inconvenience for residents' lives.

（2）Kernel Density Analysis of Educational and Cultural Facilities: The analysis of educational and cultural facilities in Nanchang Old City, including training institutions, various schools, and cultural facilities, is shown in Fig 4b. In Nanchang Old City, the educational and cultural facilities are mainly primary and secondary schools. The radiation range of education still has a certain distance. The clustering degree is evident in the boundary area between Xihu District, Donghu District, and Qingshanhu District, as it is basically located in the city centre with good educational resources, forming a high-density clustering area.

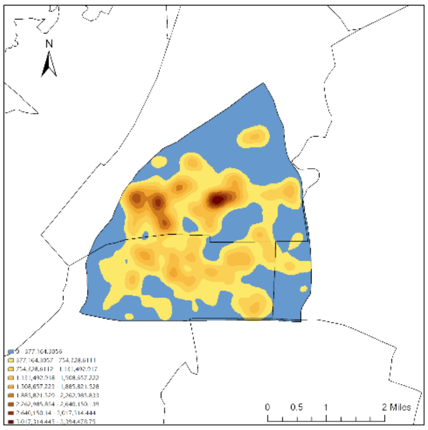
（3）Kernel Density Analysis of Commercial Service Facilities: Commercial service facilities are one of the services most closely related to residents' lives. The distribution of commercial service facilities, as shown in Figure 4c, mainly includes large shopping malls, supermarkets, convenience stores, and wholesale markets. The commercial density is high in the areas where Xihu District and Donghu District intersect, and the most concentrated area is around the Bayi Square. At the same time, there are multiple subway lines running through the old city, and the overall distribution of commercial facilities is well-equipped. In comparison with educational and cultural facilities, many commercial locations are in areas with abundant educational resources. The site selection of commercial service facilities is closely related to the flow of people.

（4）Kernel Density Analysis of Administrative Management Facilities: Compared to other service facilities, this type of facility has a certain degree of authority and is restrictive in its layout. The analysis result is shown in Fig 4d. According to the overall development of Nanchang City, the administrative management service facilities in Donghu District and Xihu District of the old city are densely distributed, with multiple concentrated points.

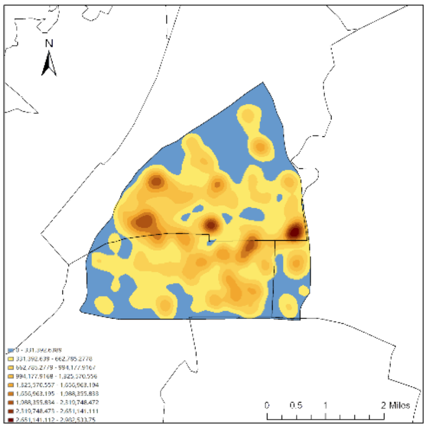
Under the current trend of urban renewal, there is an urgent need for comprehensive adjustments and considerations.

（5）Kernel Density Analysis of Community Public Facilities: The analysis results from Fig 4e. show that the distribution in the old city area is relatively concentrated, mainly including public toilets, newspaper kiosks, and other public places. The density value in Donghu District of the old city is the highest, showing a ring-shaped density distribution. After a series of urban renewal and transformation, public facilities have been improved. However, the density in Qingshanhu District and Qingyunpu District is relatively average, and further improvements are needed for such service facilities in the peripheral areas.

（6）Kernel Density Analysis of Financial Service Facilities: An Analysis of Financial Service Facilities in the Old City Area of Nanchang City, as shown in Figure 4f. Due to the economic transformation of Nanchang City's important economic hub, the financial industry in the old city area is shifting towards the development of new areas to alleviate the pressure on the economy and population. As a result, the distribution of financial service facilities in the old city area is unevenly distributed.



(a)



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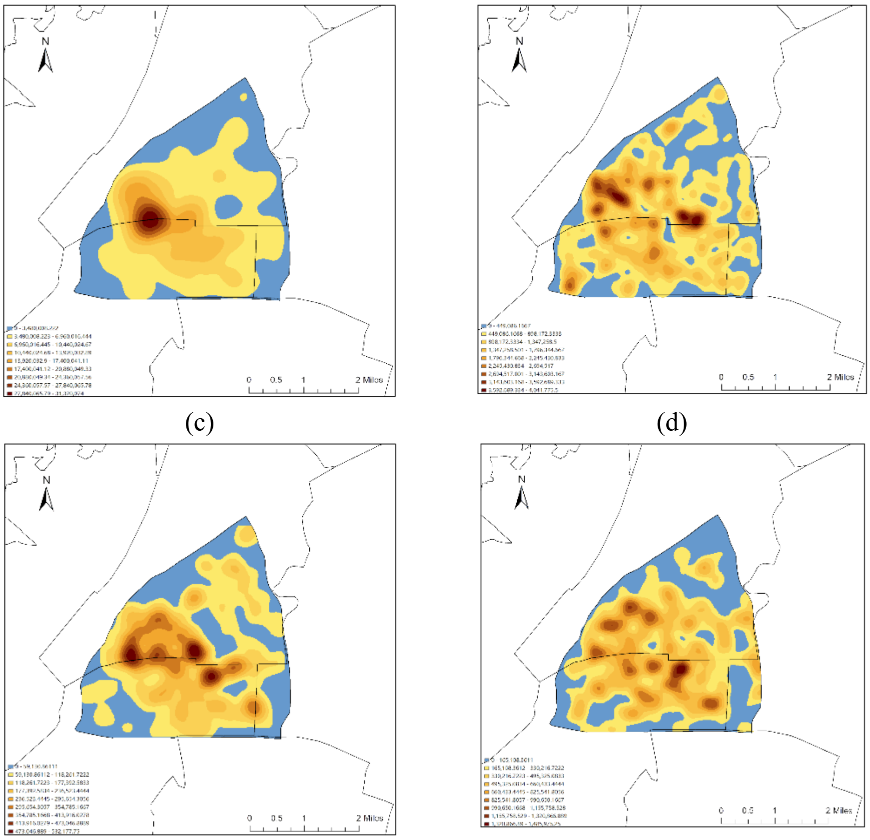


(c) (d)

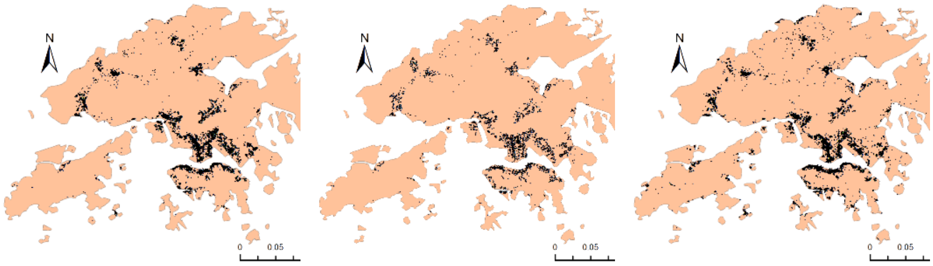
(e) (f)

Figure 4: Kernel Density Map of Various Public Service Facilities in Nanchang Old City Area (a) Medical and Health Facilities; (b)Educational and Cultural Facilities;(c) Commercial Service Facilities; (d)Administrative Management Facilities; (e)Community Public Facilities; (f)Financial Service Facilities
Source: Author

A Comparative Analysis of Various Public Facilities Distribution in Hong Kong

This research undertakes a comparative study by investigating the spatial distribution characteristics of public service facilities in Hong Kong, a city renowned on an international scale. This analysis serves to establish connections and draw parallels with the urban context of Hong Kong, fostering a deeper understanding of the spatial patterns and arrangements of these vital amenities to discover the gaps and shortcomings in the layout of public facilities of Nanchang city. This is carried out by focusing on the medical and health facilities, educational and cultural facilities, and commercial service facilities in Hong

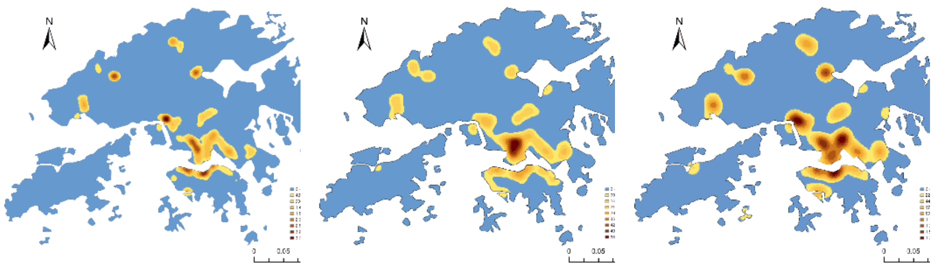
Kong as comparative data. It involved 13,718 medical and health facilities, 3,060 educational and cultural facilities and 21,349 commercial service facilities that were selected. The specific distribution is shown in Figure 5.



(a) (b) (c)

Figure 5: Distribution map of public service facilities in Hong Kong (a) Medical and Health Facilities; (b)Educational and Cultural Facilities;(c) Commercial Service Facilities
Source: Author

The spatial distribution pattern characteristics of the three types of urban public facilities in Hong Kong are analysed by using the kernel density analysis method and the results are shown in Figure 6. From the analysis results, it is observed that the layout of medical and health facilities, educational and cultural facilities and commercial service facilities in Hong Kong are all relatively concentrated, and there is a large intersection of the kernel density range, demonstrating a close relationship between the three. This analysis reflects the relative concentration of various urban resources in Hong Kong and the concurrent development of various facilities that is more balanced among them.



(a) **(b)** **(c)**

Figure 6: Kernel Density Map of Various Public Service Facilities in Hong Kong: (a) Medical and Health Facilities; (b) Educational and Cultural Facilities; and (c) Commercial Service Facilities
Source: Author

CONCLUSION

Through the multidimensional analysis of the spatial distribution characteristics of public service facilities in the old city area of Nanchang City using POI basic data and GIS technology, this study provides relevant theoretical support for the optimisation of urban public service facilities and the high-quality development of the city in the next stage. The main conclusions are as follows:

（1）Due to the historical development of the city, public service facilities in various categories are relatively concentrated in the old city area of Nanchang, with a high degree of agglomeration. However, there are fewer public service facilities in the peripheral areas of the old city area, and the spatial layout presents an imbalanced trend of "central aggregation - edge dispersion".

（2）With the acceleration of subway transportation construction in Nanchang City, multiple subway lines have been opened and are connected to the old city area, where the density of various facilities around the subway is good, especially for commercial facilities. In the subway sections where a new city planning has not yet been developed, corresponding commercial density and the evacuation of crowds should be considered to truly alleviate various pressures in the old city area.

（3）The spatial layout of education and cultural facilities is highly correlated with other types of facilities. From the analysis results, we find that education and commercial facilities are closely related. There are many university campuses in the old city area of Nanchang, and commercial facilities can meet the needs of students in learning and other aspects, while driving the economic development of the old city area. However, the location of commercial facilities should consider on the effect on university campuses.

（4）There is an obvious differentiation in the spatial layout of infrastructure such as medical facilities and community public facilities, suggesting that the peripheral areas of the old city area lack basic infrastructure. In the current trend of developing healthy cities, the construction of medical and health infrastructure should be improved to meet the daily needs of residents along with other facilities to enhance their life satisfaction and happiness.

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