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Spatial differentiation and influencing factors of attended collection and delivery points in Nanjing city, China

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Abstract - E-commerce and online shopping have become more convenient due to the rapid growth of the internet logistic industry in many developed countries and are particularly popular and suitable in China. The method is primarily based on logistic points like attended collection and delivery points (ACDPs), an emerging industry for economic development. This article includes descriptive statistics, and spatial analysis to analyse the location distribution, and influencing factors of ACDPs in Nanjing City using point of interest data (POI) of Cainiao stations and China Post stations. The results show that the spatial distribution of ACDPs in Nanjing is asymmetrical, displaying a trend to the northwest direction and a difference in the trend between the S-W and N-E axes. Their layout creates four main core areas and the number of sites decreases with distance from the core. Most of the ACDPs are in urban areas and on residential and industrial land. This study provides insightful ideas for decision-makers and planners to help formulate policies that can lead to more sustainable logistic enterprises development and for the companies that want to establish successful CDP networks in big cities.

Keywords: Attended collection and delivery points; China Post stations; Cainiao stations; spatial pattern; influencing factors; Nanjing City

1. Introduction

Over the past decade, online shopping has become increasingly popular due to the development of information and communication technologies and the widespread access to the Internet and began to replace traditional shopping methods [1]. In many European countries, shopping behaviors are changing rapidly. E-commerce has become very popular over the past decade because of the proliferation of IT platforms such as smartphones, tablets, and laptops. Recent e-commerce has experienced significant growth in various forms, in addition to Business to Business (B2B), Business to Consumer (B2C), and Consumer to Consumer (C2C) [2].

In recent years, e-commerce has grown at a double-digit rate and more and more customers are using B2C e-commerce channels to order products online and deliver to their home. However, the supply chain is a new challenge for the logistics industry as it must manage increasing fragmentation to meet customers' needs. Intense competition, decision-makers adopting a consumer-centric economy, suspension of shipments and reverse, and environmental logistics measures have increased the cost of online orders. As a result, the 'last mile' is considered the most expensive delivery area [3]–[5].

To reduce the failure of courier deliveries, a few types of research [6]–[9] evaluate alternative delivery methods, as well as Collection and Delivery Point (CDP). CDP is a third-party place where people can retrieve and return products purchased over the Internet and is considered the most cost-effective home delivery option [7]. The CDPs of many European countries (such as the Netherlands, Germany, and France), has become an essential part of the 'last mile'

movement [10], [11], and CDP is well-defined as the last stop of an enterprise. To consumer delivery services, where the goods are delivered to a certain place (for example, to a place of residence, or a collection point) [12]. If CDPs are located on main roads and close to public transportation hubs, they offer customers the chance to receive their packages during everyday commuting. Since people no longer need to go to the post office or warehouse separately, this can reduce consumers' VKT [13].

Scholars have been gradually deepening their research on logistics distribution and pickup points since the implementation of the first pickup point in 2000. [14] analyzed the role of geographical location in the express delivery industry and its position in the spatial organization of logistics activities in Paris. [11] found that there were many advantages in the network development of store pickup points and automated lockers according to a comparative study between France and Germany. [15] analyzed the e-commerce pickup network and found that the population, type of land, and residential family pattern, among other factors, have a considerable impact on the layout of pickup points.

Other researchers explored the business model of e-commerce logistics through big data analysis, revealing the basic patterns of "cross-border e-commerce logistics" and analysing the spatial distribution of e-commerce distribution in Belgium during four months, concluding that most problems of cities are related to the last mile of e-commerce logistics [16]. It has been observed that some socio-demographic characteristics are associated with the use of service points. [10], found in a study of online purchasers in the Netherlands that consumers with moderate or high experience with online shopping and limited time use service points more often. It was also noted that women consumers are more likely to use such products. Also, according to a study by [15]. In France, factors such as home broadband saturation, possession of advanced electronic equipment, frequency of purchase, and the type of residential property (apartment or family home) are a key component in determining potential CDP locations.

However, no study has investigated the influencing factors of ACDPs, particularly in the context of where the ACDPs are present on the base of POI data. This paper aims to compare the location of two types of ACDPs with influence factors in the Nanjing city area to analyze the spatial pattern and mechanisms of influence. Firstly, we shed light on the spatial distribution of the China Post and Cainiao stations by exploring the spatial pattern (i.e., wherein Nanjing the ACDPs occur). Finally, we analyze the correlation between ACDPs and population, GDP, and land use type. This work helps expand spatial research at the ACDP micro-level and provides background information for ACDP location selection and network optimization. This work also served as the scientific basis for optimizing the layout and organization of events in the Chinese logistics industry, and also contributed to solving the problem of the "last mile" in the logistics industry and contributed to the vigorous progress of the Chinese logistics industry.

2. Data Collection and Methods

2.1. Study Area

Nanjing (31–14′N - 32–37′N and 118–22′E - 119–14′E) is the capital of Jiangsu Province and the central city of the metropolitan area of Nanjing, located in eastern China in the lower reaches of the Yangtze River. As an important central city in eastern China, this city has important national scientific and educational bases and a comprehensive transportation hub approved by the State Council. As of 2018, the city has 11 districts with a total area of 6,587 square kilometers, a built-up area of 971.62 square kilometers, a permanent population of 8.362 million people, an urban population of 6.599 million people and an urbanization rate of 82.5%. It is the only city in the Yangtze River Delta and East China, as well as the International Yangtze River Logistics Center. The Yangtze River Delta exudes an important national gateway for the development of the central and western regions. Nanjing is an important city hub at the strategic crossroads of the eastern coastal economic zone and the Yangtze River economic zone.

2.2. Data Sources

The study mainly conducted using secondary data and point of interest (POI) data, road network data, administrative boundaries, population, and GDP data for the study area. The POI data were obtained through the "POI Query" from the online platform "Metro Data Tech (MDT)" (https://www.metrodata.cn/). Each POI data point contains a name, address, longitude, and latitude. After cleaning, converting, and sorting the data, extracted the reliable data for the Cainiao and China Post stations were 800 and 424, respectively shown in Table 1. Based on this, a spatial database of CDPs was created. The road network data were obtained from OpenStreetMap (http://www.openstreetmap.org/), Nanjing boundary

data were obtained from the China National Geographic Information Centre as well as population and GDP data from the National Bureau of Statistics of China.

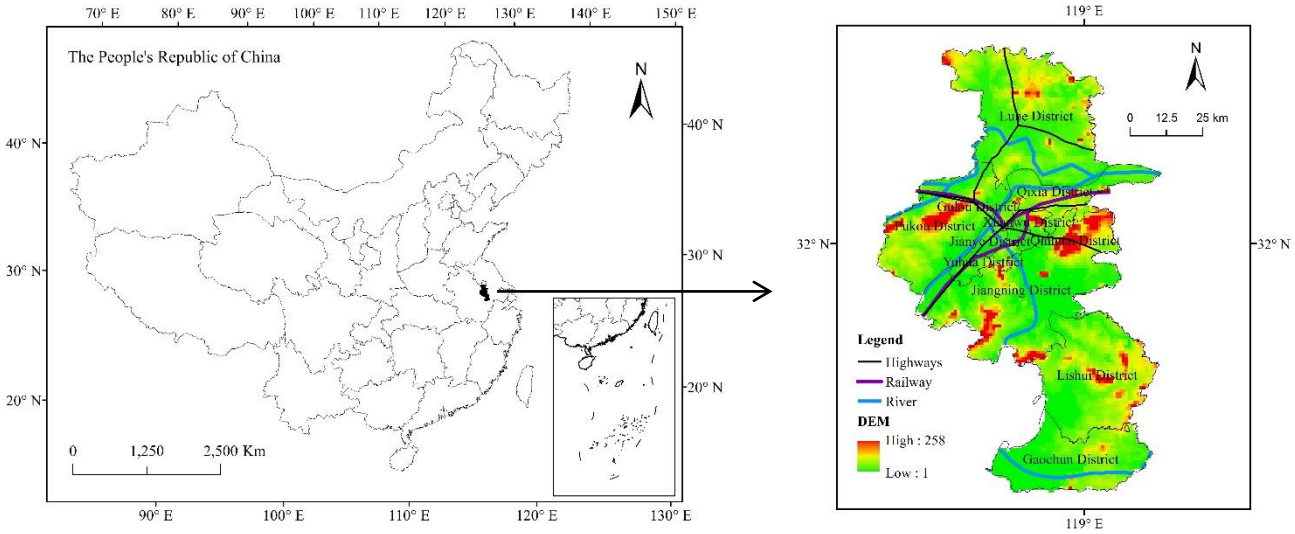

Fig. 1: Study area map.

Table 1: Percentage distribution of ACDPs in Nanjing.

		Area	Population	Number of POIs				
City area	Area attribute	(km2)	(Ten thousand people)	Cainiao Stations	China Post	Tota l	Percenta ge (%)	Density (/km^2)
Gulou District	Central urban area	53.1	131.37	60	65	125	10	2.354
Jianye District		82.7	46.4	31	20	51	4	0.617
Xuanwu District		80.97	66.2	66	56	122	10	1.507
Yuhuatai District		134.6	40.13	45	21	66	5	0.490
Qinhuai District		49.2	104.2	95	75	170	14	3.455
Jiangning District	Sub-urban area	1572.9	115.56	187	56	243	20	0.154
Lishui District		1067.3	42.09	22	30	52	4	0.049
Luhe District		1485.5	92.58	39	12	51	4	0.034
Pukou District		912.3	72.03	136	44	180	15	0.197
Qixia District		381.88	65.45	112	31	143	12	0.374
Gaochun District		802	43.43	7	14	21	2	0.026
		6622.45	819.44	800	424	1224	100.00	0.185

2.3. Research Methods

2.3.1. Standard Deviational Ellipse

The standard ellipse is a classic spatial distribution analysis algorithm to examine the characteristics of a point dataset. The algorithm is used to measure the direction and distribution characteristics of a dataset; ellipse as output [17]. The long axis of the ellipse represents the maximum diffusion direction of the test data, the short axis of the ellipse is the minimum diffusion direction of study data [18]. In this article, an ellipse with a standard deviation of the second order with points of collection and delivery of duties of 95% is selected as the output ellipse for the effective study of the distribution characteristics of collection points in Nanjing.

2.3.2. Kernel Density Estimation Method

As a nonparametric estimation method, kernel density analysis is mainly used for calculations the density of ACDPs in the surrounding community. This method sets up a specific position of the feature points and assigns the attribute value of the centre point in the specified threshold range of values. The range is usually a circle of the radius when the points are grouped in the centre with the highest density. Density gradually decreases as the distance decreases; it decreases until the density at a distance becomes 0 [19].

The function is shown in Equation (1):

$$f(\boldsymbol{s}) = \sum_i^n \frac{k}{\pi r^2}\left(\frac{d_{is}}{r}\right) \quad (1)$$

Where f(s) is the density at position S; r is the radius of the search for the estimated core density, and k is the weight of point i to the position S distance. This paper uses methods for estimating core density to determine the allocation characteristics of on-site collection and distribution points on a city-wide basis.

2.3.3. Pearson correlation

Pearson's correlation coefficient is the covariance of two variables divided by the product of their standard deviations, which displays the degree of linear correlation between variables. The formula is as follows:

$$\boldsymbol{r} = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2 \sum_i^n (y_i-\bar{y})^2}} \quad (2)$$

Where (xi, yi), (xn, yn) are sample points of the two variables (x, y). The correlation coefficients are less than or equal to 1, where 1 is a total positive linear correlation, 0 indicates no linear correlation, and -1 is a total negative linear correlation. In this paper, Pearson correlation equals to 1 is used to determine the influencing factors of ACDPs in Nanjing.

3. Results and discussion

3.1. Spatial Pattern of ACDPs in Nanjing

3.1.1. Overall pattern

A spatial pattern is a geographical representation in which the location of space and distance is expressed to analyze the direction and manner of the positioning of objects. The overall spatial distribution of the ACDPs in Nanjing are the following:

The dimensional allocation is asymmetric because they are mostly concentrated in the central part of the city and less scattered in other areas of the city. Figure 2A shows that Nanjing Cainiao Stations are mainly distributed in four districts: Jiangning District, Qixia District, Pukou District, and Qinhuai District. These are the Gulou and Xuanwu areas, in turn. The smallest Cainiao stations in Lishui, Gaochun, and Lihue are irregular and uneven. China Post is mainly located in the Gulou area, followed by the Qinhuai, Xuanwu, and Jiangning districts. As shown in Figure 2B, the smallest number of China postal stations are in the Luhe District, the Gaochun District, and the Yuhuatai District. The presence and distribution points in Nanjing are primarily allocated in the center of Nanjing, while in the adjacent areas of Nanjing, they are rarely distributed.

The overall patterns indicate dense clusters in the center and light clusters at the edges, as exhibited in Figure 2C. The spatial pattern features of ACDPs in Nanjing is more prominent. In general, the center of the distribution is a condensed zone of express delivery in Xuanwu District, Qinhuai District, and Qinhuai District that extends to the edges to make discrete distributions in the surrounding areas because of terrain, the population, and economic improvement. The overall spatial pattern for China Post and Cainiao stations and are highly dense inside the metropolis centre and isolated at the edges of Nanjing city.

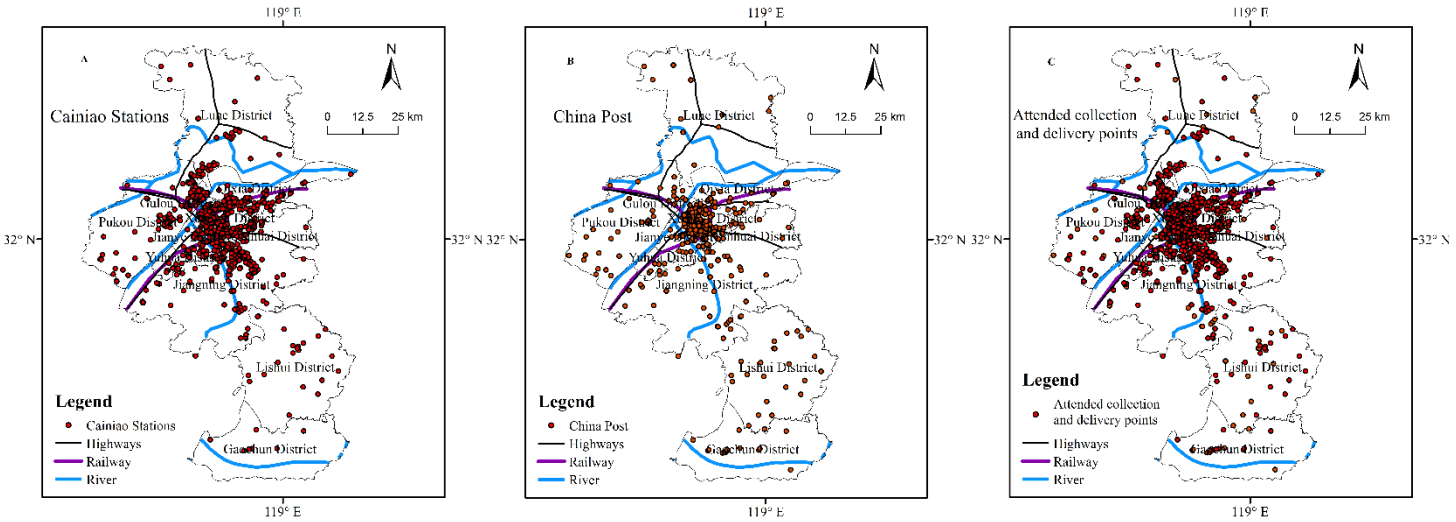

Fig. 2: Distribution of ACDPs in Nanjing.

3.1.2. Spatial allocation directional features

The standard deviation ellipse is a spatial analysis tool that examines the pattern of discrete location points. The standard deviation ellipse can be efficiently applied to analyze the distribution characteristics of the ACDPs in Nanjing. In this article, the secondary standard deviation ellipse containing 95% of positions with an arbitrary configuration is used as the size of the output ellipse. The following results are obtained:

Overall, there is a tendency from southwest to northeast. Figure 3 indicates that there is a large distinction among the vertical and horizontal axes of the Nanjing Cainiao station's ellipse, which reveals that the direction of Cainiao stations is more obvious. The distribution of post offices is more discrete, the vertical axis is longer than the horizontal. Therefore, China Post Stations is more prominent than Cainiao Stations.

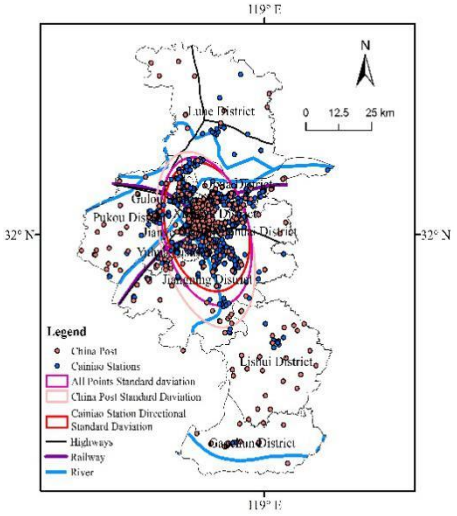

Fig. 3: Standard deviational ellipse analysis of ACDPs in Nanjing.

3.1.3. Density Distribution Features

In this study, the Cainiao station and China Post station, as well as the kernel density map of the ACDPs are used as the object of study. In general, ACDP's distribution in Nanjing has clear agglomeration trends and clear hot spots. The following features can be found in combination with the distribution maps of Nanjing.

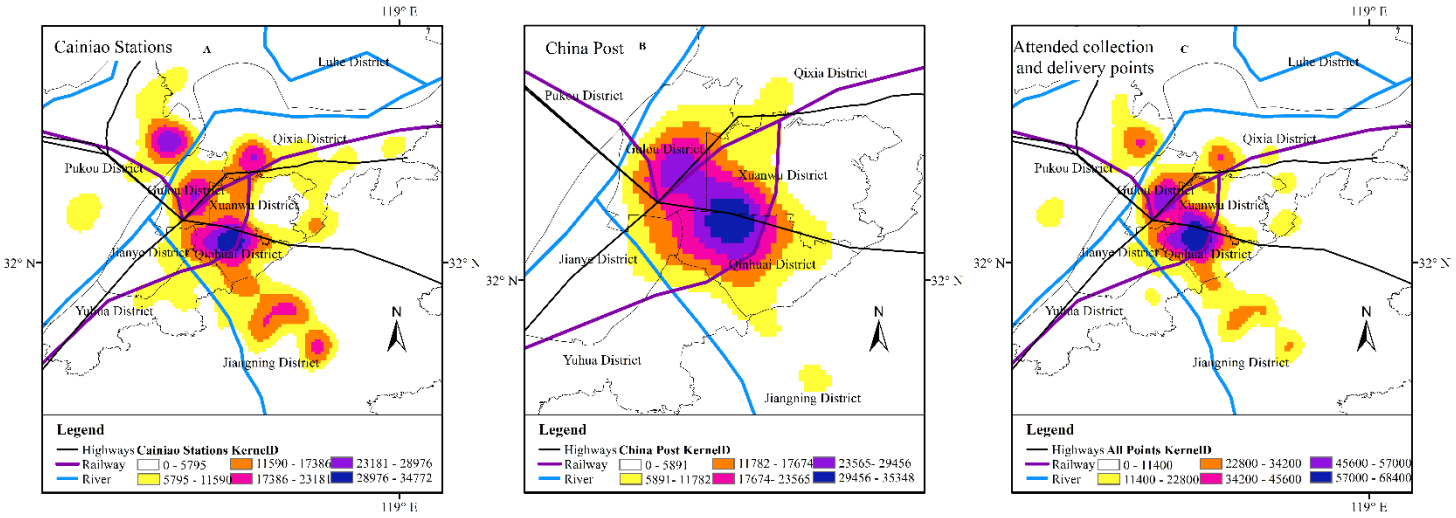

Fig. 4: Kernel density analysis of ACDPs.

1. Overall, there are common asymmetric clusters. Fig. 4A demonstrates Cainiao stations have mainly four hubs. The first important district is inside the north of Qinhuai, which is the most densely populated and agglomeration extensive location. The second key region in the northwest of the Pukou district. The third key region is the Fenghuang Street in the southwest of the Gulou district. This area is the location of community neighborhood residents' committees which are merged, adjusted, and interconnected with each other. The fourth core is the Maiqiaoqiao Street in the southwest of Qixia district, bordering with Xuanwu District from west and Gulou District from the north. It is the subcenter of Nanjing city and a hub of economics, external windows, and the culture of the Qixia district. Due to the traffic network, there is convenient traffic and transportation; there is online shopping and express delivery, though too less than in other areas.
2. While Figure 4B shows that China post stations have only one essential core region, which is the northwest part of the Qinhuai district and the west part of the Xuanwu District. The traffic in this area is convenient and prosperous and it has a full range of public welfare facilities. There are high-end residential quarters that are beneficial to the movement of products in this area. Due to these factors (i.e., development, location near institutes, etc.), the movement of people is high, and the population is dense. Therefore, the online shopping pattern in this region is frequent and China post stations are convenient as an emerging logistic delivery express system.
3. The law of distance (the law of the inverse square) seems to work along the edges of asymmetric clustering. Figure 4 confirms that the four major areas of Cainiao Station are crowdedly occupied pickup points. Though, as the results of the kernel density estimation method show, with increasing distance from the main region, the Cainiao station's quantity declines. The China post stations are distributed with one core area as the most densely populated pickup points area. Nanjing's ACDPs is inversely proportional to the distance from the central region, which is constant with the inverse square law.

3.3. An analysis of influencing factors of ACDPs in Nanjing

ACDPs are important points in the 'last mile' delivery express and people's lives through the improvement of the efficiency of 'last mile' delivery. These elements want to be taken into consideration when setting up an ACDP network. Generally, ACDPs relay on people to express delivery. Therefore, economic development is the main factor affecting the ACDPs. Online shopping is dependent upon the population where shoppers and buyers are present. So, the population is another important affecting factor of the ACDP distribution. Moreover, traffic is the main component of 'last mile' express delivery, which is connected to the road network, indicating that the road is also an influencing factor. ACDPs can also indicate where people are and in what places they are living; the land use type is also an important influencing factor. Therefore, this paper analyses the population density, GDP, traffic accessibility, and land use type as influencing factors on the distribution of ACDPs in Nanjing.

3.3.1. Regional economic level

Pearson's correlation analysis was conducted between 10,000 yuan per square kilometer GDP and ACDPs. Table 2 suggests that the correlation among GDP per square kilometer and the Cainiao Station's density is 0.865, while the correlation with the density of China Post Station is 0.934. The correlation of all ACDPs is 0.903, which is significant at a confidence level of 99%, which indicates that Nanjing's regional economic level is closely related to the density of ACDPs. Figure 5 shows that the density of logistic and information flows per capita in the Gulou, Jiangning and Qinhuai districts is very high, due to the increase in GDP per square kilometer due to densely populated areas. Yuhuatai and Lishui districts have low total GDP, large area, low population density, and relatively low regional economic development, which is why the number of ACDPs in this region is small.

Table 2. Correlation between ACDPs and GDP in Nanjing

ACDPs	GDP per square kilometer (Billion yuan/km2)
China Post	0.934**
Cainiao Stations	0.865**
All sites	0.903**

**. Correlation is significant at the 0.01 level (1-tailed).

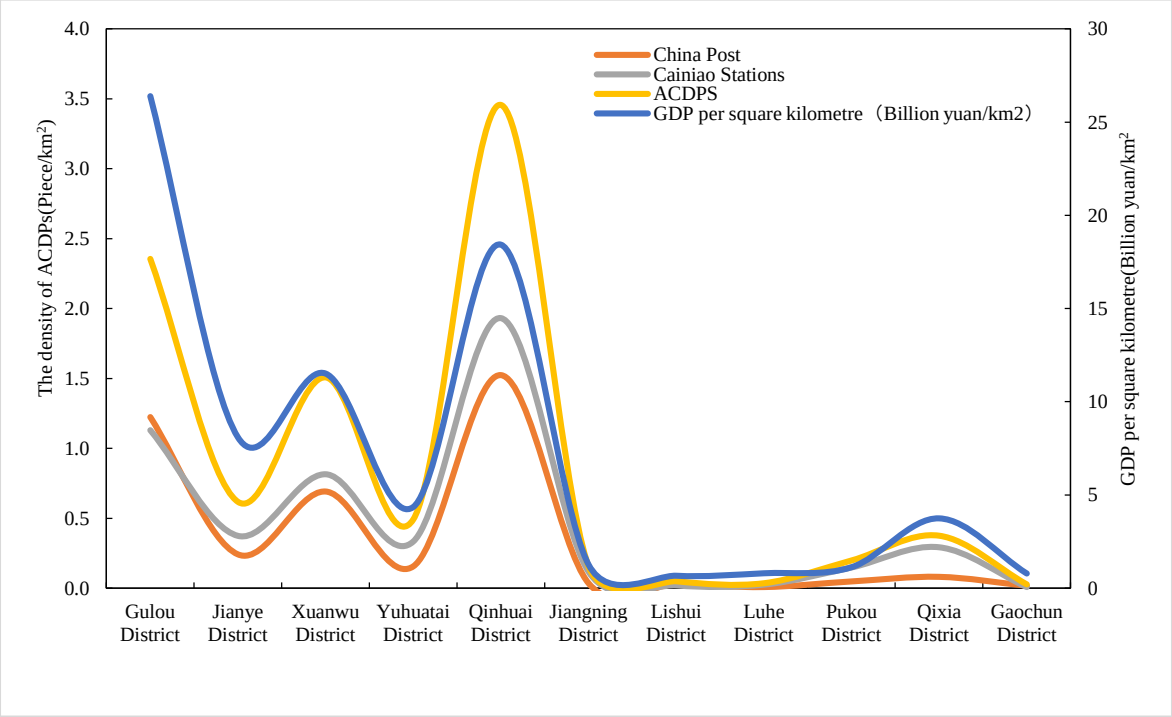

Figure 5. The relationship between ACDPs and economic level in Nanjing

3.3.2. Population Distribution factor

The population is one of the key driving factors of ACDP's location in an area. ACDP and population density data were utilized for carrying out correlation analysis. The location of ACDP is highly dependent on the population. We used population density data and ACDP data for each area in Nanjing for correlation tests. Table 3 shows that the association between China Post and population density is 0.968, and the relationship between the population and Cainiao Station is 0.909. The correlation between population density and all ACDPs is 0.943. The correlation between Cainiao Station and the population, all points, and the population reached 99%, which indicates that ACDPs, China Post Stations, and Cainiao Stations are closely related to population density. All ACDPs are very relevant to the population.

Table 3. Correlation between ACDPs and the population in Nanjing

ACDPs	Population density
China Post	0.968**
Cainiao Stations	0.909**
All sites	0.943**

**. Correlation is significant at the 0.01 level (1-tailed).

This article also includes the population densities of various streets of Nanjing city, which is superimposed with the China post stations and Cainiao stations, obtaining the association between ACDPs and the population distribution of Nanjing. Figure 6 shows that the distribution of ACDPs in Nanjing demonstrates a strong consistency with the population distribution of each city district. The areas of Gulou, Jiangning, and Qinhuai districts are the areas with the highest population distribution and the areas with the highest density of express delivery points. These are mostly distributed in the city center because this region is densely populated while the population in the remote area is scattered and the appearance of pickup points is low, leading to the sparse distribution of ACDPs. Overall, all sites are consistent with population density.

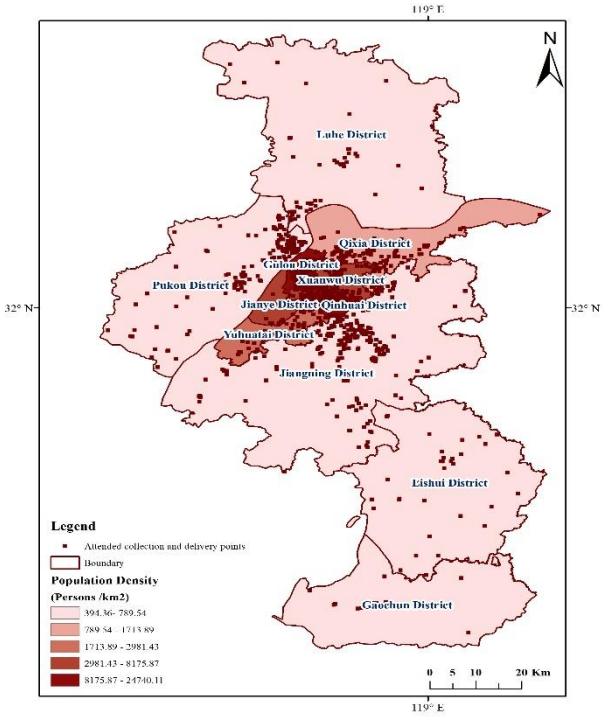

Fig. 6: Relationship between ACDPs and population in Nanjing.

3.3.3. The convenience of Traffic

Roads are the main component of the "last mile" logistic distribution, they allow consumers to pick up packages during daily trips. However, If the ACDPs are placed along with roads at walking distance or biking distance then they can become even more convenient to the consumer. Therefore, ArcGIS was used to perform a 1 km buffer analysis; the one-kilometer range was used to find the intersection of ACDPs with main traffic lines (county highways) of Nanjing city (Figure 7). The results show that the distribution of pickup points from various districts is mainly along the main roads of urban areas while central city areas have a dense traffic road network where pickup points are also concentrated. The road network density is low at the edges of the city where traffic accessibility is relatively weak.

Thus, fewer pickup points appeared. The distribution of courier sites varies depending on the convenience of moving. Overall, all sites were convenient for road networks.

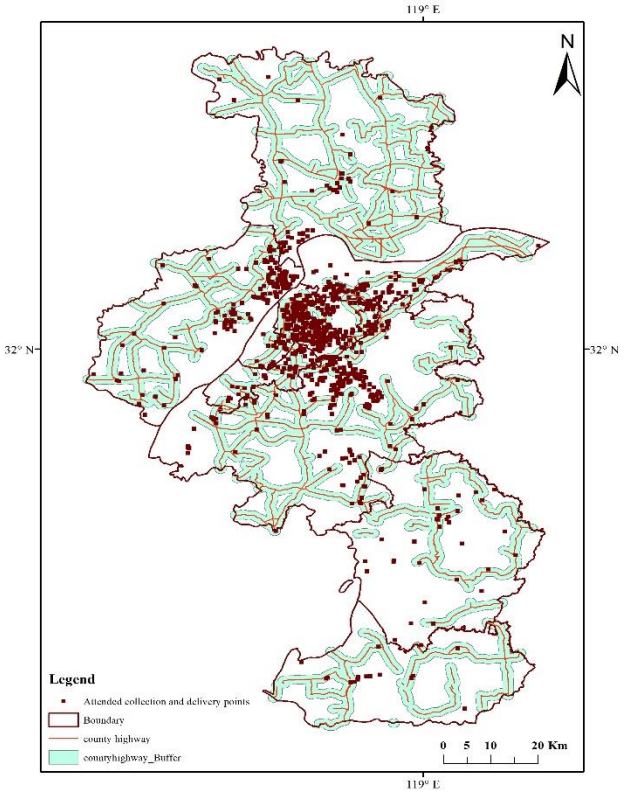

Fig.7: Relationship between ACDPs and traffic lines in Nanjing.

3.3.4. Types of land use

It was found that the ACDP's quantity distributed in urban residential areas was the largest. The population density in urban residential areas is excessive, and generally, the trend of online shopping in residential areas is way higher than the rest of the land types. Second, the impact of crop field sites on the ACDPs is mainly reflected in the distribution of croplands compared with human activities. Farmers are the main force behind online shopping consumption. The number of rural residents reflects the number of online purchases in the region and the extent of population migration, which to some extent contributed to the improvement of the shipping enterprise in the vicinity. However, the express delivery stations located in crop fields land type are comparatively less than urban areas, as the consumers rarely go for online shopping options. Other land kinds consisting of forest land, high coverage grassland, open forest land, and shrub are occupied with fewer sites. As a result, they are less relevant to the spatial distribution of ACDPs. (See table 4) Nanjing City Center land use plan (2003-2020) can be combined with ACDPs (Figure 8) to visually show that the quantity distribution of ACDPs is consistent with land-use types. Consequently, the ACDP's count in any area highly depends on the land type of that region.

Table 4: Quantity of ACDPs in various land-use types in Nanjing.

City Area	Crop Field	Forest Land	High Coverage Grassland	Open Forest Land	Other Construction Land	Rural Residential Land	Shrub	Unused Land	Urban Residential Land	Total
Gaochun District	9	0	0	0	0	4	0	2	6	21
Gulou District	0	0	0	0	0	0	0	0	125	125
Jiangning District	45	1	0	2	9	25	0	31	130	243

Jianye District	0	0	0	0	0	0	0	6	45	51
Lishui District	23	2	0	0	0	9	0	8	10	52
Luhe District	16	0	0	2	1	4	1	6	21	51
Pukou District	32	4	6	2	13	53	0	17	53	180
Qinhuai District	5	0	0	0	1	0	0	9	155	170
Qixia District	11	7	0	4	0	23	1	1	96	143
Xuanwu District	3	15	0	0	0	5	0	2	97	122
Yuhuatai District	5	4	0	1	0	3	0	21	32	66
Total	149	33	6	11	24	126	2	103	770	1224

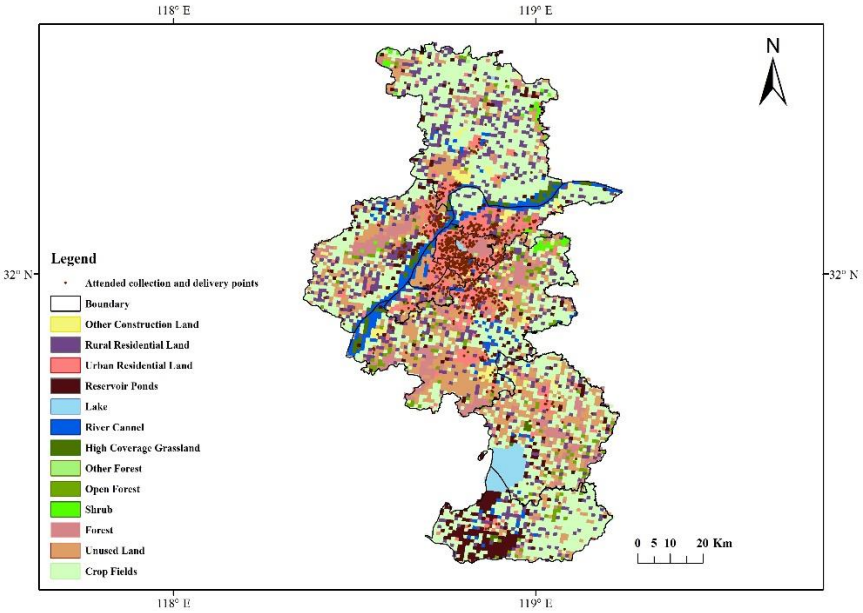

Fig. 8: Relationship between ACDPs and land use types in Nanjing.

4. Conclusions and Policy Implications

Based on the research objectives, analyses of spatial patterns, and influencing factors of the ACDPs in Nanjing city, the following conclusions are presented.

The spatial structure of ACDP in Nanjing is especially exhibited inside the overall characteristics, directional distribution, and density distribution features. The spatial pattern is asymmetrical, presenting the characteristics of 'denser clustered in the centre of the city and fewer are spreading at the edges of the city'.

ACDP's quantity has been mainly influenced by the economic level of the region, and the delivery points have a positive relationship with the economic growth of that area. All ACDPs are strongly significant with the population distribution density. Most ACDPs are distributed on urban residential land and rural residential land.

This study has important implications for decision-makers and planners in logistics companies. Based on the results of this study, policies need to be developed to optimize road network design and improve demand management for ACSPs. To create a viable ACDP environment for residents, more urban reconstruction strategies related to ACDP are needed in urban areas. For urban science planning, the spatial characteristics of ACDP, such as location, density, and direction, are important. For example, both types of ACDP have different location settings. Beginner stations are

very consistent with population distribution, and the distribution of rookie stations in urban areas is rare. Also, because of land-use analysis, most ACDPs are well planned in residential areas. Consequently, ACDP planners must emphasize the spatial equality of ACDP to improve the distribution of new regions based on land use and population density. The geospatial analysis helps ACDP's planners determine where ACDP supply and demand do not match.

Conflict of Interest Statement

The authors declare no conflict of interest.

Acknowledgments

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