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Spatial Characterization of CAINIAO e-stations in China's New First-Tier Cities Based on POI Data

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ABSTRACT

Based on the POI (Point of Interest) data of CAINIAO e-stations in China's 15 new first-tier cities such as Chengdu, Hangzhou and Chongqing, this paper comprehensively utilizes spatial statistical methods such as kernel density analysis, spatial autocorrelation analysis and standard deviation ellipsoid analysis, to conduct an in-depth study on the spatial distribution characteristics of CAINIAO e-stations and their regional heterogeneity. The results show that: (1) CAINIAO e-stations in most cities show significant spatial aggregation characteristics, and their distribution centers are usually close to core business districts or densely populated areas; (2) The distribution direction is mostly consistent with major transportation corridors, economic development axes, or urban topographic features; (3) There are significant differences in the distribution scope, direction, and degree of dispersion of CAINIAO e-stations in different cities, which can be attributed to the spatial structure of the city, logistics demand, e-commerce penetration rate, and transportation network. These differences can be attributed to the combined effects of multiple factors such as urban spatial structure, logistics demand, e-commerce penetration rate and transportation network. The study provides empirical references for optimizing the layout of terminal logistics facilities and has important practical value.

KEYWORDS

CAINIAO e-station; New first-tier cities; Spatial characteristics; Regional heterogeneity

1. INTRODUCTION

With the arrival of the Internet economy and the era of e-commerce, offline logistics is developing rapidly, but the "last kilometer" distribution problem still exists in cities and towns, so the CAINIAO e-station came into being. CAINIAO e-station is the logistics industry to solve the distribution bottleneck problem, established in 2013 for the community, campus and other third-party terminal logistics service platform, as of the opening of this paper site has reached 170,000. Taking Xi'an, one of the new first-tier cities, as an example, since its entry into Xi'an in 2018, CAINIAO e-station has 3,744 stations in Xi'an so far. In 2024, the development of CAINIAO e - stations in Xi'an has witnessed significant optimization, effectively resolving the last - kilometer distribution problem. The rapid development of the CAINIAO e-station in the express delivery industry has provided positive practical significance for the construction of stable growth, adjusting structure, promoting reform, and benefiting people's livelihood [1, 2].

As regional resource-concentrating cities, the new first-tier cities have become the economic, political, cultural and transportation centers of their regions by virtue of their strong economic foundations and strong radiation capabilities. These cities have experienced rapid urbanization and spatial restructuring, and have demonstrated significant urban expansion and functional upgrading. At the same time, the new first-tier cities have the ability to attract high-end talents and capital, and promote regional synergistic development and innovation through optimized policies. In terms of the consumer market, new first-tier cities, with their large population size and strong consumption power, provide a broad market space for the development of the logistics and express delivery industry, and have become an important target for the expansion of brands such as Cainiao Station. In addition, new first-tier cities generally implement policies to attract investment and support enterprises, and have friendly entrepreneurial environments, which provide good business support for the logistics and courier industry. Driven by regional competition, new Tier 1 cities have created strong conditions for corporate innovation and the introduction of high-end talent. Choosing to set up in new first-tier cities not only seizes market opportunities, but also leverages policy dividends and talent resources, injecting innovation power into the logistics and express delivery industry such as Cainiao Station. These qualities highlight the unique significance and development potential of new first-tier cities in the research and practice of the logistics and courier industry [3-6].

2. LITERATURE REVIEW

Existing domestic research mainly focuses on exploring the spatial characterization of single first-tier or new first-tier cities' CAINIAO e-stations and tries to explain their influencing factors and put forward optimization measures, and existing international research also focuses on studying the spatial analysis of express pickup points in specific national capitals [1, 2, 7-12], which provides a rich demonstration of the methodology and reference of the model to achieve the research objectives of this paper, but there are problems of a single perspective, lack of cross-city comparisons and data limitations problems. At present, few studies have analyzed the spatial distribution characteristics of logistics pickup points in new first-tier cities in China, and there are few analyses of the similarities and differences in the spatial distribution of CAINIAO e-stations among new first-tier cities.

3. RESEARCH METHODOLOGY

Point of Interest (POI) data is the basic data of network electronic maps, which has the advantages of simple data structure, large data volume, and strong present situation; it is used in urban planning, urban analysis, etc. [13]. This study uses Gaode Map as the data source and leverages the 'Datamap – POI Search' function provided by 'Forrest'. Keywords such as 'CAINIAO e-station' and the names of 15 corresponding cities were input, selecting the primary category of 'Life Services' and the secondary category of 'Logistics and Express Delivery'. As of the cutoff date of December 26, 2024, a total of 7,195 POI data points for CAINIAO e-stations across 15 cities were obtained. The retrieved data entries include information such as the name of the pickup point, latitude and longitude coordinates, and detailed address information.

In order to study the similarities and differences in the spatial distribution of CAINIAO e-stations in various new first-tier cities, this paper refers to the research methods of existing studies on the spatial characteristics of express pickup points in terms of spatial agglomeration degree, distribution pattern, etc. [7], and comprehensively applies spatial analysis methods such as spatial autocorrelation analysis, buffer analysis, kernel density analysis, standard deviation ellipse, etc., to analyze the spatial characteristics of the CAINIAO e-stations in the new first-tier cities in terms of agglomeration, directionality, etc. and regional heterogeneity, combined with supplementary data such as administrative area boundaries and different urban topography, business districts, residential area distribution, etc., to make possible interpretations and summarize the analysis results. Supplementary data were obtained from ArcGIS, Gaode Map API.

4. ANALYSIS OF RESULTS

4.1. Spatial Autocorrelation Analysis

Spatial autocorrelation analysis found that the Moran'I index values of the 15 new first-tier cities are all significantly positive, with a confidence level of 99.9% (Table 1), indicating that these cities have obvious clustering characteristics of the CAINIAO e-station, among which the index values of Hangzhou, Suzhou, Dongguan, and Ningbo are above 0.80, which shows that the clustering phenomenon of their CAINIAO e-stations is more obvious.

Table 1. Spatial autocorrelation analysis

NUMBER	CITY	Moran's I	P-value
1	CHENGDU	0.738870	0.001
2	HANGZHOU	0.804918	0.001
3	CHONGQING	0.472934	0.001
4	SUZHOU	0.933045	0.001
5	WUHAN	0.632086	0.001
6	XI’AN	0.461269	0.001
7	NANJING	0.641852	0.001
8	CHANGSHA	0.580190	0.001
9	TIANJIN	0.571790	0.001
10	ZHENGZHOU	0.777398	0.001
11	DONGGUAN	0.922848	0.001
12	WUXI	0.555382	0.001
13	NINGBO	0.805696	0.001
14	QINGDAO	0.693819	0.001
15	HEFEI	0.605474	0.001

4.2. Kernel Density Analysis

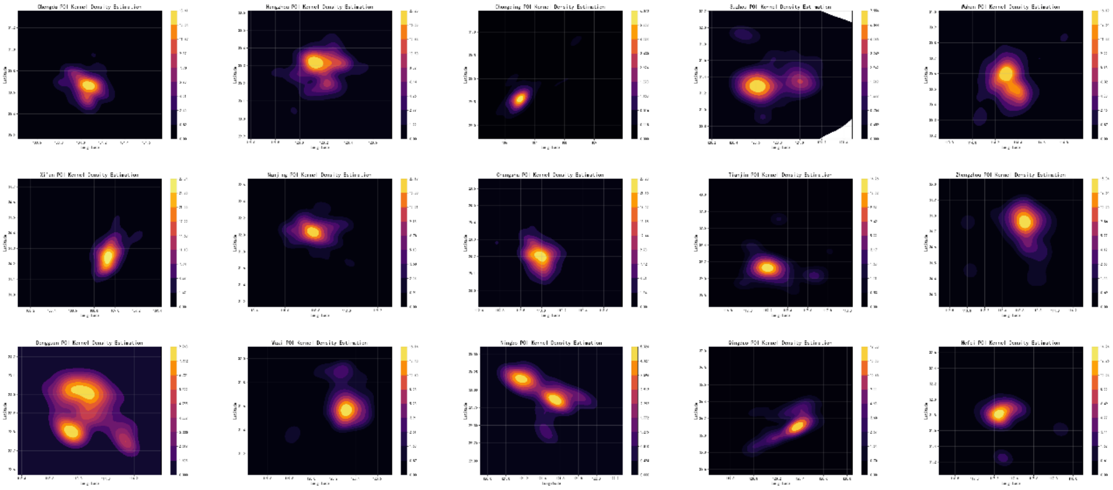

Figure 1. Kernel Density Analysis

The kernel density analysis reveals that the geospatial distribution of POIs in each of the new Tier 1 cities is non-uniform, and all have at least one area with higher density (Figure 1). These areas of higher density may reflect a more concentrated demand for express delivery and receipt in the area where the CAINIAO POIs are located, which may be related to the activity level of e-commerce transactions, the number of residents, or the functional characteristics of the area (e.g., commercial area, residential area, or university). For example, the formation of hotspots around colleges and universities may imply that the student population is the main service target, while the high-density distribution in residential areas or commercial streets may reflect the concentration of home users and business demand. In addition, the formation of these hotspots may be related to the logistics network planning of the RBPS itself and the consideration of the service coverage demand, such as prioritizing the layout in areas with high pedestrian flow or convenient transportation. In order to verify this conjecture, this paper further carries out the buffer zone analysis.

4.3. Buffer Analysis

Table 2. Buffer Zone Analysis - Residential

City	Buffer Distance (km)	Total Covered POI	Incremental Covered POI
DONGGUAN	0.5	9	9
	1	26	17
	5	211	185
	10	375	164
NANJING	0.5	17	17
	1	44	27
	5	302	258
	10	408	106
HEFEI	0.5	17	17
	1	54	37
	5	254	200
	10	347	93
TIANJIN	0.5	7	7
	1	28	21
	5	261	233
	10	350	89
NINGBO	0.5	9	9
	1	25	16
	5	111	86
	10	159	48
CHENGDU	0.5	9	9
	1	30	21
	5	226	196
	10	384	158
WUXI	0.5	23	23
	1	54	31
	5	284	230
	10	349	65
HANGZHOU	0.5	18	18
	1	39	21
	5	263	224
	10	443	180
WUHAN	0.5	17	17
	1	33	16
	5	306	273
	10	396	90
SUZHOU	0.5	17	17
	1	38	21
	5	150	112
	10	267	117
XI’AN	0.5	14	14
	1	48	34
	5	417	369
	10	448	31
ZHENGZHOU	0.5	15	15
	1	32	17
	5	269	237
	10	316	47
CHONGQING	0.5	21	21
	1	57	36
	5	250	193
	10	365	115
CHANGSHA	0.5	19	19
	1	50	31
	5	325	275
	10	440	115
QINGDAO	0.5	17	17
	1	41	24
	5	272	231
	10	349	77

Table 3. Buffer Zone Analysis - Business District

City	Buffer Distance (km)	Total Covered POI	Incremental Covered POI
DONGGUAN	0.5	11	11
	1	27	16
	5	228	201
	10	423	195
NANJING	0.5	18	18
	1	49	31
	5	297	248
	10	379	82
HEFEI	0.5	14	14
	1	30	16
	5	263	233
	10	348	85
TIANJIN	0.5	10	10
	1	24	14
	5	229	205
	10	339	110
NINGBO	0.5	6	6
	1	22	16
	5	178	156
	10	298	120
CHENGDU	0.5	13	13
	1	44	31
	5	270	226
	10	392	122
WUXI	0.5	12	12
	1	38	26
	5	322	284
	10	408	86
HANGZHOU	0.5	14	14
	1	44	30
	5	259	215
	10	390	131
WUHAN	0.5	11	11
	1	41	30
	5	311	270
	10	425	114
SUZHOU	0.5	6	6
	1	19	13
	5	240	221
	10	336	96
XI’AN	0.5	21	21
	1	72	51
	5	384	312
	10	440	56
ZHENGZHOU	0.5	12	12
	1	33	21
	5	232	199
	10	302	70
CHONGQING	0.5	24	24
	1	64	40
	5	247	183
	10	343	96
CHANGSHA	0.5	16	16
	1	53	37
	5	379	326
	10	449	70
QINGDAO	0.5	13	13
	1	61	48
	5	286	225
	10	386	100

Buffer analysis of POIs in business districts and residential areas to determine whether these areas are covered or overlap with the distribution of POIs of the CAINIAO e-stations can effectively verify the reasonableness of the above, and at the same time provide a scientific basis for optimizing the layout and service strategy.

By analyzing the POI data of residential areas and shopping districts in these 15 cities with 0.5km, 1km, 5km and 10km buffer zones (Table 2, Table 3), it is found that the hotspots of CAINIAO e-stations have a high degree of overlap with the buffer zones of shopping districts and residential areas, and the 5km buffer zones can cover over half of the CAINIAO e-stations, which suggests that the layouts are indeed driven by the demand, and this validates the logic of the above speculation.

4.4. Standard Deviation Elliptic Analysis

In order to further compare and analyze regional heterogeneity by combining the CAINIAO e-station POI data with the characteristics of each new first-tier city, this paper adopts the method of standard deviation ellipse analysis in order to highlight its directional characteristics.

From the analysis results (Figure 2), it can be seen that the spatial distribution of CAINIAO e-stations among different cities has a large regional heterogeneity, and at the same time has a certain degree of similarity, this paper combines the geographic environment of each new first-tier city, economic development planning, e-commerce penetration and other characteristics of the variables, to make the following summary and possible explanations:

4.4.1. Resemblance

In terms of similarity, most of the cities' RBPSs show a clear trend of spatial aggregation, and the center point of the standard deviation ellipse is usually close to the core area of the city, reflecting that the service demand is concentrated in the core business districts and densely populated areas. Meanwhile, the direction of the main axis of the ellipse coincides with the city's major transportation corridors, economic development axes, or topographical features; for example, the distribution of Chengdu and Chongqing unfolds along major transportation corridors or river valleys, while Hangzhou and Xi'an are distributed along the main axes of urban expansion. In addition, the ratio of the long and short axes of the standard deviation ellipse indicates that the distribution range of each city's CAINIAO e-station can basically reasonably cover the main service demand area and does not appear to be overly discrete.

4.4.2. Difference

In terms of variability, the direction, extent and degree of discrete distribution of different cities are each characterized by its own characteristics. Hangzhou and Nanjing have a clear and longer main axis direction, showing the characteristic of distribution along economic corridors, which is related to the axialized development pattern of urban planning [4, 14-16][4,14-16]. While the distribution direction of Chengdu and Chongqing is constrained by the topography [17-21][17-21], the elliptical shape is rounded, reflecting a more centralized layout characteristic. Tianjin and Qingdao have larger distributions with extensive coverage, probably due to their larger city areas and even distribution of population density, while Xi'an and Changsha have smaller elliptical ranges and are concentrated in their core areas, which are associated with high population density and logistics needs [22-24][22-24]. In addition, in terms of the degree of dispersion, Chongqing has a relatively balanced distribution with a uniform ellipse shape, while Hangzhou has a more linear distribution due to the expansion of the belt along the Qiantang River.

4.4.3. Rationale

These distributional features can be attributed to a variety of factors. Urban spatial structure and planning patterns (e.g., the axial development of Nanjing and Hangzhou) influence the direction of distribution; mountainous terrain (e.g., Chongqing and Chengdu) limits the extent of distribution.

Regional differences in logistics demand are also important, with densely populated cities (e.g., Xi'an, Changsha) having a more centralized stagecoach layout, while larger cities with clear functional zoning (e.g., Tianjin, Qingdao) require a wider layout. In addition, economically developed cities (e.g., Hangzhou, Nanjing) have higher e-commerce penetration rates, resulting in a more dense distribution; while transportation networks and topographical factors also directly influence the distribution pattern, with mountainous cities (e.g., Chongqing, Chengdu) restricted in their distribution by transportation conditions, while developed transportation in plains cities (e.g., Hangzhou, Nanjing) contributes to a wider range of distribution.

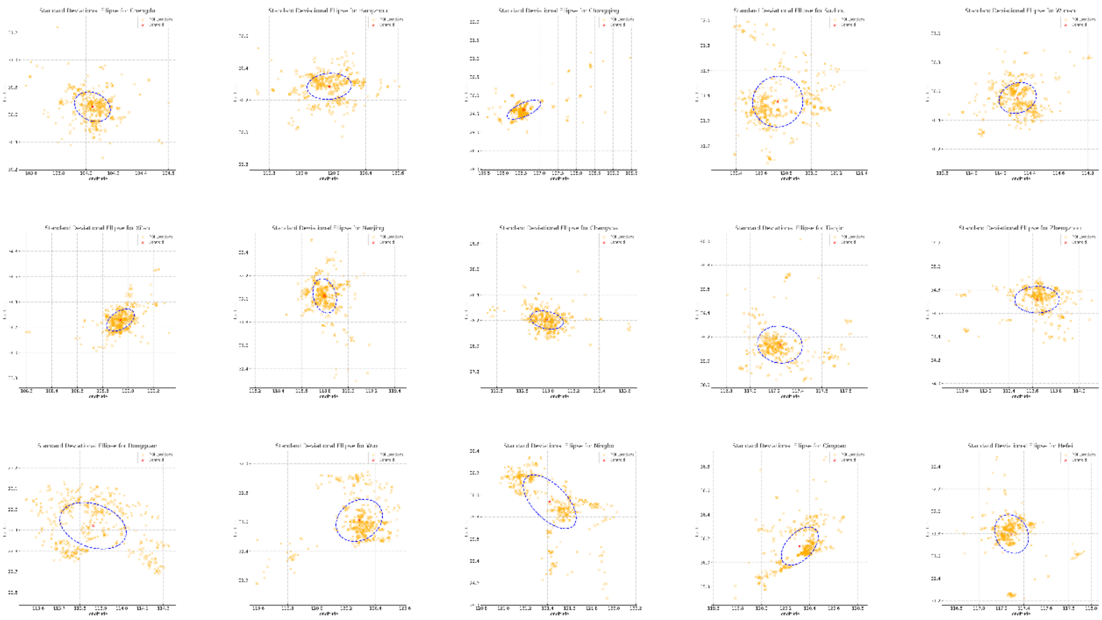

Figure 2. Standard Deviation Ellipse Analysis

5. CONCLUSION

By systematically analyzing the POI data of 15 new first-tier cities' CAINIAO e-stations, this paper reveals the similarity and regional heterogeneity in the spatial distribution of CAINIAO e-stations in these cities. The study shows that the distribution of CAINIAO e-stations in most cities exhibits significant spatial aggregation characteristics, and the center point of the standard deviation ellipse is usually close to the core area of the city, reflecting the strong demand for end-of-pipe logistics services in core business districts and densely populated areas. In addition, the direction of distribution of RBPSs is often highly consistent with the city's transportation corridors, economic development axes or topographic features, demonstrating the rationality and functionality of the spatial layout.

However, there are still significant differences among the cities in terms of distribution range, direction and degree of discretization. The distribution of stagecoaches in Hangzhou and Nanjing shows a high degree of concentration along the economic axes, which is closely related to the axialized development pattern of urban planning, while Chengdu and Chongqing are constrained by the topography and the layout of stagecoaches is more concentrated in the core areas. Tianjin and Qingdao have a wider distribution of stagecoaches due to their larger city area and uniform population density, while Xi'an and Changsha concentrate on high-density core areas to meet more centralized logistics needs.

The formation of these features can be attributed to a combination of factors, including the urban spatial structure, topographical conditions, logistics demand, e-commerce penetration and the influence of transportation networks. It is found that urban planning and the degree of development of transportation infrastructure have a significant impact on the layout pattern of stagecoaches, while the level of urban economy and functional zoning further determine the scope of distribution and the degree of densification.

In summary, this study not only provides empirical evidence for understanding the spatial distribution pattern of end-of-line logistics facilities in new first-tier cities, but also provides scientific guidance for optimizing the layout strategy of CAINIAO e-stations. Future research can further combine dynamic logistics data and real-time population distribution to deepen the optimization research on the layout of CAINIAO e-stations, which will provide support for the construction of a more efficient and accurate end-to-end logistics network.

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