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Spatial Connection Characteristics and Driving Mechanism of Regional Logistics in Guangdong-Hong Kong-Macao Greater Bay Area

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Abstract. The paper adopted the entropy weight TOPSIS method and the gravity model to explore the characteristics of logistics spatial connection of Guangdong-Hong Kong-Macao Greater Bay Area that includes nine prefecture-level cities and two special administrative regions, and analyzed the driving factors of the formation of logistics spatial connection pattern by geographical detector model. The results shows that: There are obvious imbalance in the comprehensive capacity of logistics in different regions, and the cities around the Pearl River estuary are generally strong in the logistics quality, like Guangzhou, Shenzhen and Hong Kong. The total amount of logistics links in different cities is significantly various. The logistics connection between cities are mainly weak, and the strong links are concentrated between Hong Kong and Shenzhen. In addition, Hong Kong, Guangzhou and Shenzhen are the three core nodes of the regional logistics network in Guangdong-Hong Kong-Macao Greater Bay Area. Industrial structure, economic scale, population scale, consumption level, the development of post and telecommunications industry are the main factors for the formation of the logistics spatial connection pattern. Moreover, these factors have a prominent driving effect on the cities with large amount of logistics links.

1. Introduction

Guangdong-Hong Kong—Macao Greater Bay Area is located in the central part of Guangdong Province and the Pearl River Delta, including Hong Kong and Macao Special Administrative Regions and nine core cities of Guangzhou, Shenzhen, Dongguan, Foshan, Zhuhai, Jiangmen, Zhongshan, Huizhou and Zhaoqing. Regional logistics is a new growth point and accelerator to promote the development of regional economy. With the proportion of the tertiary industry in the GDP of Guangdong-Hong Kong—Macao Greater Bay Area increasing year by year, the logistics industry plays an important role in realizing inter regional goods exchange, economic circulation and enhancing the economic strength. At present, the development of logistics industry in Guangdong-Hong Kong—Macao Greater Bay Area is still quite different. How to achieve the balanced development of logistic in Guangdong-Hong Kong - Macao Greater Bay Area, which is of positive significance to enhance the comprehensive strength, promote the economic development and give play to the core competitiveness of this area. Therefore, it is necessary to study the development level of regional logistics, the spatial connection pattern of regional logistics, and the driving mechanism of the formation of the spatial connection pattern of regional logistics.

In recent years, regional logistics research has received attention from scholars at home and abroad. Domestic scholars' research mainly focuses on the spatial structure of logistics network[1-2], the evaluation of logistics development level and competitiveness, and the driving factors of logistics industry development. In the research of logistics network structure, the regional logistics network is constructed with the help of principal component analysis and city gravity model to study the network structure of different regions. In the research of measuring the comprehensive competitiveness of logistics, In terms of measuring the comprehensive competitiveness of logistics, the regional logistics competitiveness evaluation model is constructed according to the principles of scientific, systematization and accessibility, and different regional logistics competitiveness is evaluated and compared by using hierarchical analysis[3] and entropy weight method[4], principal component analysis and entropy value method, factor analysis [5]and other research methods. In the study of the development drivers of logistics industry, Tang Jianrong [6]studied the spatial structure evolution characteristics of logistics network and its influencing factors in some regions of China by using the social network analysis method and ArcGIS visualization method.

In summary, existing studies have conducted relatively in-depth research on regional logistics networks, logistics competitiveness and the development drivers of the logistics industry, but there are fewer research results on logistics competitiveness, logistics network structure and other related issues in the cities of the Guangdong-Hong Kong-Macao Greater Bay Area. Moreover, the spatial econometric model is mainly used for the factors influencing the development of logistics industry. In view of this, this paper intends to take nine cities and two special administrative regions of Guangdong, Hong Kong and Macao as the research objects, and use entropy power-TOPSIS method, improved gravity model and geographic probe to measure the comprehensive strength of logistics in the Greater Bay Area, the intensity of inter-regional logistics spatial linkage, and the driving factors of the formation of logistics spatial linkage pattern. Moreover, the spatial linkage pattern of regional logistics and its driving mechanism are explored, aiming to provide reference for optimizing the logistics network structure of Guangdong-Hong Kong-Macao Bay and the spatial layout of logistics node cities.

2. Research Methods

2.1. Evaluation Model of Regional Logistics Comprehensive Capacity

Based on relevant studies[7], this paper adopts the entropy-TOPSIS method to evaluate the comprehensive regional logistics capacity of Guangdong-Hong Kong-Macao Greater Bay Area in order to effectively eliminate the influence of subjective factors. The entropy-TOPSIS method is an improvement of the traditional entropy method and TOPSIS method. The entropy method is used to determine the weights of the evaluation indicators, and then the TOPSIS method is used to determine the ranking of the evaluation objects by approximating the ideal solution.

2.2. Regional Logistics Spatial Linkage Network Model

In view of the complexity of transportation in Guangdong, Hong Kong and Macao, the small scope of logistics distribution in the region, the single route of logistics transportation, and the large proportion of road transportation in the regional logistics system, the economic distance in the gravitational correction model adopts the road transportation time and road transportation distance between each prefecture-level city[8-9]. The relevant index data was obtained with the help of Baidu Map's road driving reference, and the road transportation cost prices were obtained from Baidu Map's road toll prices.

2.3. Geodetector Model

As a statistical method to detect the driving force of spatial differentiation, Geodetector[10] has been widely used in the study of natural environment, economic environment and social environment, which can effectively detect whether a certain factor affects the spatial distribution of a certain type of indicators. In this paper, Geodetector model is introduced into the study of the drivers of the formation of the spatial linkage pattern of regional logistics in Guangdong-Hong Kong - Macao Greater Bay Area.

3. Spatial Linkage Pattern of Regional Logistics

3.1. Regional Logistics Comprehensive Capacity Analysis

3.1.1. Weight Analysis of Regional Logistics Comprehensive Capacity Evaluation Index

In order to comprehensively, accurately and objectively evaluate the level of regional logistics development in Guangdong-Hong Kong—Macao Greater Bay Area, the selection of evaluation indicators follows the principles of scientific research, methodological feasibility, evaluation system and comparability of indicators, With reference to the practice of related scholars[10-13], the comprehensive evaluation system of urban logistics is constructed from 14 indicators in four dimensions: economic development status, logistics supply and demand status, logistics support level, and logistics informatization degree.（Table.1）

Table 1. Comprehensive city logistics capacity evaluation system.

Primary Indicators	Secondary Indicators	Variables
Economic development status	Gross regional product (billion yuan)	X_1
	Gross regional product per capita (yuan)	X_2
	Value added of tertiary industry (billion yuan)	X_3
Logistics supply and demand level	Total industrial output value (billion yuan)	X_4
	Total import and export value (billion yuan)	X_5
	Total retail sales of social consumer goods (billion yuan)	X_6
	Total cargo volume (million tons)	X_7
Logistics support level	Port cargo throughput (million tons)	X_8
	Year-end number of employees on the job in the transportation, storage and postal industry (million people)	X_9
	Density of road transportation network (km/100 km^2)	X_{10}
	Local fiscal expenditure (billion yuan)	X_{11}
Degree of logistics informatization	Cell phone subscribers (million)	X_{12}
	International Internet users (million)	X_{13}
	Total post and telecommunications business (billion yuan)	X_{14}

The judgment matrix was constructed from the comprehensive logistics capacity evaluation index system, and the entropy value and weight of each index of Guangdong-Hong Kong-Macao Bay Area was calculated.

Table 2. Entropy weight w_j and information e_j of comprehensive capacity of urban logistics.

Indexes	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
w_j	0.043	0.060	0.083	0.061	0.093	0.052	0.077	0.063	0.118	0.100	0.076	0.058	0.080	0.036
e_j	0.892	0.849	0.794	0.847	0.768	0.869	0.808	0.842	0.705	0.751	0.811	0.856	0.801	0.911

As can be seen from Table 2, the number of employed workers at the end of the year in the transportation, storage and postal industry is the largest among the weighted indicators (0.118). In addition, road transport network density, total imports and exports and value added of tertiary industry also have greater weights (>0.08). This indicates that the number of employees employed in the transportation, storage and postal industry at the end of the year, the density of road transportation network, total imports and exports, and the value added of the tertiary industry are the main components of the comprehensive regional logistics capacity. Among the indicator weights, the weight of per capita regional GDP, total industrial output value, total freight, port cargo throughput, local fiscal expenditure, and international Internet users is larger (⩾0.06). However, gross regional product, total retail sales of social consumer goods, cell phone subscriber indicators, and total postal and telecommunication business indicators have a smaller weight (<0.06). From the weight values, it can be indicated that the level of logistics support occupies the largest weight in regional economic competitiveness, followed by the level of logistics supply and demand, while the economic development status and the degree of logistics informatization occupy relatively small weights. This prominently shows that the support level of regional logistics human, financial and infrastructure resources is the basis of regional logistics competitiveness and the dynamic balance between logistics supply and demand is an important condition for regional logistics development.

3.1.2. Regional Logistics Comprehensive Capacity Spatial Differentiation

Based on the entropy power analysis, the comprehensive capability score of regional logistics C_i is calculated according to TOPSIS method, and the larger the value of C_i, the stronger the comprehensive competitive strength of logistics of the city. In order to reveal more intuitively the spatial pattern of regional logistics differences among Guangdong-Hong Kong-Macao Greater Bay Area, this paper conducts a GIS spatial analysis of its comprehensive logistics capacity (Table 3). The natural breakpoint method was used to classify the evaluation value of the comprehensive logistics capacity of cities in Guangdong-Hong Kong-Macao Greater Bay Area into five types: high, higher, medium, lower and low values, and Figure 1 was drawn.

Table 3. 2018 logistics comprehensive evaluation index.

City	Index	Ranking	City	Index	Ranking
Guangzhou	0.6314	1	Zhongshan	0.1041	9
Shenzhen	0.6139	2	Jiangmen	0.1333	7
Zhuhai	0.0901	10	Zhaoqing	0.0412	11
Foshan	0.2223	6	Macau	0.3039	4
Huizhou	0.1152	8	Hong Kong	0.5501	3
Dongguan	0.2696	5			

Figure 1. Spatial differentiation of the comprehensive logistics capacity.

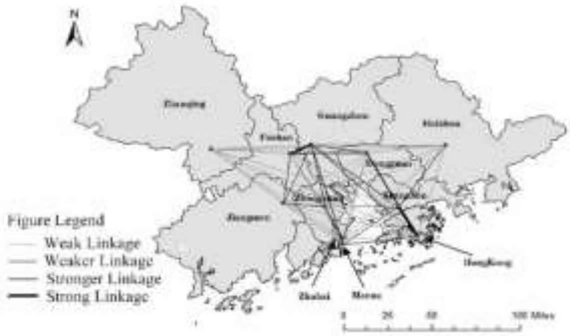

Figure 2. Regional logistics spatial linkage network map.

As it can be seen from Table 3 and Figure 1, Guangzhou City ranks first in terms of comprehensive logistics development and Shenzhen, Hong Kong and Macau are among the top regions, while Zhaoqing City, Zhuhai City and Zhongshan City are at the bottom. Specifically, in 2018, the region with the highest level of logistics development was Guangzhou (0.6314), and the city with the lowest level of development was Zhaoqing (0.0412), with an extreme difference of 0.5902. The cities in the high value area are Hong Kong, Guangzhou and Shenzhen, the higher value area is Dongguan and Macau, the medium value area is Foshan, the low value area is Zhaoqing, and the rest of the cities are in the lower value area. On the whole, the level of logistics development in the Guangdong-Hong Kong-Macao Greater Bay Area shows a spatial pattern of high in the center and low in the east and west.

3.2. Analysis of Spatial Linkage Characteristics of Logistic

The strength of logistics linkages and the total number of logistics linkages of each city in the Guangdong-Hong Kong-Macao Greater Bay Area in 2018 were calculated separately according to the modified gravity model. The natural breakpoint method was used to classify the logistics linkages among the 11 regions into four types: strong linkages, stronger linkages, weaker linkages, and weaker linkages (Table. 4).

Table 4. Regional logistics spatial linkage classification results.

Type	Region A to Region B
Strong connection (F_{ij}≥6.72)	Guangzhou-Foshan; Hong Kong-Shenzhen; Foshan-Guangzhou; Shenzhen - Hong Kong.
Stronger association (6.72>F_{ij}≥1.77)	Guangzhou-Dongguan; Guangzhou-Shenzhen; Shenzhen- Guangzhou; Shenzhen-Dongguan; Dongguan-Shenzhen; Dongguan-Guangzhou; Macau-Zhuhai.
Weaker ties (1.77>F_{ij}≥0.56)	Guangzhou- Zhongshan; Guangzhou -Jiangmen; Guangzhou - Hong Kong; Guangzhou-Macau; Shenzhen-Huizhou; Shenzhen-Macau; Foshan-Jiangmen; Zhuhai-Macau; Huizhou-Shenzhen; Dongguan-Foshan; Dongguan-Hong Kong; Zhongshan-Guangzhou; Zhongshan-Zhuhai; Jiangmen- Guangzhou; Jiangmen-Foshan; Jiangmen-Zhongshan; Macau-Guangzhou; Macau-Zhongshan; Macau - Hong Kong; Macau-Shenzhen; Hong Kong - Guangzhou; Hong Kong-Dongguan; Hong Kong- Macau.
Weak connection (F_{ij}<0.56)	Zhaoqing-Guangzhou, etc.

Combining Table.4 and Figure.2, the uneven distribution of spatial logistics links in the Guangdong-Hong Kong-Macao Greater Bay Area is relatively obvious. Spatially, there are obvious differences in inter-regional logistics links, with the weaker and weaker links dominating. The strong links are the "Guangzhou-Foshan" linkage and the "Shenzhen-Hong Kong" linkage. The stronger linkage is mainly reflected in the mutual logistics linkage between the three cities of "Guangzhou-Dongguan-Shenzhen" and the logistics gravitational linkage of Macau to Zhuhai. There is no obvious circle structure in the linkage network. It is mainly concentrated in the central part of the Pearl River Delta, Guangzhou City, and the eastern coastal area of the Pearl River estuary, showing a multi-core network structure with Guangzhou City, Shenzhen City and Hong Kong as the center. The linkages between the east and west regions are mostly weak logistics spatial linkage areas. On the whole, the spatial linkage network of central cities is extensive and radiates outward. The central cities have different degrees of influence on the logistics development of other cities, and the logistics links between the central cities and between the central cities and their neighboring cities are more obvious.

4. Analysis of the Driving Mechanism of Regional Logistics Spatial Linkage Pattern

4.1. Selection of Driving Force Indicators

A series of factors work together to form the existing spatial pattern of logistics linkages in the Guangdong-Hong Kong-Macao Greater Bay Area. The process of establishing logistics links among cities depends on the scale of city economy, industrial structure, logistics facilities and the degree of logistics specialization. Regions with higher level of logistics infrastructure are more likely to establish logistics spatial links with surrounding cities, and the density of logistics links in this region is higher. With the continuous upgrading of people's consumption level and consumption concept, the market consumption capacity becomes an important driving force for urban logistics development and inter-city logistics cooperation. Among them, the population size of cities is the most commonly used factor in measuring inter-city logistics interactions, and the consumption level of cities directly affects the demand level of inter-city logistics transportation. As the planner, manager and macro regulator of urban logistics development, the government force can play an important role in building inter-city logistics links and regulating the spatial distribution of logistics links.

With reference to the existing literature studies[14-17], this paper analyzes the driving mechanism of the formation of the spatial linkage pattern of logistics in the Guangdong-Hong Kong-Macao region by using the advantage of the geodetector model in the measurement of spatial heterogeneity. Collecting the cross-sectional data of nine prefecture-level cities and two special administrative regions in the Guangdong-Hong Kong-Macao Bay Area in 2018, we try to analyze the formation of the spatial linkage pattern of Guangdong-Hong Kong-Macao regional logistics from four perspectives: logistics foundation, market consumption, administrative support, and informationization degree.

4.2. Analysis of the Causes of Regional Logistics Spatial Differentiation

The data of the respective variables were divided into three categories according to the natural breakpoint method, and the influence of each driver on the formation of the spatial pattern of logistics was measured using a geographic probe (Table. 5). In terms of the magnitude of the *q* statistic value, the influence of industrial structure, economic scale, population size, consumption level, development level of post and telecommunications industry and governmental behavior on the degree of inter-city logistics network linkage and the scale and role of logistics node centers shows significant (>0.8).

Table 5. Intensity of the effect of each influencing factor.

Detection index	*eco*	*ind*	*por*	*spe*	*pop*	*con*	*gov*	*pos*
q statistic	0.8546	0.8753	0.7952	0.7828	0.8471	0.8471	0.8005	0.8471
p value	0.0060	0.0030	0.0807	0.0194	0.0117	0.0117	0.0892	0.0117

(1) Logistics base. *q* statistical value detection results show that the degree of influence of industrial structure in logistics base on regional logistics spatial linkage is the largest among all variables, with q value of 0.8753, and it passes the 1% significance test. The industrial structure of cities with high total logistics linkage is obviously inclined to the tertiary industry, leading to a significant increase in the level of development of their tertiary industry. This makes cities with high total logistics linkage have the advantages of logistics radiation and aggregation that distinguish them from other cities, and thus occupy a prominent position in the logistics linkage network. In addition, the economic scale is the basis for the establishment of logistics linkages in different regions, and economic growth is an important support for the development of logistics level, similarly, the high speed and high quality development of logistics industry will also bring economic level to the cities. The detection results show that the q-statistic value of gross regional product is 0.8546, which shows that the influence of economic development on improving the level of logistics spatial linkage is also quite significant. The two variables of logistics base, port logistics scale and degree of specialization, mainly influence the spatial aggregation and radiation of logistics nodal centers at all levels as well as the scale and status of this network nodal center through maritime infrastructure and employment in urban logistics industry. Although these two variables also pass the significance test, their influence on the spatial interaction of logistics performs relatively weakly.

(2) Market consumption. Population size and consumption level are included under the market consumption index. Population size and consumption level are important driving forces for regional logistics to achieve exchange in space. The two variables q-statistics have the same result with the value of 0.8471, and both pass the 5% significance test. With the increasing reliance of the public on e-commerce platforms, the population size determines the level of demand for urban logistics to a certain extent. The higher the pursuit of quality of life in cities with larger resident populations, the greater the demand for social consumer goods, and thus the higher the demand for e-commerce logistics transportation capacity. And the increase in the level of retail sales of social consumer goods will also promote the upgrading and improvement of logistics network routes, improve the accessibility of goods between regions, and refine the role and function of logistics outlets governed under each logistics node center.

(3) Administrative support. Fiscal expenditure reflects the level of local government's financial investment in urban development. The results of the geographic detector show that the *q*-statistic value of fiscal expenditure is 0.8005 and passes the test, indicating that administrative support has a certain influence on the spatial distribution of inter-city logistics links. The higher the power of local government to regulate fiscal expenditure autonomously and the higher the level of financial investment in urban logistics, the easier it is to establish frequent logistics links between that city and other cities.

(4) Degree of information technology. The postal and telecommunication business includes postal business and telecommunication business, which reflects the total achievement of postal and telecommunication business development in each city in a certain period of time and is an important

indicator to measure the development of information technology in cities. The results of the geographic detector show that the q-statistic value of total postal and telecommunication business is 0.8471, and it passes the 5% significance test. This indicates that the stratification results of the total post and telecommunications business indicators of each city are similar to the distribution of total logistics spatial links, and the level of post and telecommunications business development in each city is positively correlated with the spatial distribution of inter-city logistics links.

4. Conclusion

Analyzing inter-city logistics linkages in the Guangdong-Hong Kong-Macao Greater Bay Area is not only conducive to guiding the spatial development of urban logistics, but also to the rational organization of inter-city logistics cooperation. This paper analyzes the spatial linkage pattern of logistics industry and its driving force in Guangdong-Hong Kong-Macao Greater Bay Area using entropy-TOPSIS method, gravity model and geographic probe model, and the main research findings are as follows.

(1) The comprehensive logistics capacity and total logistics linkage of cities in Guangdong, Hong Kong and Macau region are widely different. Among them, the comprehensive logistics capacity of cities is mainly composed of the year-end number of employed workers in transportation, storage and postal industries, the density of road transportation network and the total amount of import and export. Guangzhou, Shenzhen and Hong Kong are significantly ahead of other regions in the Greater Bay Area in terms of logistics development, and the quality of logistics development in most cities is low. On the whole, the development level of logistics in Guangdong, Hong Kong and Macao is uneven, and the density of logistics network is low. The comprehensive strength of logistics in the Greater Bay Area is mainly reflected in the area around the mouth of the Pearl River, and gradually decreases along the line of "Guangzhou-Shenzhen-Hong Kong" to the east and west, and lacks depth inland and extension along the coastline.

(2) The intensity of logistics links among cities in the Guangdong-Hong Kong-Macao Greater Bay Area has obvious divergent characteristics.

On the whole, the spatial logistics links among cities are mostly weak, and the strong links are concentrated between the two points of "Hong Kong-Shenzhen", with Hong Kong, Guangzhou and Shenzhen being the three core cities of the regional logistics linkage network. The logistics linkages in the Guangdong-Hong Kong-Macao Greater Bay Area rely excessively on the gravitational role and bridging role of the core cities Guangzhou, Shenzhen and Hong Kong. Generally speaking, cities with large total spatial logistics linkages, such as Hong Kong, Guangzhou and Shenzhen, have strong comprehensive logistics strength, and these cities are more likely to become the main logistics linkage cities for neighboring cities, but the larger the total spatial logistics linkage, the stronger the comprehensive logistics strength.

(3) The main influencing factors for the differences in regional logistics spatial linkages among Guangdong, Hong Kong and Macao include local fiscal expenditure, foreign direct investment amount, logistics location entropy, resident population, and total retail sales of social consumer goods. These factors have a particularly significant driving effect on regions located in the central part of Guangdong, Hong Kong and Macau with medium or higher total logistics linkages, such as Hong Kong, Shenzhen and Guangzhou. Almost all the measured influencing factors have less significant driving effects on regions with sparse inter-city logistics linkages such as Zhaoqing, Huizhou, Jiangmen, Zhongshan, etc. The development of regional logistics industry is driven by a combination of outward force, endogenous force and administrative force, while market force has less influence on it.

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