Research on the network connection mode of logistics economy in Guangdong province based on social network analysis

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Abstract

Purpose – This paper aims to clarify the spatial connection characteristics and organization mode of logistics economy of 21 cities in Guangdong Province under the background of the integrated development of Guangdong, Hong Kong and Macao Bay area, and explore the spatial development characteristics and influencing factors of logistics economy in Guangdong Province.

Design/methodology/approach – This paper constructs the development level model of urban logistics economy in Guangdong Province from three aspects: demand level, supply level and support level, and uses the entropy weight method to measure the development level index of urban logistics economy in Guangdong Province. Then, the traffic accessibility index model is used to measure the traffic accessibility index between cities in Guangdong Province. Finally, using the social network analysis method, combined with the development level index of urban logistics economy in Guangdong Province and the urban traffic access index in Guangdong Province, this paper analyzes the spatial connection characteristics and influencing factors of logistics economy network in Guangdong Province.

Findings – There are regional differences in the development level of logistics economy in Guangdong Province; The overall network density of its logistics economic connection is large, but there is an imbalance in the network structure, and the core edge phenomenon is obvious; Logistics economic space presents the characteristics of double core development.

Research limitations/implications – Because the research object is the spatial connection characteristics of logistics economy in Guangdong Province, the research results may lack universality. Therefore, researchers are encouraged to put forward further tests.

Practical implications – By studying the spatial connection mode of logistics economy in 21 cities in Guangdong Province, China, this paper promotes the original methods and empirical contributions, and constructs the research framework of spatial relationship of logistics economy. This research framework is universal to a certain extent.

Social implications – This paper is conducive to promoting the integrated development of logistics economy in Guangdong Province and improving the balance of regional development of logistics economy.

Originality/value – Firstly, this study provides a new perspective to understand the spatial relationship and spatial spillover of logistics economy from relational data rather than attribute data. Secondly, This study enriched and broadened the research topic of spatial correlation of logistics economy. Thirdly, this research aims to promote the original methods and empirical contributions. Specifically, this study establishes a comprehensive research framework on the spatial network structure of logistics economy.

Keywords Guangdong province, Logistics economic network connection, Social network analysis

Paper type Research paper

1. Introduction

In 2019, *the layout and construction plan of national logistics hub jointly* issued by China's national development and reform commission clearly stated that the national logistics hub will cooperate with the implementation needs of major national strategies to establish and improve the modern logistics service system and improve the development level of logistics industry, Logistics industry has become a strategic industry in China's economic development and a new driving force for regional economic growth (Fan and Zhang, 2004; Mačiulis *et al.*, 2009). The logistics industry widely integrates different industries and links all sectors of society into an organic whole. Its development can not only improve the real economy, but also become an important force for the country to promote industrial optimization and upgrading and promote economic growth at this stage. Economic growth will inevitably bring about the circulation and aggregation of production factors, enhance logistics demand, promote logistics investment, drive the development of logistics industry, which builds a virtuous circle. Guangdong is located in the southeast coast and is an important logistics node of the maritime Silk Road. It is of great value to study the development of logistics industry in Guangdong Province. The development of logistics industry is also a hot research topic for scholars at home and abroad. The integrated development of logistics industry in Guangdong Province is of great significance to promote the further integrated development of its regional economy and the economic development of Guangdong, Hong Kong and Macao Bay area. In February 2019, the CPC Central Committee and the State Council issued *the outline of the development plan of Guangdong Hong Kong Macao Bay area*, which proposed to "build a networked spatial pattern led by Guangdong Hong Kong Macao Bay area and supported by poles and axes". A total of nine cities in Guangdong Province are included in the Guangdong-Hong Kong-Macao Greater Bay Area, including nine Pearl River Delta cities in Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen and Zhaoqing. According to the statistical yearbook of Guangdong Province in 2019, the permanent resident population of Guangdong Province in 2019 reached 115.21 million, with a total GDP of 10,767.107 billion yuan, of which the permanent resident population of nine cities in the Pearl River Delta was 64.469 million, with a total GDP of 8,689.905 billion yuan, accounting for 80.70% of the total GDP of Guangdong Province in that year. There is a regional imbalance in urban economic development in Guangdong Province. The added value of the secondary industry in Guangdong Province in 2019 was 4,354.643 billion yuan, of which Guangzhou and Shenzhen ranked the top two, accounting for 38.92% of the added value of the secondary industry in the region. The total value added of the primary industry is 435.126 billion yuan, of which the total value of the primary industry in Guangzhou and Shenzhen accounts for 6.35% of the total value of the primary industry in the region, which does not match the proportion of the added value of the secondary industry in the region, reflecting the spatial dislocation between the production and consumption markets of the primary industry and the secondary industry in Guangdong Province, and the flow of industrial products from core cities to marginal cities, agricultural products flow from marginal cities to core cities.

Logistics is an important link of economic integration in Guangdong Province and an important guarantee to promote the promotion of commodity circulation. The logistics economy of Guangdong Province is developing rapidly. According to the statistical yearbook

data, in 2019, the freight turnover of Guangdong Province was 2923.087 billion ton kilometers, the total freight volume was 4,460,184,300 tons, the port cargo throughput was 1,918,194,100 tons, and the number of employees in transportation, warehousing and postal industry was 1.33 million. However, the development of logistics economy in Guangdong Province is unbalanced, the development of urban logistics economy is unbalanced, and the freight turnover is 2,179.309 billion ton kilometers; The extreme difference in gross freight volume was 1,330.94 million tons and the extreme difference was 556,000 employees. In this context, it is particularly important to explore and study the spatial distribution pattern and connection characteristics of logistics economic development in Guangdong Province.

2. Literature review

The research on logistics industry mainly focuses on the impact of logistics industry on economy (Rosenstein_Rodan, 1943; Rostow, 1960; Kisperska, 1992; Joel *et al.*, 1996; Camuthers *et al.*, 2004b), Logistics plays an increasingly important role in the economic and social system. There is a positive cycle relationship between economic development and logistics development. While underdeveloped areas actively develop economy, they should also pay attention to the development of logistics economy and promote a virtuous cycle between them. For cities with high logistics level are already in a virtuous cycle of economic development and logistics scale, we need to focus on improving logistics efficiency and promoting the improvement of comprehensive economic strength. The agglomeration and spatial layout of logistics industry affect the development and distribution of economy and manufacturing industry. Therefore, the spatial distribution and network structure of logistics economy have become the focus of scholars. The impact of logistics industry agglomeration on regional economy (van den Heuvel *et al.*, 2013; Mori and Nishikimi, 2002; Chhetri *et al.*, 2014; Rivera *et al.*, 2014, 2016; Kayikci, 2010; Sheffi, 2012), logistics warehouse location and path optimization (Cheng *et al.*, 2021; Liu and Ying, 2020; Shahparvari *et al.*, 2020; Ferhat Candas and Kutanoglu, 2020; Alptekin *et al.*, 2020; Zhang *et al.*, 2021; Chen *et al.*, 2021), and the research subject gradually changes from macro to individual. In addition to qualitative research, scholars also conduct research through various quantitative methods, mainly including vector autocorrelation and Granger causality test (Taniguchi and Van Der, 2000; Basatab, 2001; Hong – Oanh and Jose, 2010), DECD model (Skjott – Larsen *et al.*, 2003; Camuthers *et al.*, 2004a), time series (Mohammad, 2013; Sultan and Emrah, 2014), production function (Coto-Millán *et al.*, 2014) and spatial econometric model (Kumar *et al.*, 2017; Peter and Catherine, 2018; Bai *et al.*, 2022; He *et al.*, 2019). The early research on logistics mainly focused on the relationship between logistics and economy. Rosenstein Rodan believes that logistics is an important infrastructure. Infrastructure is a prerequisite for social and economic development and should be given priority (Rosenstein_Rodan, 1943; Rostow, 1960), Scholars in transitional Poland found that logistics development played an important catalytic role in Polish economic development (Kisperska, 1992), Joel Honeyman *et al.* found that logistics can promote rural economic development (Joel *et al.*, 1996). Through the research on the relationship between logistics and economic development in Hong Kong and Singapore, it is found that increasing logistics investment can not only improve logistics efficiency, but also promote economic development (Camuthers *et al.*, 2004b).

With the development of logistics industry, industrial agglomeration appears. The impact of logistics agglomeration on regional economy has become the focus of scholars' research, it is found that with the development of economic agglomeration (van den Heuvel *et al.*, 2013; Mori and Nishikimi, 2002), local government support, external economies of scale and regional agglomeration of logistics services, the logistics industry presents agglomeration (Chhetri *et al.*, 2014), a study on the US logistics industry found that the spatial agglomeration of the logistics industry showed an upward trend, the social logistics cost has been continuously reduced, the service level and response speed of the logistics industry have been improved (Rivera *et al.*,

2014), and the agglomeration of the logistics industry has improved the operation efficiency of the logistics industry (Rivera *et al.*, 2016). Logistics industry agglomeration promotes regional economic development by strengthening the transformation efficiency of different logistics transportation modes and improving the linkage of multimodal transportation, strengthening inter regional business activities (Kayikci, 2010; Sheffi, 2012).

With the development of data economy, the research of logistics industry has gradually shifted from the macro perspective to the micro perspective, Logistics enterprise location and route optimization have become the focus of international scholars, Scholars optimize the location of complex logistics system through platform data and geographic information system (Cheng *et al.*, 2021), Liu Peide *et al.* explore a multi-attribute decision-making method for the location of integrated logistics distribution center by using two-dimensional language (Liu and Ying, 2020), Shahrooz shahparvari *et al.* proposed a GIS-LP integration method for logistics hub location (Shahparvari *et al.*, 2020), every customer needs a certain level of service based on response time, scholars introduced a nonlinear mixed integer optimization model to optimize inventory (Ferhat Candas and Kutanoglu, 2020), scholars also selected logistics center location based on fuzzy SWARA and CoCoSo methods (Alptekin *et al.*, 2020), Chinese scholars try different solutions for cold chain warehouse location and logistics optimization on the premise of low carbon emission (Zhang *et al.*, 2021; Chen *et al.*, 2021).

Scholars also use various quantitative research methods to study the development of logistics industry, Taniguchi and Van Der (2000), Basatab (2001), Hong – Oanh and Jose (2010) and others used vector autocorrelation and Granger causality test, Skjott – Larsen *et al.* (2003) and Camuthers *et al.* (2004a) used DECD model and input-output method to empirically analyze the relationship between logistics industry and regional economy, this paper demonstrates the pulling effect of logistics industry on regional economic development. Mohammad (2013), Sultan and Emrah (2014) respectively studied the Granger causality between the logistics industry and regional economic development in Indonesia and Turkey by using the time series data of GDP and freight volume. Pablo C and others used the production function proposed by Mankiw, combined with the panel data of 34 countries from 2007 to 2012, and used the stochastic frontier analysis method to study the impact of logistics industry and information technology on the technical efficiency of world output (Coto-Millán *et al.*, 2014). Kumar *et al.* studied the marginal contribution of logistics industry agglomeration to US regional economic growth by using spatial econometric model. The results show that logistics industry agglomeration has a positive impact on US regional economic growth and employment promotion (Kumar *et al.*, 2017). Peter and Catherine further demonstrated the two-way synergistic growth relationship between logistics industry agglomeration and regional economic growth by increasing the accuracy of spatial measurement (Peter and Catherine, 2018). Bai, Dongling made a spatial analysis of China's logistics ecological efficiency and its influencing factors based on super SBM undesirable and spatial Dobbin model (Bai *et al.*, 2022). Meiling he used panel data to study the temporal and spatial evolution of logistics enterprises in the Yangtze River Delta and found that logistics enterprises gradually transferred from the urban center to the suburbs (He *et al.*, 2019).

To sum up, the existing literature focuses on the impact of logistics industry on economy, the impact of logistics industry agglomeration on regional economy, and the optimization scheme of logistics warehousing. Quantitative research also focuses on efficiency research and spatial structure research, but lacks the analysis of logistics industry network structure in different cities. With the development of regional integration and logistics economy, logistics talents, technology, capital and other production factors flow among regions and the spatial connection of logistics economy in different regions is closer (van den Heuvel *et al.*, 2013; Mori and Nishikimi, 2002; Chhetri *et al.*, 2014; Rivera *et al.*, 2014; Rivera *et al.*, 2016; Kayikci, 2010; Sheffi, 2012). The research on the spatial relationship model between urban logistics economy has practical significance. In recent years, social network analysis method has been widely used in various research fields (Adam and Jaffe, 2002; Beni and Sheikh-El-Eslami, 2021; Abdul Jalil and

Abdul Rasam, 2021; Diego *et al.*, 2021). It is feasible to explore the spatial network structure mode
of logistics economy by using relational data. Scholars mostly explore the temporal and spatial
evolution characteristics of logistics economic development from the perspective of attribute
data (Chhetri *et al.*, 2014; Peter and Catherine, 2018; Bai *et al.*, 2022; He *et al.*, 2019). However,
scholars failed to pay enough attention to the spatial network structure of logistics economy
based on spatial relationship data. In particular, there are few studies on the role of logistics
economy in the spatial network structure of Guangdong Province, a major economic province in
China. In order to fill this gap, this study takes the logistics economy of 21 cities in Guangdong
Province as the research object to explore the spatial network structure characteristics of
logistics economy. This study is one of the earliest studies to explore the spatial network
structure of urban logistics economy. Our research has made three contributions to the existing
research on logistics economic space. Firstly, this study provides a new perspective for us to
understand the spatial connection and spatial spillover of logistics economy from relational data
rather than attribute data. Secondly, the previous literature mainly focused on the evaluation of
the development level of logistics economy, while this study enriched and broadened the
research topic of spatial correlation of logistics economy. Thirdly, our research aims to promote
the original methods and empirical contributions. Specifically, this study establishes a
comprehensive research framework on the spatial network structure of logistics economy.
Although the example is limited to 21 cities in Guangdong Province, China, this research
framework is universal to a certain extent.

3. Research method
3.1 Analysis method of spatial connection strength of logistics economy
3.1.1 Gravity model. The measurement of economic spatial connection is the main content of
economic spatial structure research. This paper intends to analyze the spatial structure of
logistics economy in Guangdong Province through the method of spatial connection analysis.
The traditional gravity model is mainly used in the fields of geographical distance attenuation
and spatial interaction. It is a common model for spatial structure analysis. With the continuous
improvement of modern transportation network and the changes of various factors affecting the
development of logistics economy, the original gravity model is difficult to accurately and
objectively measure the logistics economic relationship between cities from the perspective of
distance attenuation. In this paper, the time dimension is introduced to construct the logistics
traffic accessibility index (such as 3.1.4), and the gravity model is modified (Wang and Li, 2020).
The modified gravity model formula is shown in formula (1).

$$I_{ij} = G \frac{M_i M_j}{D_{ij}^b} \tag{1}$$

where, I_{ij} is the logistics economic connection strength between city i and city j, M_i is the
regional logistics economic development quality of city i, M_j is the regional logistics economic
development quality of city j, $M_i M_j$ is the score of logistics economic development level, and
D_{ij} is the logistics traffic accessibility index between city I and city J; b is distance friction
coefficient, value 2; G is the gravitational constant, value 1.

 3.1.2 Entropy weight method. Entropy weight method can make objective assignment to the
index and avoid the randomness of subjective assignment. The entropy weight method needs to
set the index matrix ($i = 1,2,3, \ldots m, j = 1,2,3, \ldots n$). Assuming that the data have m items to be
evaluated and N evaluation indicators, the data can be represented by an n × m matrix A (n
rows and m columns, that is, there are n rows of records and M characteristic columns). The
stronger the data dispersion in the matrix, the more information provided, the smaller the
information entropy, the greater the weight of the index, and the greater the impact on the
comprehensive evaluation; on the contrary, the weaker the data dispersion, the less information

provided, the greater the information entropy, the smaller the weight of the index, and the smaller the impact on the comprehensive evaluation. Entropy weight method is widely used in the evaluation of logistics development level (Tang, 2019; Dang, 2020). Therefore, this paper uses entropy weight method to evaluate the development level of urban logistics economy.

Computational procedure:

(1) Data standardization $A = [a_{ij}]n \times m$:

$$X_{ij} = \frac{a_{ij} - min\{a_{ij}\}}{max\{a_{ij}\} - min\{a_{ij}\}}$$

(2)

(2) Calculate the proportion of index j in year i:

$$p_{ij} = \frac{X_{ij}}{\sum\limits_{i=1}^{m} X_{ij}}$$

(3)

(3) Calculate the entropy of the j-th index e_j, and the formula is as follows:

$$e_j = -\frac{1}{lnm} \sum\limits_{i=1}^{m} (p_{ij}lnp_{ij}), \; e_j = [0,1]$$

(4)

(4) Calculate the difference coefficient g_i, and the formula is as follows:

$$g_i = 1 - e_j$$

(5)

(5) Calculate the index weight of item j:

$$w_j = \frac{g_i}{\sum\limits_{j=1}^{m} g_i}$$

(6)

(6) Calculate the comprehensive score of each sample D_i, the logistics economic development level of 21 cities in Guangdong Province is calculated by entropy method, D_i shows the logistics economic development level of 21 cities in Guangdong Province:

$$D_i = \sum\limits_{j=1}^{m} w_j \times p_{ij}, \; i = 1, 2, \ldots, n$$

(7)

3.1.3 Min-Max data normalization method. The original value of the comprehensive score of logistics economic development level of 21 cities in Guangdong Province is calculated by entropy weight method. In order to facilitate the comparison of the development level of logistics economy, the Min-Max data standardization method is used to standardize the original data. Min-Max data normalization method is to project the original data to the specified space [min, Max]. Generally, the original data are transformed to [0,10]. The purpose of selecting the value of [0,10] is to make the normalized data fall in the range of 0–10. The data normalization formula is shown in equation (8):

$$V' = \frac{(new\,maxA - new\,min\,A)}{(maxA - minA)} * (V - minA) + 1$$

(8)

where, V 'represents the data after normalization processing, V represents the original data, maxA and minA represent the maximum and minimum values of the original data column respectively, and represent the maximum and minimum values of the data transformation normalization interval respectively.

3.1.4 Traffic accessibility index model. The traffic accessibility index model is used to calculate the logistics traffic accessibility index between city i and city j D_{ij} (Ge *et al.*, 2021; Li *et al.*, 2019). Traffic accessibility is an index to measure the difficulty of moving between network points, which can be measured by accessibility index. The lower the traffic accessibility index, the better the accessibility.

$$D_{ij} = \frac{1}{2}\left[\frac{T_{ij}}{\sum T_i/n} + \frac{T_{ij}}{\sum T_j/n}\right]$$ (9)

Among them, D_{ij} represents the traffic accessibility index between city i and city j, the higher the traffic accessibility index, the better the accessibility; T_{ij} represents the shortest traffic time between city i and city j, and $\sum T_i/n$, $\sum T_j/n$ represents the average time in the shortest traffic mileage between city i, j and other n cities. To sum up, this paper will calculate the spatial connection strength of logistics economy in Guangdong Province on the basis of the self variable of urban logistics economic development level (Mi), the spatial connection variable between cities (D_{ij}), and take it as the basis for the analysis of the spatial connection mode of logistics economy.

3.2 Social network analysis method

Based on the analysis of the spatial connection strength of logistics economy, this paper will use the social network analysis method to explore the spatial connection mode of logistics economy. Social network analysis method is an analysis method to describe the overall form of network and the characteristics of organizational relationship (Bai *et al.*, 2020; Zhang *et al.*, 2020; Liang and Ben DerudderLiu, 2018), this paper mainly analyzes the network density, network centrality and core edge structure, and shows the overall form, structure and characteristics of the spatial connection network of logistics economy in Guangdong Province (Borgatti and Everett, 2000).

(1) Network density analysis

Network density mainly measures the density of logistics links between cities. The greater the density, the closer the links. The calculation formula is shown in equation (10).

$$D = \sum_{i=1}^{k}\sum_{j=1}^{k}d(n_i, n_j)\bigg/ k(k-1)$$ (10)

D is the network density and K is the number of node cities. The greater the value of D, the more connections between nodes. When D = 1, there is a connection between network nodes. When D = 0, there is no connection between nodes.

(2) Network centrality analysis

Network centrality analysis is a quantitative analysis of the subject's power in the network from the perspective of relationship, mainly including point centrality, proximity centrality and intermediary centrality. The specific calculation formula is shown in formula (11-13).

- *Point degree centrality.* Point degree centrality measures the number of nodes directly connected to a logistics node in the network, reflecting the close communication ability

between the node and other nodes in the network and the degree of participation in the network relationship.

$$C_{Di} = \sum_{i=1}^{I} r_{ij} \qquad (11)$$

C_{Di} represents the centrality of representative points; I represents the number of other nodes associated with node i; r_{ij} represents the actual number of contacts.

- *Intermediary centrality*. Intermediary centrality measures the number of times a node in the network is at the shortcut distance between other nodes, reflecting the node's control ability over other nodes and the degree of being in the "middle" of the logistics economic transmission path of other nodes.

$$C_{Bi} = \sum_{i}^{I} \sum_{K}^{I} g_{jk}(i) \Big/ g_{jk} \qquad (12)$$

$i \neq j \neq k$ and $j < k$, C_{Bi} represents intermediary centrality; g_{jk} represents the number of shortcuts between j and k. $g_{jk}(i)$ represents the number of shortcuts between j and k that can only be connected through node i.

- *Near centrality*. Proximity centrality measures the shortcut distance between a node and other nodes (the number of lines included in the shortcut), which reflects the tightness of the connection between the logistics node and other logistics nodes and the degree that it is not controlled by others in the network.

$$C_{Ci} = 1 \Big/ \sum_{j=1}^{I} d_{ij} \qquad (13)$$

C_{Ci} Represents near centrality, d_{ij} epresents the shortcut distance between i/j two points.

(3) Edge core structure analysis

The analysis of marginal core structure is to distinguish a series of actors with high density, namely, the core city of logistics economy, and a series of actors with low density, namely, the marginal city of logistics economy. The exchange relationship between the core city and the marginal city is in an advantageous position, on the contrary, the marginal city is in a disadvantageous position.

4. Construction of index system and data source
4.1 Construction of index system
According to the principles of integrity, authenticity, reliability and comparability, this paper constructs the development level model of urban logistics economy in Guangdong Province from the three aspects of demand level, supply level and support level, and selects the five indicators with the strongest correlation with the development level of logistics economy, as shown in Table 1.

4.2 Data sources
The data are obtained from the 2019 Guangdong Provincial Statistical Yearbook and the 2019 Statistical Yearbook of 21 cities in Guangdong Province.

5. Empirical study on the spatial relationship of logistics economy in Guangdong province

5.1 Analysis on the development level of urban logistics economy in Guangdong province

Using the entropy weight method, the original value of the comprehensive score of urban logistics economic development level (M) in Guangdong Province is calculated according to equations (2)–(7). In order to facilitate the comparison between data, min max data normalization method is adopted. According to equation (8), the comprehensive score standard value of logistics economic development level is obtained. As shown in Table 2 below, the comprehensive scores and ranking of logistics economic development level of 21 cities in Guangdong Province are as follows:

There is a big gap in the scores of logistics economic development among cities in Guangdong Province, and the level of logistics development is extremely unbalanced. As shown in Table 2, Guangzhou is the city with the highest level of logistics economic development in Guangdong Province, and the standard value of comprehensive score is 10 points, followed by Shenzhen with a score of 3.366, and Jieyang with the lowest comprehensive score of 1. From the original value of the comprehensive score of logistics economic development, the initial score of Guangzhou is 0.9720, which is the city with the highest level of logistics economic development in Guangdong Province. The difference between Guangzhou with the highest initial score and Jieyang with the lowest initial score is

Target layer	Code layer	Measures layer	Variable (unit)
Urban logistics and economic evaluation index	Demand level	Total freight	Ten thousand tons (X1)
		turnover of freight traffic	One hundred million ton km (X2)
	Supply level	railway track in use	kilometre (X3)
		Transportation, warehousing and postal industry practitioners	thousands of people (X4)
		Fixed asset investment in the transportation, warehousing and postal industries	100 million (X5)

Table 1.
Urban logistics economy evaluating indicator

City/Score	Initial score (original value)	After the transformation score	Sort	City/Score	Initial score (original value)	After the transformation score	Sort
Guangzhou	0.9720	(standard value)	1	Jiangmen	0.0597	(standard value)	12
Shenzhen	0.2683	10.000	2	Zhongshan	0.0590	1.400	13
Zhanjiang	0.1035	3.366	3	Heyuan	0.0572	1.393	14
Foshan	0.0972	1.813	4	Shantou	0.0496	1.376	15
Huizhou	0.0884	1.753	5	Zhaoqing	0.0451	1.304	16
Qingyuan City	0.0862	1.670	6	Yangjiang	0.0434	1.262	17
Shaoguan	0.0825	1.650	7	Zhuhai	0.0373	1.246	18
Maoming	0.0769	1.615	8	Shanwei	0.0258	1.189	19
Meizhou	0.0761	1.562	9	Chaozhou	0.0185	1.080	20
Dongguan	0.0675	1.554	10	Jieyang	0.0173	1.011	21
Yunfu	0.0648	1.473	11	/	/	1.000	/

Table 2.
Comprehensive score of logistics and economic development level in 21 cities of Guangdong province

0.9547, which is extremely large. The initial scores of Guangzhou, Shenzhen and Zhanjiang are greater than 0.1, which are 0.9720, 0.2683 and 0.1037 respectively. The logistics economic development level of these three cities is significantly higher than the average level of logistics economic development of Guangdong Province, which is 0.1141. The initial scores of the other 17 cities are less than 0.1, indicating that the logistics economic development level of these cities is far lower than the average level of the whole province.

5.2 Traffic accessibility index of cities in Guangdong province

The spatial characteristics of logistics economic development are directly related to the traffic accessibility between cities. Cities with low traffic accessibility index are conducive to the mobility of science and technology, while cities with high traffic accessibility are not conducive to the mobility of science and technology.

Due to the rapid development of modern transportation technology, the shortest traffic distance between two cities should consider travel modes such as high-speed rail, bullet train and aviation. The shortest traffic time data used in this paper is the traffic time data between cities obtained by querying the published train timetable and long-distance bus timetable between two cities. If there is a direct train between two cities, the shortest train running time on the official timetable shall be selected as the original data. If there is no direct train, the shortest driving time between the two cities in Baidu map is taken as the standard. The query time is June 25, 2021. The traffic accessibility index of each city in Guangdong Province is calculated according to equation (9), as shown in Table 3.

5.3 Guangdong logistics economic network connection strength

According to the data in Table 2 and Table 3, combined with the gravity model, the logistics economic network connection model of Guangdong Province is constructed. According to formula (1) the gravity model formula of logistics economic development, the total logistics economic spatial network connection strength of cities in Guangdong Province is calculated, and the results are shown in Table 4.

There are regional differences in the spatial network of logistics economy in 21 cities in Guangdong Province. The top five cities in the total number of logistics economic spatial network connections of 21 cities in Guangdong Province are Guangzhou, Shenzhen, Dongguan, Foshan and Zhongshan. The total amount of logistics economic spatial network connections in these five cities accounts for 55.530% of the total value of logistics economic spatial network connections in Guangdong Province, exceeding 50% of the cumulative total. It shows that the above cities are relatively concentrated areas of logistics economic spatial network in

City	Traffic accessibility index	Sort	City	Traffic accessibility	Sort
Guangzhou	14.921	1	Huizhou	19.692	12
Dongguan	15.221	2	Shaoguan	20.248	13
Shenzhen	16.168	3	Yunfu	21.144	14
Zhongshan	16.287	4	Heyuan	21.482	15
Foshan	17.168	5	Shantou	22.115	16
Jiangmen	17.601	6	Jieyang	23.916	17
Qingyuan	18.276	7	Maoming	24.346	18
Zhuhai	18.556	8	Zhanjiang	24.918	19
Shanwei	18.839	9	Meizhou	26.819	20
Yangjiang	19.228	10	Chaozhou	27.109	21
Zhaoqing	19.598	11	/	/	/

Table 3.
Urban transportation access index of Guangdong province

City	Logistics economic space network总联系量	Occupied proportion	Sort	Cumulative percentage	City	Logistics economic space network总联系量	Occupied proportion %	Sort	Cumulative percentage
Guangzhou	128.988	29.201	1	29.201	Yunfu	13.007	2.894	12	79.952
Shenzhen	48.467	10.972	2	40.174	Zhaoqing	12.783	2.693	13	82.846
Dongguan	24.620	5.574%	3	45.747	Shanwei	11.895	2.619	14	85.539
Foshan	22.849	5.173%	4	50.920	Heyuan	11.567	2.535	15	88.157
Zhongshan	20.362	4.610%	5	55.530	Zhanjiang	11.196	2.347	16	90.692
Qingyuan	19.021	4.306%	6	59.836	Shantou	10.365	2.303	17	93.038
Jiangmen	17.515	3.965%	7	63.801	Maoming	10.172	1.889	18	95.341
Huizhou	16.581	3.754%	8	67.555	Meizhou	8.344	1.550	19	97.230
Shaoguan	15.182	3.437%	9	70.992	Jieyang	6.847	1.220	20	98.780
Zhuhai	13.454	3.046%	10	74.038	Chaozhou	5.388	2.894	21	100.000
Yangjiang	13.117	2.970%	11	77.007	/	/	/	/	/

Table 4.
Total strength of
logistics economic
spatial network of
cities in Guangdong
province

Guangdong Province. Combined with geographical distribution, Guangzhou, Shenzhen and Dongguan are located in the traffic fortress of Guangdong Province. At the same time, they have a broad consumer market, a solid economic foundation and better basic conditions for the development of logistics economy. Therefore, their external relations of logistics economy have obvious regional advantages. The connection value of Guangzhou logistics economic network is 128.988, accounting for 29.201%, ranking first in the list. Except for the top four cities, the total number of logistics economic network connections in other cities in Guangdong Province is less than 5%, indicating that there are huge regional differences in logistics economic network connections in Guangdong Province. There is a gap in the combination of logistics economic network connection strength between cities in the region and other cities. The logistics economic network connection in Guangdong Province is mainly concentrated between Guangzhou and Shenzhen. The specific connection strength is as follows: Guangzhou Shenzhen (15.120), Shenzhen Guangzhou (12.877), Guangzhou Zhanjiang (8.142) and Guangzhou Qingyuan (7.409). There are 441 spatial connection combinations of logistics economy in 21 cities of Guangdong Province, of which 361 connection combinations are less than 1, indicating that the connection degree of logistics economic network between cities is low.

5.4 Spatial connection of logistics economy in 21 cities in Guangdong province
5.4.1 Establishment of network model. According to the strength value of spatial connection of logistics economic development among 21 cities in Guangdong Province, taking 21 cities in Guangdong Province as network nodes, the original matrix is binarized by using social network analysis method and UCINET software. In total, there are 441 connection values, and 220 values greater than 0.483. According to the 50% principle, the selected breakpoint value is 0.483, the value greater than the breakpoint value is assigned as 1, and the value not exceeding the breakpoint value is assigned as 0 to obtain a new bisection matrix, as shown in Table 5.

| | Point centrality | | Near centrality | | |
City	Point out degree	Point entry degree	Point out degree	Point entry degree	Intermediary centrality
Guangzhou	20	20	100.0	100.0	92.027
Shenzhen	20	19	100.0	95.2	73.027
Foshan	20	13	100.0	74.1	19.527
Dongguan	20	8	100.0	62.5	3.211
Zhongshan	19	8	95.2	62.5	1.961
Qingyuan	18	12	90.9	71.4	9.477
Jiangmen	17	8	87.0	62.5	0.661
Huizhou	16	12	83.3	71.4	6.942
Shaoguan	13	11	74.1	69.0	3.167
Zhuhai	9	7	64.5	60.6	0
Zhaoqing	7	8	60.6	62.5	0
Yangjiang	7	8	60.6	62.5	0
Yunfu	6	9	58.8	64.5	0
Shanwei	4	6	55.6	58.8	0
Heyuan	3	9	54.1	64.5	0
Zhanjiang	2	15	52.6	80	0
Maoming	2	10	52.6	66.7	0
Meizhou	2	10	52.6	66.7	0
Shantou	2	8	52.6	62.5	0
Jieyang	2	4	52.6	55	0
Chaozhou	1	5	51.3	57.1	0

Table 5.
Contact center of logistics economic network of Guangdong province

Combined with the drawing tool Netdraw of UCINET, the logistics economic spatial network connection structure of 21 cities in Guangdong Province is drawn, as shown in Figure 1.

The number of connections between nodes accounts for more than 0.502% of the maximum possible total connections, and the standard deviation is 0.499, which can explain the overall characteristics of the network. As can be seen from Figure 1, the regions with close logistics economic network in Guangdong Province are mainly concentrated in the Pearl River Delta, covering Guangzhou, Shenzhen, Dongguan, Foshan, Zhuhai, Zhongshan, Jiangmen, Qingyuan and Huizhou. The logistics and economic network between the northern mountainous areas, eastern wing and western wing urban agglomeration of Guangdong Province is generally close.

5.4.2 Analysis on the connection structure characteristics of logistics economic network in Guangdong province.

(1) Network density analysis

Network density compares the total number of actual relationships with the total number of theoretical relationships in the network to judge the tightness of the overall network relationship. According to equation (10), calculate the network density value of the logistics economic network connection in Guangdong Province. The theoretical value of the maximum network connection number composed of 21 nodes is 421. In the binary network matrix, the actual connection number is 220, the overall network density is 0.502, and the standard deviation is 0.499, reflecting that the logistics economic connection among the urban nodes in the logistics economic network in Guangdong Province is relatively close, However, there is a certain gap in the tightness of logistics economic network in different metropolitan areas.

(2) Network centrality analysis

According to equations (11–13), calculate the point centrality, intermediary centrality and proximity centrality of logistics economic network in Guangdong Province. The results are shown in Table 6.

• Point centrality

As shown in Table 5, from the point out degree, the point out degrees of Guangzhou, Shenzhen, Foshan and Dongguan are all 20, which are the core cities in the logistics economic
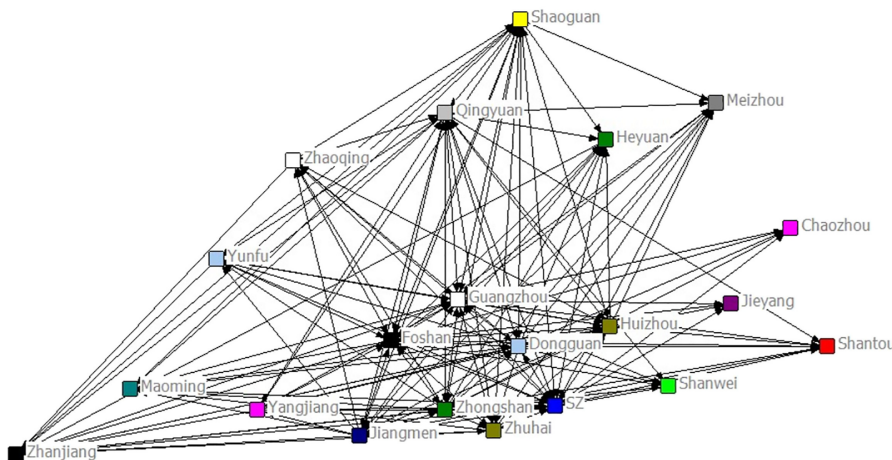

Figure 1.
Spatial network
structure of logistics
economy in 21 cities of
Guangdong province

network of Guangdong Province. The sum of the point out degree of the logistics economic network connection of the four cities accounts for 50% of the total point out degree of the logistics economic network connection in Guangdong Province, which has a great impact on the spatial radiation function of the logistics economy of other cities in Guangdong Province. The point out degree of Zhanjiang, Maoming, Meizhou, Shantou and Jieyang is 2, and the point out degree of Chaozhou is 1. Its logistics economic development level is low, it is far from the transportation core city, and its radiation ability to the logistics economy of other cities is weak.

From the perspective of point entry, the point entry of the point centrality of the logistics economic network of nine cities in Guangzhou, Shenzhen, Foshan, Qingyuan, Huizhou, Shaoguan, Zhanjiang, Maoming and Meizhou is greater than 10, which reflects their strong logistics absorption ability and can actively establish logistics economic development ties with other cities in Guangdong Province to promote the integration and utilization of logistics economic resources in the province. The point degree of logistics economic connection, the point in degree of centrality and the point out degree of Guangzhou are equal to 20, ranking first in the list, indicating that Guangzhou's logistics economy has equal absorption and radiation in the logistics economic network of Guangdong Province, and is the strongest pole of logistics economic development in the region. Shenzhen, Foshan, Dongguan, Zhongshan, Qingyuan, Jiangmen, Huizhou, Shaoguan and Zhuhai have a point degree of logistics economic connection, and the point in degree of centrality is lower than the point out degree, indicating that their logistics attraction to surrounding cities is lower than the radiation. Zhaoqing, Yangjiang, Yunfu, Shanwei, Heyuan, Zhanjiang, Maoming, Meizhou, Shantou, Jieyang and Chaozhou are on the contrary. The point in degree of point centrality is higher than point out degree, and the inflow of logistics economy is higher than outflow. Among them, the gap between point in and point out in Zhanjiang, Maoming and Meizhou ranks among the top three, 13, eight and eight respectively, indicating that their logistics absorption is greater than logistics radiation.

- Near centrality

Proximity to centrality refers to the sum of the shortest distances from a node to other nodes. The closer it is to centrality, the more the logistics economic development level of the node city is in the core position in the logistics economic network connection, indicating that the logistics economic development of the node city is not controlled by the logistics economic development of other node cities. As shown in Table 6, the average outgoing degree of the close to center point of the logistics economic network in Guangdong Province is 71.38, the standard deviation is 19.71, the average incoming degree of the close to center point is 68.10, and the standard deviation is 11.41, reflecting the strong overall accessibility, convenient transportation and close connection of the urban logistics economic network in Guangdong Province. The point out degree of the logistics economy in Guangzhou is 100, indicating that it occupies a core position in the logistics economic connection network of Guangdong Province

| | | | Density matrix | |
| | | | Core area | Core area |
Core edge structure	Node city			
Core area	Guangzhou, Shenzhen, Dongguan, Foshan, Zhongshan, Huizhou, Jiangmen, Shaoguan, Qingyuan		1.000	0.843
Core area	Shantou, Zhaoqing, Yangjiang, Zhanjiang, Zhuhai, Meizhou, Yunfu, Jieyang, Chaozhou, Heyuan, Maoming, Shanwei		0.361	0.061

Table 6.
The core-edge structure of Guangdong provincial logistics and economic contact network

and has the ability to control the development of logistics economy in other cities. Zhanjiang, Maoming, Meizhou, Shantou, Jieyang and Chaozhou are relatively small in point out and point in close to the center, and their logistics economic development is less independent, which is easy to be affected by the logistics economic development of other cities.

- Intermediary center degree

Intermediary centrality measures the extent, to which a point is located in the "intermediary" role of other points in the logistics economic network. The degree of logistics economic network connection intermediary Center represents the degree of centralized control of logistics economic network resources in the region by the logistics economic development of a node city. The higher the degree of logistics economic network intermediary center of a city, it shows that the city has rich logistics economic resources and plays the role of intermediary center in logistics economic development and logistics economic circulation.

As shown in Table 5, the average value of the intermediary centrality of the logistics economic network in Guangdong Province is 10, and the standard deviation is 24.148. The intermediary centrality of the logistics economic network in some cities is 0. Among the 21 cities in Guangdong Province, only 9 cities such as Guangzhou, Shenzhen, Foshan, Dongguan, Zhongshan, Qingyuan, Jiangmen, Huizhou and Shaoguan play the role of the intermediary of the logistics economic network in Guangdong Province. There is a wide gap in the intermediary role of the above nine cities as intermediary nodes. As an urban logistics economic network in Guangdong Province, Guangzhou has a maximum intermediary centrality of 92.072, followed by Shenzhen, with an intermediary centrality of 73.027, The third is that the intermediary centrality of the logistics economic network connection in Foshan is 19.527. The intermediary centrality of the logistics economic network connection in 12 of the 21 cities is the minimum value of 0 and the range is 92.072, reflecting that some nodes in the overall network of the logistics economic network connection in Guangdong Province are isolated. The intermediary centrality value of logistics economic network connection in Guangzhou, Shenzhen and Foshan is greater than the average value. It plays an important intermediary role in the whole logistics economic network connection in Guangdong Province. It is an important intermediary hub for the logistics economic development of other node cities and has strong control over the logistics economic development of other cities.

(3) Core edge structure analysis

Analyze the core edge structure, and clarify the structural position of node cities in the logistics economic network of Guangdong Province; Clear the core area and the edge area; Clarify the internal relationship between the core area and the marginal area. The core area refers to the node city with high connection density in the logistics economic network structure of Guangdong Province, good location advantages, logistics development infrastructure and good economic foundation. The edge area refers to the node city's low density in the logistics economic development network, with the characteristics of low logistics economic development level, remote location and low traffic accessibility in the distribution of the overall spatial network. The core area of logistics economic development has pulling effect and spillover effect on the marginal area of logistics economic development.

As shown in Table 6, the core areas of Guangdong's logistics economic network are mainly concentrated among the core circles of the Pearl River Delta, including Guangzhou, Shenzhen, Dongguan, Foshan, Zhongshan, Huizhou and Jiangmen. In addition, Shaoguan and Qingyuan are also the core areas of Guangdong's logistics economic network as the main traffic fortresses connecting the north out of the province. There are obvious structural stratification in the logistics economic connection network of Guangdong Province.

The remaining 12 cities Shantou, Zhaoqing, Yangjiang, Zhanjiang, Zhuhai, Meizhou, Yunfu, Jieyang, Chaozhou, Heyuan, Maoming and Shanwei are located at the core area of the logistics economic connection network of Guangdong Province. The density matrix shows that the internal tightness of the core area is 1 and the internal tightness of the core area is 0.061, indicating that the urban logistics economic network between the core areas is closely connected. The logistics economy of the nine cities in the core area of the logistics economic network of Guangdong province promotes each other and develops together, gradually forming a logistics economic development community with Guangdong and Shenzhen as the core. The logistics economic network connection value between the core area and the core area is 0.843, indicating that the cities in the core area of the logistics economic network have a large spillover effect on the cities in the core area. The connection degree between cities in marginal areas can be ignored, and its value is 0.061. The connection degree between the edge area and the core area is 0.361, indicating that the connection degree of logistics economy between the edge area and the core area is general.

6. Conclusions and countermeasures

6.1 The conclusion

This paper takes 21 cities in Guangdong province as the research object, uses the modified gravity model to calculate the logistics economic connection between these cities, explores the network structure characteristics of logistics economic connection between 21 cities in Guangdong Province. Analyzing the spatial organization mode of logistics economy in Guangdong Province based on this, and draws the following empirical conclusions:

Firstly, the development level of logistics economy in Guangdong province has the unbalanced distribution of regional development. Guangzhou, Shenzhen, Zhanjiang, Foshan and Huizhou have prominent advantages in logistics economy, highlighting their characteristics of logistics economy highland in the regional network. In the other 16 cities, the level of logistics economy is relatively low due to the influence of location and the constraint on economic development foundation. The development level of logistics economy in Guangdong province presents the characteristics of double core development, The two cities of Guangzhou and Shenzhen are the poles of logistics economic growth, and radiate along the Pearl River and the Beijing-Guangzhou and Beijing-Kowloon railways.

Secondly, the overall network density of logistics economic ties in Guangdong Province is large, but the links in the network structure are unbalanced, and the core edge phenomenon is obvious. With a broad consumer market and strong manufacturing strength, Guangzhou is the core city of the development of logistics economy in Guangdong Province, and is in the core leading position in the whole logistics economic network. With strong comprehensive strength in logistics economy, Shenzhen and Foshan have become sub core cities in Guangdong Province with strong radiation ability in logistics economy and the ability to drive the development of logistics economy in surrounding cities. Dongguan, Qingyuan, Zhongshan, Huizhou, Shaoguan and Jiangmen are at the upper middle level in terms of comprehensive strength of logistics economy and are important logistics economic cities. The other 12 cities have a low level of logistics economic centrality, which is marginalized in the network.

Thirdly, the spatial organization form of logistics economy in Guangdong Province presents the characteristics of double core development. Guangzhou has the highest position in the regional logistics economic network and is the core logistics city, followed by Shenzhen and Foshan, corresponding to the sub core logistics city. The three cities together constitute the central growth pole of logistics economic development in Guangdong Province, forming the logistics economic growth pole of Guangdong Province with Guangzhou Foshan and Guangzhou Shenzhen metropolitan area as the dual core. Other marginal logistics cities, with

relatively low network location, are connected in series along the Pearl River waterway, railway and expressway, forming a stable trend of integrated development of logistics economic network.

6.2 Development countermeasures
First, give play to the leading role of core cities and promote the overall logistics economic level of Guangdong Province. Accelerate the integrated development of logistics in Guangdong Province, actively expand the logistics economic radiation effect of central cities on surrounding cities and reduce regional differentiation. With Guangzhou, Shenzhen and Foshan as the centers, promote the integrated development of regional logistics, realize the coordinated development of regional logistics, promote the integrated development of logistics between central cities and surrounding cities, promote the construction of unified development standards of logistics market, the integrated and efficient construction of infrastructure, enhance the comprehensive logistics economic capacity and radiation driving role of metropolitan areas and comprehensively improve the quality of logistics economic development in Guangdong Province, reduce regional differences.

Second, strengthen the construction of logistics channels and improve the density of logistics networks between cities in Guangdong Province. We should strengthen the construction of logistics channels in Guangdong Province, accelerate the construction of the golden waterway of the Pearl River, promote the transfer of freight to rail in Guangdong Province, give full play to the economy and scale of railway transportation, improve logistics efficiency, strengthen the construction of high-speed railway and high-speed road network, realize high-speed railway in cities and counties, improve the density of logistics economic network, and strengthen the radiation of core cities to marginal cities.

Third, optimize the division of labor of logistics industry and realize the coordinated development of logistics industry in the region. Guangdong Province should actively cultivate the development of logistics industry, integrate the logistics functions in the area, and realize the integrated development of logistics economy. The region should actively carry out division of labor to reduce and avoid industrial homogenization and isomorphism. For example, the construction of the Pearl River golden waterway should ensure the rationality of port resource allocation and realize the good interactive development of home port and feed port. All cities in the region should adopt the logistics dislocation development strategy. According to the existing resource conditions, economic conditions, natural endowment and different levels of logistics economic development, the focus and direction of improving the level of logistics economic competitiveness should be different, so as to form a characteristic and good logistics economic division pattern dominated by dislocation competition.

To sum up, based on the relational attribute data, this paper uses the social network analysis method to analyze the spatial organization mode of logistics economy in 21 cities in Guangdong Province and explore its spatial structure characteristics. This paper promotes the further integration of spatial theory and empirical research, and provides a new perspective and new empirical research paradigm for the spatial research of logistics economy. At the same time, it provides suggestions for further promoting the connection and integrated development of logistics economic space in Guangdong Province. Therefore, the research of this paper has certain theoretical and practical significance.

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