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Research Article

Analysis of the Spatio-Temporal Evolution and Factors Influencing the Freight Network in the Middle Reaches of the Yangtze River

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The study uses python software to crawl O-D big data on the freight information platform and construct a frequency matrix based on freight connections between cities, then forming a freight network. There are 31 cities in the middle reaches of the Yangtze river that form the subject of the research. The study adopts the methods of the node degree, community analysis, network motif analysis, and multielement regression analysis to assess the differences of the spatio-temporal evolution and factors influencing the freight network in 2014 and 2018. The following conclusions can be drawn: (1) the freight network has experienced a change in pattern from "island" to "radial," and the tightness of the freight network is strengthened. (2) The circulation accumulation of elements causes the change of node degree to have a high tendency of agglomeration of capital and central cities. (3) The phenomenon of "enclave freight" and "freight union" exists in the inner-city group, but the "freight alliance" formed by the "enclave" is relatively loose. (4) With the increase in the scale of the freight network, the module characteristics are gradually simplified. (5) Science and technology run through the entire process of the formation and development of the urban freight network.

1. Introduction

The urban agglomeration in the middle reaches of the Yangtze river has a total area of about 317,000 square kilometers, and regional GDP reached 11.09 trillion yuan in 2020. In 2015, a development plan for urban agglomeration in the middle reaches of the Yangtze river was approved by the State Council, which declared the region a super-large urban agglomeration mainly formed by the urban agglomeration of Wuhan, Changsha-Zhuzhou-Xiangtan, and Poyang Lake. It includes the Hunan province, Hubei province, Jiangxi province, a total of 31 cities, and their provincial capitals (Wuhan, Changsha, and Nanchang), forming a pattern of tripartite confrontation.

The urban agglomeration in the middle reaches is an important part of the Yangtze River Economic Belt, which plays the function of connecting east and west, and south and north. It undertakes the strategic tasks of the development of the Yangtze River Economic Belt and is a strategic fulcrum and an important economic growth pole for the rise of the central region. It has excellent traffic conditions, modern ports, regional hub airports, and trunk lines, forming a three-dimensional transportation network and laying a solid foundation for the establishment of intercity logistics network. However, the logistics spatial layout and factor allocation are suboptimal, the logistics supply chain is incomplete, the information platform construction is underdeveloped and so on [1–3]. These have impaired the construction and development of the logistics network interconnections of the urban agglomeration in the middle reaches of the Yangtze river. Therefore, under the background of promoting it as a new economic growth pole, the construction of the interconnectivity of thefreight network will become a new direction in the integrated development of urban agglomeration.

This study intends to select the methods of the node degree and city freight connection strength to measure the structural characteristics of the region. Based on community and network motif analysis, the study explores the spatio-temporal evolution of its freight network and uses multiple linear regression to ascertain the factors influencing the freight network. It aims to identify the evolutionary characteristics and factors affecting the freight network, promote the construction of large logistics channels, and realize the high-quality development of freight.

2. Literature Review

In establishing a new development pattern of domestic and international double circulation, modern logistics, as an important link between production and consumption, plays a vital role in optimizing regional resource allocation and regional economic structure. It is an important strategy to integrate regional coordinated development into domestic circulation and domestic and international double circulation to promote regional high-quality development. Regional integration is an important consideration in regional coordinated development [4, 5], and the construction of logistics network interconnection is an important part of the development of regional integration. Intercity logistics is an important part of the urban network [6, 7].

Looking for appropriate related media to construct a network and conducting network measurement analysis are two important aspects in the research into urban network structures. Ye and Duan [8] used the network analysis method to study the spatial structure and factors influencing the urban network in the Yangtze River Delta based on their data on a branch of the headquarters of the top 100 logistics enterprises in China. Wang et al. [9] used an economic connection model and social network analysis method to compare and reveal the dynamic evolution of spatial network structure. The results found that the development of a multicenter network structure is key to realizing the rise of the middle reaches of the Yangtze river.

The rapid development of information network technology compresses space-time, and the flow of information, capital, people and other elements are imperceptibly reshaping the urban system [10, 11]. With the acceleration of logistics information, new logistics business forms are emerging, and the specialized freight information platform is one such. Professor Wang et al. points out that multi-source information mining has become an important method in transportation research, different characteristics of data can be used to study different problems, and freight big data in the context of "Internet +" are one such [12]. The development of the Internet professional freight information platform has brought new development opportunities to the Chinese freight market and has also become a "new channel" which promotes the interconnection of logistics network, deepens logistical cooperation, and strengths interregional network coordination [13, 14].

There has been little research into logistics networks based on Internet logistics information platforms. Under the background of "Internet+," the structural characteristics and formation mechanism of China's logistics network mapping on the urban geographic spatial structure remain unclear [15, 16]. The present study uses freight information platform data to ascertain spatio-temporal evolution and factors influencing the intercity freight network, covering 31 prefecture-level, urban agglomerations in the middle reaches of the Yangtze River, and explores the interaction between urban nodes and freight network structure, thereby providing a practical basis and technical path for the improvement of the freight network layout of urban agglomeration in the middle reaches of the Yangtze river.

3. Research Area, Data Sources, and Methods

3.1. Research Area. The planning scope of the middle reaches of the Yangtze river urban agglomeration includes Wuhan, Huangshi, Ezhou, Huanggang, Xiaogan, Xianning, Xiantao, Qianjiang, Tianmen, Xiangyang, Yichang, Jingzhou, Jingmen, Changsha, Zhuzhou, Xiangtan, Yueyang, Yiyang, Changde, Hengyang, Loudi, Nanchang, Jiujiang, Jingdezhen, Yingtan, Xinyu, Yichun, Pingxiang, Shangrao, Fuzhou, and Ji'an. The study selects these 31 cities as research objects.

3.2. Data Source and Processing. Using the python software to crawl the freight information of the Haoyun Logistics Network (http://www.haoyun56.com/), one of the biggest freight information in China ((1) on the homepage of the official website of Haoyun Logistics, there are signs of "China's Leading Logistics Information Website" and "National Leading Logistics Network." (2) The Haoyun Logistics Network was established in 2010 and has a history of 11 years. It has a long operating period. Its business covers our whole country, and it contains comprehensive freight information. (3) There are many freight information websites, but only a few of them are recognized by the Department of Public Security, such as Haoyun Logistics Network). Then, we choose three parameters (starting city, arrival city, and travel time) to form O-D data between cities. After sorting, we obtained 1345 items of data in 2014 and 1876 items in 2018 for urban agglomeration in the middle reaches of the Yangtze River ((1) In April 2015, the State Council approved the "Development Plan of Urban Agglomeration in the Middle Reaches of the Yangtze River." It is meaningful to select the years before and after the plan (2014 and 2018) to compare and analyze the changes of the freight network. (2) Among all freight data, there have a relatively large amount of data and include 12 months of the whole year in 2014 and 2018. Based on the availability of data and the comprehensiveness of time coverage, we select the data of these two years). Finally, according to internal contact information, we constructed a freight frequency matrix (31×31) to form an intercity network.

3.3. Research Method

3.3.1. Node Degree. The sum of the degree of connection between a node and other nodes is expressed as the node degree. The greater the node degree, the larger the dominance of that city in the network, which plays an important role in the development of regional logistics. The formula is as follows:

$$D_{i(\text{out})} = \sum_{j=1}^{n} T_{ij}, \quad D_{i(\text{in})} = \sum_{j=1}^{n} T_{ji}, \tag{1}$$

$$D_i = D_{i(\text{out})} + D_{i(\text{in})}, \quad i \neq j, \ j = 1, 2, \ldots, n, \ (n = 31), \tag{2}$$

where $D_{i(\text{out})}$ is the out-degree of city i, $D_{i(\text{in})}$ is the in-degree of city i, D_i is the node degree of city i, AND T_{ij} is the frequency between cities i and j.

3.3.2. City Freight Connection Strength. Herein, the sum of the frequency of connections between cities is used to characterize the freight connection strength. The specific formula is as follows:

$$M_{ij} = M_{i\text{to}j} + M_{j\text{to}i}, \tag{3}$$

where M_{ij} is the strength of the road freight connection between cities i and j, $M_{i\text{to}j}$ represents the freight frequency from city i to city j, and $M_{j\text{to}i}$ represents the freight frequency from city j to i.

3.3.3. Community Analysis. A community, also known as a cluster, is a collection of actors, in which actors have a relatively strong, direct, and close relationship. The study uses the CONCOR method (an iterative correlation convergence method) to divide the urban agglomeration in the middle reaches of the Yangtze river into several urban clusters. Then, according to the clustering index, we evaluate the results of the division: the higher the index, the better the results of the division, the lower the index, indicating that the current network community structure is not prominent. In addition, to calculate the density of the community, the concept of weighted average node degree is introduced, that is, the node degree of all cities in the community is weighted and averaged, and the value is the density of the community. The larger the value, the closer the intersubgroup connections, the higher the degree of synergy between cities.

3.3.4. Network Motif Analysis. Many complex networks have common global characteristics, however, networks with similar global structural characteristics may have distinct local structural characteristics. The motif is a basic mode of interaction that occurs repeatedly in the network. Identifying and analyzing the motif in the network is conducive to a better understanding of the local structure of the network. Motifs are overrepresented in a network when compared to randomized networks. The analysis is mainly based on the frequency, P value, and Z value of the motifs, where Z is given by [17]:

$$z_i = \frac{N_{\text{real}} - N_{\text{rand}}}{\sigma_{\text{rand}}}, \tag{4}$$

where z_i captures statistical significance of motif i, N_{real} represents the number of occurrences of motif i in the actual network, N_{rand} represents the number of occurrences of motif i in the random network, and σ_{rand} represents the standard deviation.

3.3.5. Multiple Linear Regression. Using multiple regression, we verified the correlation and revealed the factors that affect the evolution of the freight network of the urban agglomeration in the middle reaches of the Yangtze river. Assuming a linear relationship between the dependent variable and multiple independent variables, the main model is as follows:

$$\begin{cases} y = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_p x_{ip} + \varepsilon_i, \\ i, j = 1, 2, \ldots, n, \end{cases} \tag{5}$$

where y is the explained variable and x is the explanatory variable.

4. Analysis of the Freight Structure Characteristics of Urban Agglomeration in the Middle Reaches of the Yangtze River

4.1. City Node Degree. Formula (1) is used to calculate the city node degree (Figure 1). For convenience of comparison, the parameter of relative node degree is introduced, which mainly represents the proportion of the city node degree in the sum of all city node degrees in a certain year.

By comparing the node degree and relative node degree, it is found that they account for about half of the cities in which the node degree based on freight has increased and decreased significantly. Thus, the trend to urban polarization is obvious. The total node degree increases from 326 in 2014 to 564 in 2018, an increase of 73%. Cities are increasingly connected. In 2018, the top three cities in terms of node degree are Wuhan (222), Changsha (38), and Nanchang (35), as in 2014. Thus, city "power" is highly relevant to a city's economic development level and regional status. Elements cycle accumulation makes the node degrees with high tendency of provincial capital central city agglomeration. In addition, there are cities with less communication

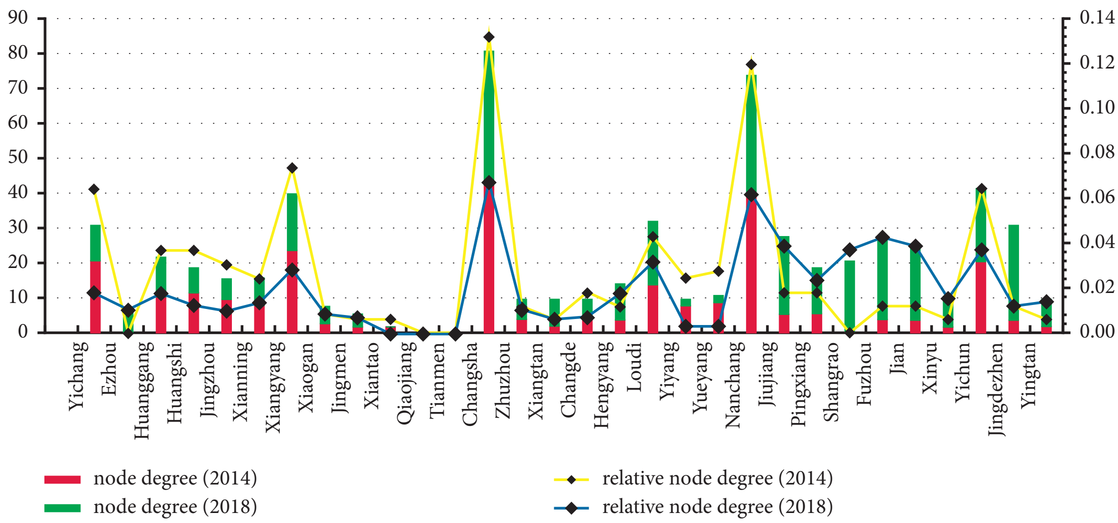


Figure 1: The changes to the city node degree. (Notes: the value of Wuhan is so large that it affects the scale of the picture, so data for Wuhan are not portrayed).

with the outside world, such as Tianmen, Qianjiang, Xiantao, and Jingdezhen.

4.2. City Freight Connection Strength. According to formula (2), the strength of freight connection between cities is calculated. The natural discontinuous method is used to divide cities into five levels. Both the node degree and freight connection strength are visualized in ArcGIS (Figure 2).

As can be seen from Figure 2, compared with 2014, the overall pattern of freight connection changed from loose to concentrated in 2018. In 2014, there are 55 pairs of intercity links, including 34 pairs of first-level and two pairs of fifth-level links. Most of them have a low intensity of intercity links. In 2018, there are 60 pairs of intercity connections, including 27 pairs of first-level and five pairs of fifth-level. The degree of intercity connections has been deepened.

In 2014, the overall pattern of freight traffic is "island-like," and the three suburban agglomerations formed the requisite "islands," each with an obvious internal agglomeration effect. Among them, Wuhan, Xiangyang, and Yichang constitute three core centers, forming a triangular spatial structure, with a freight connection intensity of greater than 12. Nanchang and Yichun constitute a "dual core" spatial structure with a connection intensity of 17, which drives the urban development in the Jiangxi province. The single core node of Changsha is a "one-angle" spatial structure, which is closely connected with other prefecture-level cities.

In 2018, freight transport links generally show a "radial" pattern, showing a typical ladder trend of "one core and multiple centers." With Wuhan as the core, Xiangyang, Changsha, Loudi, Nanchang, Yichun, and Fuzhou belong to the second gradient center, and the intensity of connection with Wuhan is greater than 13. In addition, compared with 2014, the freight connection between Wuhan and Changsha and Nanchang has improved significantly. The freight connection between Changsha and Nanchang has grown from nothing. These changes may be related to the signing of the Cooperative Plan for Provincial Capital Cities of the Middle Yangtze River Urban Agglomeration (2017–2020). We need to coordinate the construction of expressways and national highways, move faster to connect them with the national backbone network and establish an intelligent and integrated transport cooperation system. The connection of Wuhan, Changsha, and Nanchang can improve the construction of the urban circle along the traffic line, and the development will play a leading, propagating role. The development of big cities will drive growth in small and medium-sized cities and then promote the axial development of the Yangtze River Economic Belt.

5. Spatio-Temporal Evolution of the Freight Network in the Urban Agglomeration in the Middle Reaches of the Yangtze River

5.1. Central Evolution Analysis. To demonstrate the flow of freight between cities, ECharts software is used to program in JavaScript language to obtain the flow diagram of freight connections (Figure 3).

From Figure 3, the first city in the regional urban agglomeration is the provincial capital, which plays a dominant role in the regional freight network. In addition, compared with 2014, the freight network is more closely connected in 2018, and Wuhan ranks first. The number of connections between provincial and nonprovincial capitals is increasing, and Wuhan's growth rate is much faster than those of Changsha and Nanchang. In 2014, Nanchang has more contacts with cities in the Jiangxi province, and in 2018, its contacts with cities outside Jiangxi Province are gradually strengthened. What this may be related to the continuous improvement of the traffic network around the Poyang Lake city cluster. For example, in 2016, Nanchang planned to add Wuhan–Jiujiang and Nanchang–Liuyang intercity routes in the original Nanchang–Jiujiang intercity

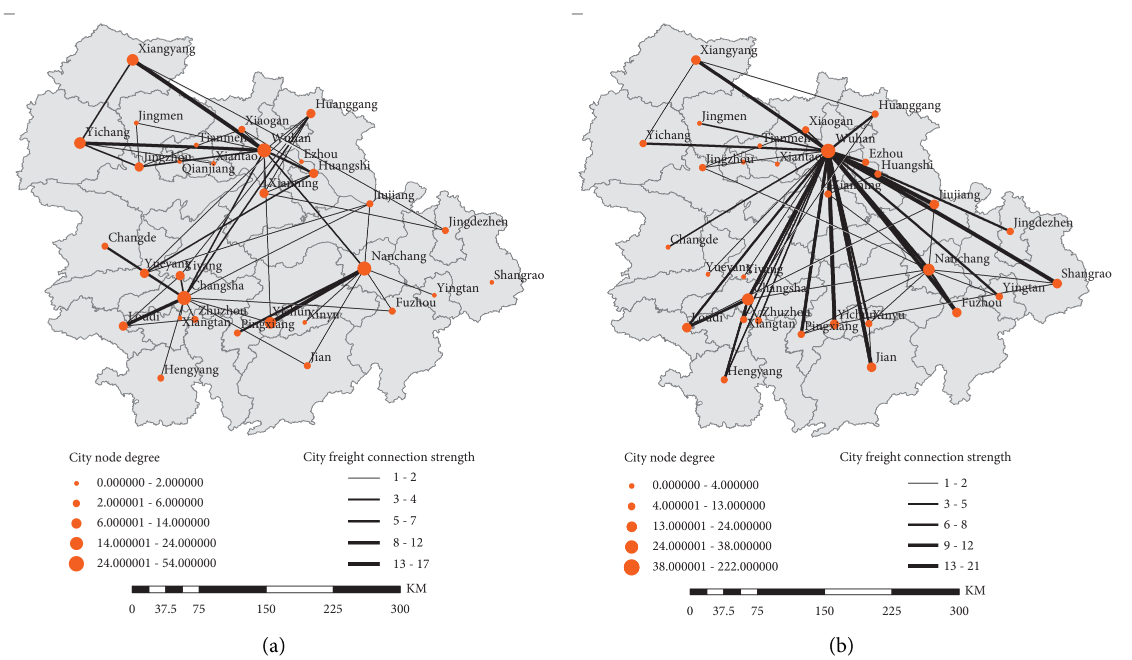


FIGURE 2: Characteristics of freight connection intensity of urban agglomerations in the middle reaches of the Yangtze river in 2014 (a) and 2018 (b).

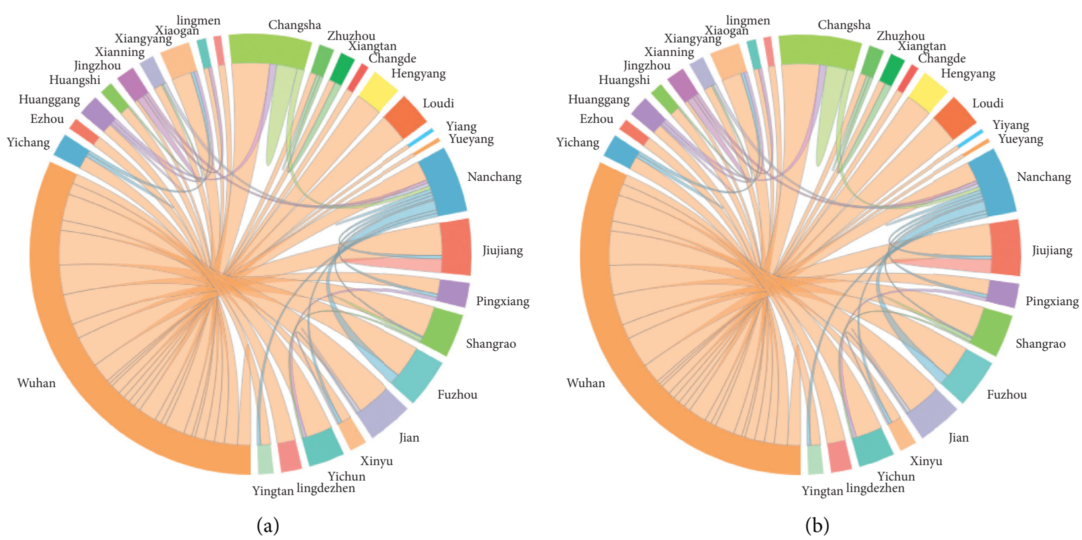


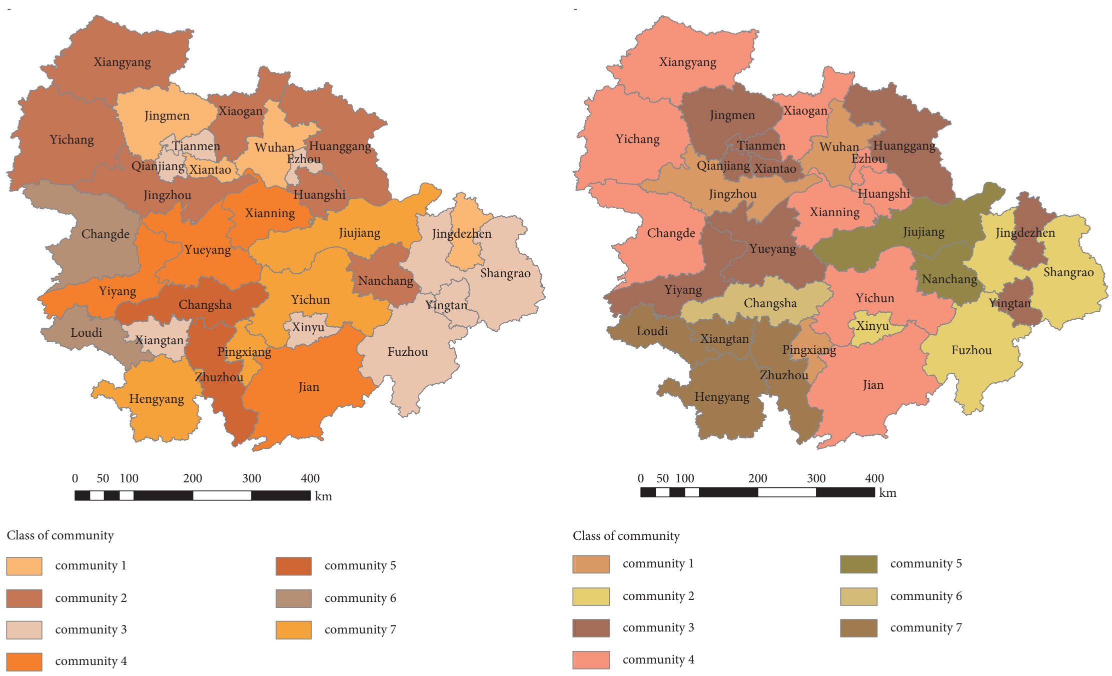
FIGURE 3: Freight connection flow diagram of urban agglomerations in the middle reaches of the Yangtze river in 2014 (a) and 2018 (b).

routes and Shanghai–Kunming passenger dedicated corridor.

5.2. Community Analysis. Community analysis is a typical method applied to complex network systems: it can explore the distribution of urban network communities and study the agglomeration characteristics between and within communities. The CONCOR algorithm is used to divide the city freight matrix data, and the results are shown in Figure 4.

In general, in 2014 and 2018, the urban freight network is divided into seven communities, and the modularity is 0.127 and 0.253. In 2014, the community distribution is relatively widely dispersed, as is greatly influenced by high-grade cities with spill-over effects across provincial administrative boundaries. In 2018, the community distribution is relatively concentrated, showing a trend of agglomeration, with obvious characteristics of provincial administrative divisions.

According to Figure 4, the classification results of 2014 and 2018 are significantly different. In 2014, the community classifications are relatively scattered. There is a



(a) (b)

Figure 4: Composition of freight network communities in urban agglomerations in the middle reaches of the Yangtze river in 2014 (a) and 2018 (b).

phenomenon of "enclave freight" bubbles. In 2018, the communities are mainly composed of cities in the same province, showing a trend of agglomeration and "freight alliance" phenomenon. In the "Internet+" environment, information flow, logistics flow, and traffic flow are important driving forces that directly shape intercity relationships. There are more information discovery paths between cities, "enclave freight" and "enclave alliance" bubbles being just two such examples.

According to the calculated density matrix between communities and the weighted average node degree value within communities, the Gephi software is used to visualize the internal and external connection strength of communities (Figure 5).

Combining Figures 4 and 5, in time, the strength of connection between communities increases, as does the internal connection. In 2014, Community 1 is composed of Wuhan, Jingdezhen, Xiantao, and Jingmen; in 2018, Community 1 is composed of Wuhan, Pingxiang, and Jingzhou. Compared with 2014 (47.42), the weighted average node degree in 2018 (205.35) increases by more than 300%. Jingdezhen and Xiantao are both marginal cities. In 2018, Jingzhou and Pingxiang replace these two cities and form a new Community 1 with Wuhan. The new community's urban freight capacity is generally stronger than that in 2014. Besides which, not all communities are interconnected. Some communities have internal connections such as Communities 1, 2, and 5 in 2014, and Communities 1, 4, and 5 in 2018. Some communities have only one-way connections such as Communities 2 and 3, 3 and 5, 4 and 6 in 2014, or Communities 3 and 6, 3 and 5, 5 and 7 in 2018. There are "spill-over effects" between inner cities; there are "unilateral effects" between unidirectionally connected communities, leading to differences in spill-over and absorption effects between cities. There are core and marginal cities in each province, but in terms of the internal community, formed by the mixed marginal cities of the three provinces having a low degree of coordination over a small scale. The "freight alliance" formed by the "enclaves" is relatively loose, and the development of urban freight networks is slow.

5.3. Microcorrelation Model of the Freight Network. The motif analysis method can explore the microscopic correlation mode of intercity freight network. Motif identification includes three steps: random network generation, subgraph search, and motif characteristic evaluation. This study directly uses FANMODE software to detect motifs. This software is embedded within the Rand-ESU algorithm, which is faster speed and more suitable for application to various scales of network [18]. This study identifies the motif structure for $N = 3$ and $N = 4$ in the freight network of the urban agglomeration in the middle reaches of the Yangtze River in 2014 and 2018, allowing assessment of which motif plays a significant role in the freight network (Table 1).

From Table 1, in 2014, urban models have four main characteristics: transitivity, interactivity, agglomeration, and dispersion.

Motif 12 and Motif 2116 indicate the transitivity between urban models. The frequency of Motif 12 is the highest, but the Z value is the lowest, indicating that the importance of this microcorrelation model is limited but its range of

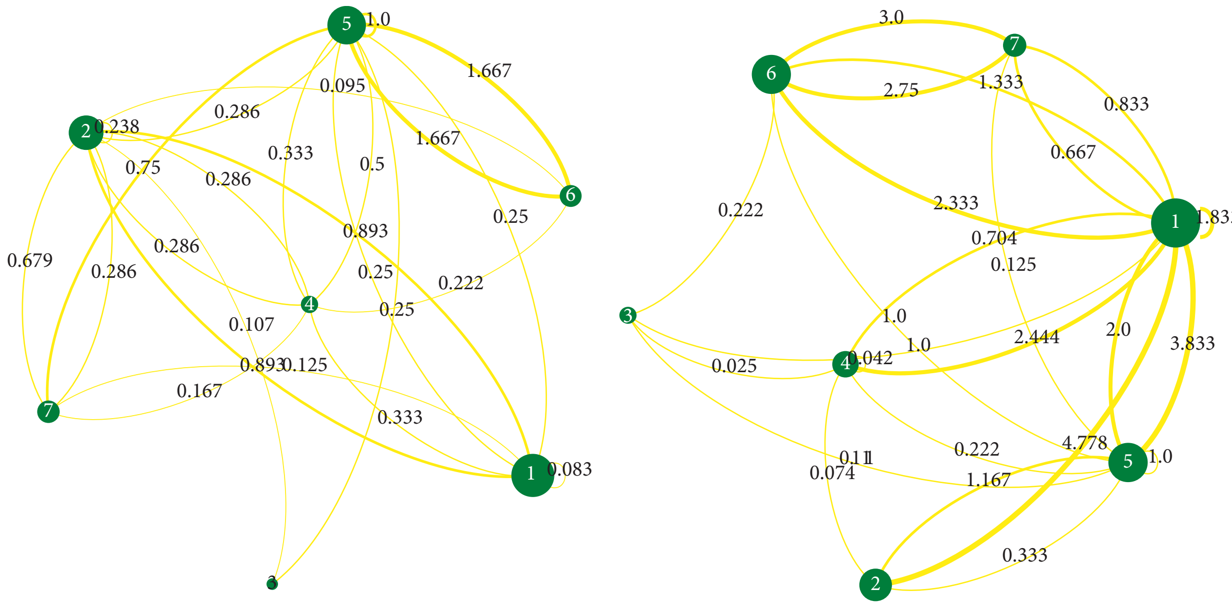


Figure 5: Connectivity intensity of freight network communities in urban agglomerations in the middle reaches of the Yangtze river in 2014 (a) and 2018 (b). (Notes: the size of the ○ in the figure represents the weighted average node degree of the community, and the thickness of the line represents the contact density value between communities).

Table 1: Analysis of freight network motifs.

Year	N	ID	Adj	Frequency (original) (%)	Mean-freq (random) (%)	Standard-dev (random)	Z-score	P value
2014	$N=3$	174		4.54	3.05	0.0082	1.8024	0.038
		12		19.19	17.26	0.0114	1.6878	0.022
	$N=4$	4958		0.83	0.01	0.0007	10.9170	0.001
		2116		4.86	3.61	0.0052	2.3894	0.004
		18568		3.91	2.94	0.0042	2.2753	0.011
		30		4.27	3.01	0.0057	2.2005	0.012
		2184		0.95	0.65	0.0016	1.7455	0.046
		8598		4.75	3.90	0.0056	1.4894	0.045
2018	$N=4$	392		0.67	0.32	0.0015	2.2222	0.017

distribution is wide. The transmission characteristics of this motif are obvious, indicating that the freight connection between most cities is indirect; cities with relatively mature logistics development such as Wuhan, Changsha, and Nanchang act as "intermediary cities" and play a communicating role in freight traffic between other cities. Motif 2116 is akin to the association pattern of Motif 12, but on this basis, a node city is added, which represents the further development trend of Motif 12. Motif 4958 is more interactive. The Z value of the module is the largest, but the frequency is the lowest, which shows that the influence of this motif in the freight network is limited, and there is a two-way interaction between each node. The external node can break through the closed subnet and interact with an internal node; however, in the real freight network, although there are some interactive characteristics within the provinces, the interaction between provinces is mainly realized through several freight-center cities, there remain certain unbalanced associations, so the frequency of this balanced network motif is low [17]. The microscopic correlation model represented by this motif proves the existence of "enclave freight" scenarios; for example, the "freight circle" formed by three cities with close freight links between themselves, and the "out-of-circle city" only has freight exchanges with one city within the circle. This phenomenon is mainly reflected in Wuhan, Yichang, Jingzhou, and Changsha. Wuhan, Yichang, and Jingzhou are in the Hubei province (they form a freight circle), and freight exchanges between each other are frequent, while Changsha only has freight links with Wuhan.

Motif 8598 has the characteristics of dispersion and transitivity. This motif represents a "progressive mode," that is, there is no freight links between the lower cities, only freight links with other cities through the higher-level cities, where in the higher cities act as a medium. This motif exists at the interprovincial and intraprovincial. Motif 2184 and Motif 18568 reflect the freight model of "central agglomeration," that is, several cities only have one-way freight links with central cities. These central cities often become the agglomeration centers of the region by the virtue of convenient transportation and geographical location. Goods from different cities are gathered here and then are evacuated to all parts of the country in some way. For example, in Wuhan, goods from other cities are mostly transported elsewhere in the countryside through the developed water transport system in Wuhan. Motif 30 and Motif 18568 are similar, but they represent two distinct models. Motif 30 is characterized by dispersion, indicating that there are some core nodes with frequent foreign freight and a significant radiating effect in the freight network.

In 2018, only Motif 392 with four nodes is detected. The Z value and frequency of Motif 392 are low, indicating that the role of this motif in the network is very limited. This correlation model has obvious transmission characteristics, which mainly includes two types of cities: one is that a city directly carries out freight with other cities, and the other is that a city needs to use the "intermediary city" to have a unidirectional freight link to others. Compared with 2014, the scale of freight network in 2018 is significantly expanded, and the effect within each suburban agglomeration is weakened. With the improvement of economic development and transportation infrastructure construction, the multicenter freight network structure began to appear, the freight links between cities became more frequent, and the freight is no longer always borne through the "intermediary city." This explains the small number of freight network model test results of the urban agglomeration in the middle reaches of the Yangtze river in 2018. This is also the reason why the small number of freight network models are detected.

Through analyzing the microstructure of freight network in 2014 and 2018, it can be found that the characteristics of freight links in urban agglomerations in 2014 are obvious: some cities are in a dominant position in the freight network, and the "intermediary transmission" and "direct connection" mode coexist. In 2018, the freight links between cities increased significantly, which broke through the previous "intermediary transmission" mode. The direct freight links between cities became more frequent, but there are still core cities with obvious advantages. Overall, the freight network structure is becoming more complex. With the increased scale of the freight network, its modular characteristics are simplified: from the perspective of local topology, the freight network has better connectivity.

6. Analysis of Influencing Factors

In this study, the node degree of midstream cities is taken as the dependent variable, and parameters are four aspects, including geographic conditions, resource elements, infrastructure, and scientific and technological innovation, with reference to the Statistical Yearbook of Chinese Cities. SPSS 21.0 software is used for multiple regression analysis.

To prevent the distortion of the regression model caused by the high correlation between the independent variables, the variance inflation factor (VIF) is introduced to conduct the multicollinearity test. According to Ye and Duan [8], in general, $0 \leq \text{VIF} < 10$ indicates no multicollinearity, $10 \leq \text{VIF} < 100$ implies strong collinearity, and $\text{VIF} \geq 100$ suggests super-collinearity. The results of collinearity testing are summarized as Table 2.

In Table 2, except GDP, the VIF values of other independent variables are all within 10, indicating that independent variables are mutually independent and can be selected as factors influencing the analysis (the influence of GDP will not be explained separately below). According to the model analysis and analysis of variance results, the findings are displayed in Table 3.

According to the results obtained in Table 3, the adjusted values of R^2 in 2014 and 2018 are 0.814 and 0.938. The regression model could explain more than 80% of the information, indicating that the regression model had a good fitting effect. In addition, the F-test results of the model are significant ($P \leq 0.001$), and the regression coefficient of at least one explanatory variable in the regression model is nonzero. The established regression model has statistical significance, indicating that it is appropriate to use a linear model to describe the relationship between dependent variables and independent variables (Table 4).

Regression analysis (Table 4): (1) in 2014, the road freight volume, actual urban road area at the end of the year, number of patents granted, and science and technology expenditure pass the significance test. It shows that city with resources, urban infrastructure construction, and the capability for scientific and technological innovation has impact on the development of freight. Neither the number of Internet broadband users nor the expenditure on urban maintenance and construction has any effect on urban freight, perhaps because the expenditure on urban construction has less influence on freight. (2) In 2018, the city scale, the number of Internet broadband users, the number of patents granted, and science and technology expenditure pass the significance test. It shows that the geographic conditions, resource elements, and technological innovation are the driving forces behind the development of the freight network, therefore, cultivating high-quality logistics professionals, construction of city logistics and freight increasing resource input and promoting the rapid development of technological capacity can generate opportunities for urban freight development. (3) Geographic conditions, resource elements, infrastructure, and scientific and technological innovation promote the evolution and development of urban freight network to different extents. In general, scientific and technological innovation ability plays the biggest role. Science and technology is the most important factor affecting urban freight connection and development.

Table 2: Collinearity checklist.

Level indicators	The secondary indicators	VIF (2014)	VIF (2018)
Geographical conditions	Urban size	2.515	3.248
	GDP	19.076	18.250
Resources	Road freight volume	2.833	3.304
	Number of subscribers with broadband internet access	9.672	7.661
Infrastructure	Expenditures for urban maintenance and construction	6.771	1.403
	Actual urban road area at the end of the year	8.037	7.778
Scientific and technological innovation	Number of patents granted	3.214	7.304
	Expenditure on science and technology	4.338	2.202

Table 3: Model analysis and analysis of variance.

Year	Model analysis			Variance analysis		
	R	R^2	Adjusted R^2	Mean square	F	Significance
2014	0.929	0.864	0.814	574.925	17.414	$P \leq 0.001$
2018	0.977	0.954	0.938	5452.284	57.322	$P \leq 0.001$

Table 4: Regression analysis of factors influencing the freight network of urban agglomeration in the middle reaches of the Yangtze river.

	Standardization factor			Significant P	
	Year	2014	2018	2014	2018
	(Constant)			0.464	0.583
Geographical conditions	City scale	0.005	0.035	0.970	0.050**
	GDP	0.276	−0.264	0.431	0.189
Resources	Road freight volume	0.205	0.064	0.039*	0.450
	Number of internet broadband users	0.655	−0.044	0.074	0.029*
Infrastructure	Urban maintenance and construction expenditure	0.174	−0.038	0.404	0.494
	Actual urban road area at the end of the year	0.266	0.041	0.036*	0.886
Scientific and technological innovation	Number of patents granted	−1.480	0.335	0.004**	0.029*
	Science and technology expenditure	1.110	0.970	0.009**	0.001***

Notes. $^{*}P \leq 0.05$, $^{**}P \leq 0.01$, $^{***}P \leq 0.001$.

7. Conclusion and Recommendations

Based on the freight data pertaining to the urban agglomeration in the middle reaches of the Yangtze River in 2014 and 2018, this study analyzes the structural characteristics, temporal and spatial evolution, and influencing factors its freight network. The main conclusions are as follows:

(1) From the perspective of the characteristics of freight structure, for a single city, the cyclic accumulation of elements causes the change in node degree to agglomerate in provincial capitals and central cities. Wuhan, Changsha, and Nanchang are the regional centers of the three provinces, with strong resources and economic advantages. The freight structure has undergone a change from an “island-like” to a “radial” pattern. The preferential connection mechanism of Wuhan’s external freight transportation is stronger than the geographical proximity effect, which is typical of the “collapse” dilemma facing the Tianmen-Xiantao-Qianjiang area. At the same time, Northern Hunan is in a state of “depression” with regard to the development of freight transportation in the urban agglomeration around Changsha-Zhuzhou-Xiangtan. The trickle-down effect caused by the triangular pattern of urban agglomeration around Poyang Lake benefits the surrounding nodal cities.

(2) From the perspective of the temporal and spatial evolution of the freight network, the freight network of the middle reaches of the Yangtze river develops from the “three pillars” of Wuhan, Changsha, and Nanchang to the “one city dominant” model (that being Wuhan). The freight network is closely connected: there are “enclave freight” and “freight alliance” phenomena within the urban agglomeration because of the differences in the economic development level, geographic distance, and industrial structure of the alliance cities, the “freight alliance” formed by the “enclaves” is still relatively loose.

(3) From the perspective of the micro-correlation model of freight, the network has good connectivity and the agglomeration characteristics of freight links are obvious. The urban motif has the characteristics of transitivity, interaction, agglomeration, and decentralization. The structure of the freight network has become increasingly complex over time. With the increase in the scale of the freight network, the characteristics of the motif gradually become simple.

(4) From the perspective of factors influencing this network, science and technology become the most important factor, affecting the development of urban freight. Science and technology run through the whole process of the formation and development of the freight network, and promote the development of intercity freight in the direction of specialization and higher intelligence. Geographic conditions, resource elements, and infrastructure also have a certain effect on the development of freight, in which the key is to improve the quality of logistics professionals, logistics business, levels of information, and road construction.

To improve the level of freight and promote the integration of the midstream urban agglomeration into the construction and development of the Yangtze River Economic Belt, the following suggestions are proposed:

(1) Based on urban transformation, create a city card. In addition to accepting the benefits of core cities, fringe cities must find their own positioning and development path. For example, Jingdezhen can take the ceramic industry as its forerunner, disseminating its products through the freight network. Tianmen can continue to Polish the “Lu Yu tea” culture brand and build on the background of tea culture. A business district integrating preliminary and processing, wholesale trading, warehousing and logistics, and relying on the tea culture city attract investment and promote high-quality economic development.

(2) Give full play to the advantages of urbanization and seize the opportunity to integrate into the Yangtze River Economic Belt. Cities along the Yangtze River should play the role of internal transportation corridors and factor flows, reconnecting the fracture points between cities, thus giving play to geographical advantages to promote the linking role of axis cities. For example, Jiujiang and Yueyang play the role of port-type national logistics hubs in carrying cities, connecting domestic and international routes and port collection and distribution networks, and improving logistics services. Nanchang and Changsha should give full play to the advantages of land-port-type and production-service-type logistics hubs to carry urban resources, providing smooth domestic and international logistics organizations, modernizing the supply chain and information services.

(3) Strengthen the trickle-down effect of core nodes, build freight ports such as highway ports, and relieve the pressure on such functions at Wuhan’s freight hub. The medium- and low-end industries of Wuhan can be transferred to Yichang, Xiangyang, and Huanggang, thus improving the freight capacity of those cities and transforming them from mere satellite cities of Wuhan to the principal central cities of western, northern, and eastern Hubei, respectively.

(4) Increase investment in logistics technology, especially in logistics information technology, and cultivate high-quality logistics professionals. Policy support and corresponding subsidies can be given to scientific and technological research and development to improve the logistics technology innovation ability of logistics enterprises and researchers.

Data Availability

Data of freight demand data are all sourced from the Haoyun Logistics Website which is openly available at: http://www.haoyun56.com. The [.xlsx] data used to support the findings of this study have been deposited in the data3 repository (https://github.com/h9h9/data3.git).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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