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Research on Regional Transport Network Connection under the Background of Multimodal Transport

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ABSTRACT. *Considering the reality of regional internal transport infrastructure and the accessibility of foreign communications, the development system of multimodal transport with inland waterway transportation as the core in the Pearl River-Xijiang Economic Zone is analyzed. Based on highway, waterway and railway transportation modes, Arcgis is used for qualitative and quantitative analysis of traffic network. Spatial weighted distance and shortest time are taken as evaluation indexes, and index weights are defined by integrated weighting method.Then it discusses the connectivity of transportation network of each node city, and makes a comparative analysis of the advantages and disadvantages of its transportation network layout, which provides an objective theoretical reference for promoting the coordinated development of regional integration and integrated logistics.*

KEYWORDS: *multimodal transport, Arcgis, integrated weighting, connectivity*

1. Introduction

With the requirement of economic integration for sustainable development of regional integrated transport network, multimodal transport is a new type of green transport mode, which integrates the advantages of various transport modes, realizes the interlinkage between inland river transport and land transport of goods, and effectively reduces logistics costs.

Current traffic network research mainly focuses on the accessibility analysis within the city, but from the perspective of multi-modal transport analysis is relatively deficient. Connectivity is an important index reflecting the development of regional multimodal transport network. To some extent, it also reflects the regional transport capacity and the convenience of communication with the outside world. Taking the inland waterway transport as the core of the Pearl River-Xijiang Economic Belt as the research object, this paper establishes a multi-index transportation connectivity evaluation model, solves the OD travel cost matrix based

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on Arcgis, and establishes a classification map according to the connectivity index. At the same time, combined with relevant economic development policies and spatial layout planning, the advantages and disadvantages of each city in the development of regional multimodal transport are analyzed from the perspective of connectivity, providing reference for regional transport infrastructure layout planning and multimodal transport research.

2. Data sources and research methods

2.1 Data sources

Taking Guangzhou,Foshan, Guigang, Nanning, Wuzhou, Baise, Laibin, Liuzhou and Chongzuo 11 cities within the planning scope of the Pearl River-Xijiang Economic Belt as the research areas, and based on the "China Traffic Atlas" published by the People's Transport Publishing House in 2017, the traffic network of cities at all levels and vector data was obtained from map and related documents.At the same time, referring to the statistical year-books and bulletins of various cities in 2018, we can get the data of transportation infrastructure construction and GDP and other social and economic development.

2.2 Research methods

In the process of evaluating transportation connectivity, firstly, the evaluation index should be constructed, and then the weights of each index should be determined according to the index data. Finally, the comprehensive evaluation model of transportation connectivity should be established.

2.2.1 Evaluation index

(1) Spatially weighted distance index

Spatial shortest distance is currently a widely used measurement method in the field of traffic network research .However, in view of the different transportation capacity under different technical levels and types of actual road network, this paper uses a weighted method to measure the connectivity level between nodes in K_i , which is defined as:

$$K_i = \frac{\sum_{j=1}^{n} l_{ij} \times {}^{1}\!/_{W_j}}{n} \tag{1}$$

l_{ij} devotes the operation line length of the traffic network between node i and node j , W_j refers to the weights under various traffic network types(Table 1). And n devotes all the node cities connected with city.

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Table 1 Weight assignment of road network

Road network type	Subtype	Weight
Highway	Trunk line	1.5
Inland waterway	First-class channel	2
	Second-class channel	1.5
	Third-class channel	1
	Fourth-class channel	0.8
	Fifth-class channel	1
Railway	Double-track standard track	2
	Single track standard track	1.5

(2) Minimum time index

The time index is used to judge the level of regional connectivity by measuring the time between nodes, which is expressed by M_i . t_{ij} represents the shortest time between the two cities, v represents the design speed under- various traffic types. Its specific values refer to "Highway Engineering Technology Standards" and inland waterway transport and railway related report documents.

$$M_i = \sum_{j=1}^{n} t_{ij} \Big/ n \tag{2}$$

$$t_{ij} = l_{ij} / v \tag{3}$$

Combining with some actual road and non-road influencing factors, according to different traffic grade types, the road network speed in each mode of transportation is reasonably defined as the running speed parameter in the attribute table, as detailed in Table 2.

Table 2 Running Speed of Road Network

Mode of transport	Design speed(km/h)
Expressway	100
Class I Highway	80
Ordinary rail	100
Fast rail	150
Waterway	30

2.2.2 Index weight

Firstly, before comprehensive evaluation, it is necessary to standardize the extreme value of evaluation index, and use linear proportionnal method to dimensionless evaluation index [8], which is defined as X^*, x_{ij} as the evaluation index of each index, and $\bar{x}_i$ as the average value of the index.

$$x^* = \frac{1}{x} \tag{4}$$

$$x^* = \frac{x_i}{\bar{x}_i} \tag{5}$$

In order to ensure the accuracy and objectivity of the evaluation results, this paper adopts the method of integrated weighting [8], and sets p and q as the weight coefficients of the two indicators based on the principle of defference and function-driven. is defined as the weight coefficients with set characteristics under two kinds of information, where k_1 and k_2 are undetermined constants ($k_1 > 0$, $k_2 > 0$). The Lagrangian conditional extremum method is used to obtain:

$$w_i = k_1 p_i + k_2 q_i \tag{6}$$

The values of p and q refer to the corresponding node grades of highways, waterways and railways in each city.

$$k_1 = \frac{\sum_{i=1}^{n} p_i x_i}{\sqrt{(\sum_{i=1}^{n} p_i x_i)^2 + (\sum_{i=1}^{n} q_i x_i)^2}} \tag{7}$$

$$k_2 = \frac{\sum_{i=1}^{n} q_i x_i}{\sqrt{(\sum_{i=1}^{n} p_i x_i)^2 + (\sum_{i=1}^{n} q_i x_i)^2}} \tag{8}$$

r_k denotes the ratio of weight coefficients of each evaluation index, that is:

$$r_k = \frac{w_{k+1}}{w_k} \tag{9}$$

r_{k+1} and r_k satisfy, $r_{k+1} > 1/r_k$ .and by comparing the importance of r_{k+1} and r_k , as shown in Table 3.

Table 3 r_k assignment definition table

r_k	Importance
1.0	x_{k+1} is equal to x_k
1.25	x_{k+1} slightly greater than x_k
1.5	x_{k+1} obviously greater than x_k
1.75	x_{k+1} far greater than x_k

(10)

$$w_n = (1+\sum_{k=1}^{n}\coprod_{i=k}^{n} r_i)^{-1}$$

$$k = n, n+1, ..., 2 \qquad (11)$$

The index weights p and q under the two driving principles are calculated by using the ordinal relation method and the mean square deviation method respectively, and the weight coefficients are as follows:

$$w_i = \frac{S_i}{S_n} \qquad (12)$$

$$S^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x_i})^2 \qquad (13)$$

$$\overline{x_i} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad (14)$$

$$i = 1, 2, \cdots n \qquad (15)$$

3. Evaluation of Connectivity

3.1 Road Network Analysis

3.1.1 Vector Analysis

This paper takes the city as the research unit, vectorizes the map of regional traffic network with Arcgis software, defines the information of road length, grade and design speed, and creates network data set. Combining highway, waterway and railway transportation modes, OD cost alysis function, and the shortest travel time and the shortest travel distance cost are obtained. Fig. 1 is a vector map constructed by combining the elements of the road network. It mainly shows the route matrix based on city center, port and railway station is established by using network an elements of the backbone traffic such as expressway, class I highway, railway and waterway.

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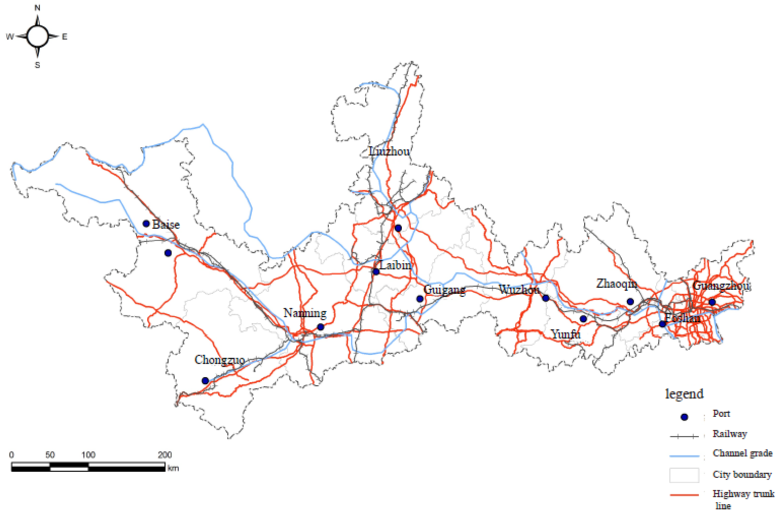

Figure. 1 Regional road network vector map

3.2 Connectivity Evaluation Model

Previous research methods show that the geographical location of the city has a significant impact on the level of accessibility, which is not conducive to the objectivity and rationality of the research results. Considering the impact of different transport modes and station levels on the evaluation results of connectivity of each node city, the weighting method of station level is adopted. Highway according to the administrative level of each city is divided into three levels: the first level is Guangzhou, the second level is other cities. According to the scale of port throughput, waterways are divided into three grades: Guangzhou Port is a national hub port, Foshan Port, Guigang Port, Nanning Port and Wuzhou Port are regional hub ports, and other ports are local ports. On the railway, relying on the grade of each freight station, it can be divided into three levels: Guangzhou Station, Nanning Station and Liuzhou Station are high-grade stations, Guigang Station is medium-grade station. Yunfu Station, Zhaoqing Station, Foshan Station, Wuzhou Station, Baise Station, Guest Station and Chongzuo Station are low-grade stations. According to the importance of each node in regional transportation network and economic development, the weights are 1, 0.75 for highway node, 1, 0.75, 0.5 for port and 1, 0.75, 0.5 for railway station.

Combining the index weight analysis of formula (4-15), considering the function and ballance of evaluation results, a comprehensive evaluation model is established. The connecting evaluation values of highways, waterways and various modes of transportation are calculated respectively (as shown in Figure 2). Specifically specifically as follows:

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$$A_i = \sum_{i=1}^{n} w_i^{(1)} x_{ij}^* + \prod_{i=1}^{n} x_{ij}^{* \, w_i^{(2)}} \tag{16}$$

$$y = \lambda_1 A_1 + \lambda_2 A_2 + \lambda_3 A_3 \tag{17}$$

Let λ_1 , λ_2 and λ_3 be the proportions of highway, waterway and railway transportation modes respectively. $w_i^{(1)}$ and $w_i^{(2)}$ represent the weight coefficients of each evaluation index in the evaluation model. A_i is the connectivity evaluation value of cities under each mode of transportation. y is the comprehensive connectivity index of cities. The higher the connectivity index, the more the city expresses the regional multimodal transport network. The better the infrastructure layout in the structure, the greater the development potential.

Table 4 Evaluation Values of Accessibility of Various Traffic Modes

Type	Guang zhou	Yun fu	Zhao qing	Fo shan	Gui gang	Nan ning	Wu zhou	Bai se	Lai bin	Liu zhou	Chong zuo
Highway	3.89	4.11	3.79	3.29	3.89	4.03	4.71	1.96	4.22	2.81	2.75
Waterway	3.44	3.30	2.88	3.40	6.26	3.37	5.73	1.23	3.78	2.18	2.11
Railway	3.75	3.38	3.20	2.67	6.05	4.60	3.88	1.45	2.78	3.52	1.31

At the same time, referring to the scale of passenger and freight transport and the role of various modes of transport in regional economic development, the weight of each mode of transport needs to be redefined in order to evaluate the connectivity of regional external traffic more objectively and take into account the functionality and balance of the evaluation results. Due to social and economic development, policies and population, the advantages of water and road transport in the Pearl River-Xijiang Economic Zone are obvious. Railway transport has risen in recent years, which not only effectively improves the convenience of regional links, but also changes the spatial pattern of regional social and economic development. According to the research center, λ_1 , λ_2 and λ_3 are determined to be 0.3, 0.4 and 0.3 respectively, which is the basis for comprehensive analysis and evaluation of external traffic accessibility of cities.

The construction of regional multimodal transport system and economic development have a certain mutual feedback relationship. Combining with regional GDP information, this paper preliminarily explores the correlate on between regional transport network connectivity and economic linkages (Figure 2). Based on SPSS software, clustering analysis is carried out for different cities'connectivity evaluation values, taking the connectivity Index of 4.0, 3.5 and 2.5 as the limit index, which are divided into four grades: good connectivity, good connectivity, general connectivity and poor connectivity. Grating interpolation function in Arcgis is used to construct connectivity level schematic figure 3.

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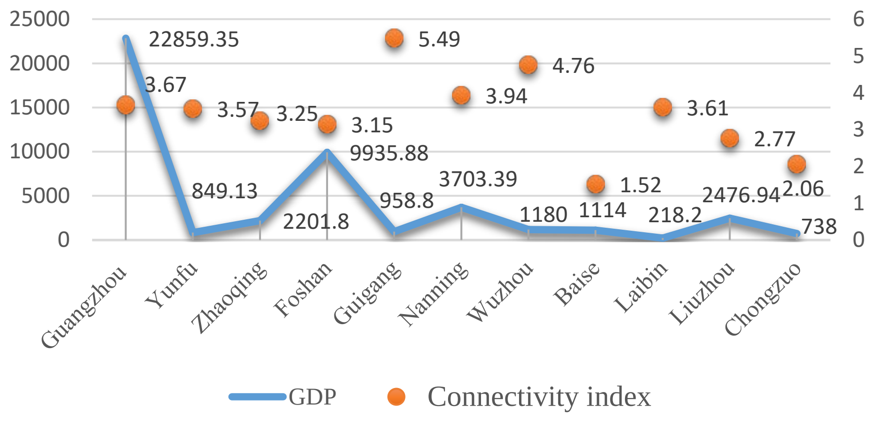

Figure. 2 Evaluation of Transportation Connectivity

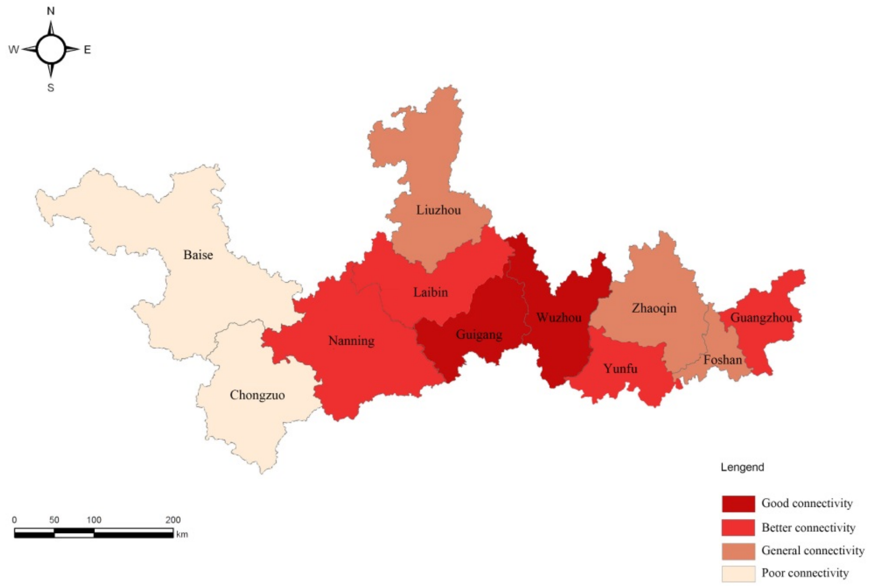

Figure. 3 Connectivity level classification diagram

From Figure 3, it can be seen that the spatial distribution of the connectivity of the multimodal transport system in the Pearl River-Xijiang Economic Belt is unbalanced, and there are obvious differences among regions.Gener- ally speaking,

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the advantages of regional central urban agglomeration are obvious, with Guigang and Wuzhou as the regional centers, showing a decreasing trend towards the periphery, showing a horizontal and vertical distribution along the backbone traffic network.

Guangzhou and Nanning, as the core development cities of the Pearl River-Xijiang Econ- omic Belt, play an important role in promoting radiation in the whole region, especially in the surrounding areas. However, their connectivity connectivity is insufficient compared with Guigang and Wuzhou. Guests and Yunfu are more neutral and play an important role in regional multimodal transport network. The connectivity level of Liuzhou, Zhaoqing and Foshan is at the middle level in the region. Compared with the remote cities in the west, the transportation infrastructure construction is relatively perfect, but there is still a certain gap compared with the central cities. Baise and Zhaoqing have the worst connectivity and need to be further strengthened in the construction of their foreign transport system.

Combining with Figure 1, it shows that the economic links of highways, railways and port stations in the eastern and eastern part of the region are close, but the links between core cities and sub-core cities, as well as cities in remote areas are not close, which will affect the formation and stability of the whole multimodal transport network and regional economic links network, and is not conducive to the development of regional integration.

4. Conclusion

Transportation network is the key carrier of intercity industry, economy and other flows, which is of great significance to the social and economic links in the region. Combining the interaction and connection between transportation network and city can not only make up for the limitation of spatial attribute description, but also give full play to the advantages of social network analysis. Based on Arcgis, this paper analyses the connectivity of transportation network in the multimodal transportation system of Pearl River-Xijiang Economic Belt, and evaluates the connectivity of transportation network in each node city comprehensively. The results show that:

1) According to the analysis of regional connection level at present, we need to focus on strengthening the construction of expressway and railway facilities in Baise and Chongzuo, and speed up the process of freight connection with other cities. At the same time, we should strengthen the connection and coordination between Guangzhou, Nanning and the surrounding and remote cities in the development of multimodal transport, so as to realize the sustainable development of region of regional cohesion and outreach.

2) The development of multimodal transport in the Pearl River-Xijiang Economic Zone is based on the deepwater waterways of the Pearl River and the Xijiang River and centered on the Inland ports. Therefore, in the process of overall layout of multimodal transport hub, the inland waterway transport should be taken as the starting point.

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