

Quantitative Study on Relationship between Regional Spatial Structure and Regional Intercity Rail Transit Network

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Abstract: The regional spatial structure and traffic system have the time and space interactive relationship. In this paper, a new graph is described for the relationship between regional spatial structure and regional intercity rail transit network. Taking Wuhan urban agglomeration as an example, the quantitative relationship between the spatial structure and the intercity rail transit network is analyzed. Study results: (1) The main economic relation intensity network and the intercity rail transit network have a correlation. (2) The economic relation intensity between cities is strongly related to the passenger volume. (3) The economic relation intensity and the intercity rail transit construction schedule also have a high correlation. Therefore economic relation intensity is the foundation of regional intercity rail traffic network layout.

1. Introduction

Regional spatial structure is the spatial distribution state and spatial interaction relationship of regional economic activities. It has the time and space interactive relationship with traffic system. In the time dimension, they are developed simultaneously. In the space dimension, urban spatial layout determines the spatial pattern of transportation network, and it is the main contribution factor of transportation network. Economic space layout and population spatial distribution determine the level of the transportation lines. At the same time, the transportation network reacts to the spatial structure and guides the development of spatial structure. According to the development experience of developed countries, it is pointed out that there exists close spatial relations between urban agglomerations and intercity rail transit [1]. Literature [2] systematically analyzed the interaction mechanism of intercity rail transit and urban agglomeration spatial structure, and their connotation and influencing factors. Based on the dynamic feedback mechanism between traffic system and urban spatial structure and bus-oriented development strategy, the research on passenger flow forecast of intercity rail transit corridor was carried out [3]. So domestic and foreign scholars have agreed that the regional traffic and urban agglomeration spatial structure has mutual relationship, but the current research on the relationship between the two mostly qualitative description. This paper is quantitative proved the internal logic between regional spatial structure and intercity rail network.

2. The relationship between regional spatial structure and intercity rail transit network

The concept of regional spatial structure is abstract. In order to facilitate research, this paper explains regional spatial structure in five aspects: the population spatial layout, economic spatial layout, urban



spatial layout, traffic facilities spatial layout and intercity relations. The first four represent the spatial location of economic activity. Intercity relations represent the interaction between economic objects, including political and economic. The political mainly refers to the administrative management relations, the economic relations mainly reflect in intercity passenger flow, logistics, information flow, capital flow and so on.

(1) *Regional spatial structure determines the spatial pattern of intercity rail transit network.*

The urban spatial layout is the structural reason of traffic demand. It determines the main origin and destination of passenger flow in the region, and determines the spatial pattern of regional intercity rail transit. The economic spatial layout, population spatial layout and intercity relationship determine the size of the passenger flow and the level of the transportation lines. The spatial scale of the region determines the choice of the passenger's transportation mode to a certain extent. Therefore, the intercity rail transit network layout should be compatible with the spatial structure.

(2) *As a large volume, rapid and public transport mode, the regional intercity rail transit has strong feedback and remodeling effect on the evolution of regional spatial structure [4].*

① As a fast mode of transportation, regional intercity rail transit has greatly changed the accessibility of regional space. It guides the restructuring of the industrial space and reasonable distribution of population [5]. It has an important role in promoting the development of regional integration.

② The characteristics of large volume and public transportation of regional intercity rail transit make the connection between cities more convenient and close. There has corridor effect and regional urbanization effect in the region. The advantage of urban location along the intercity rail has changed. This inevitably brings about the reconstruction of the regional space, and forms a new balanced development structure.

③ The sites of regional intercity rail transit also play a role of reconstruction for some of urban interior space. Under normal circumstances, the site will be the center of the formation of a circle structure model, and may be coupled with the existing spatial structure.

In summary, regional intercity rail transit is a product of regional development to a certain stage. In the spatial structure, they form a certain spatial mapping relationship. Regional intercity rail transit will not only meet the regional traffic demand, but also play a strong role in feedback and guidance to the development of regional spatial structure (Figure 1). They will always be two-way dynamic feedback relationship [6]. Therefore, the regional intercity rail transit network layout should be coordinated with the regional spatial development.

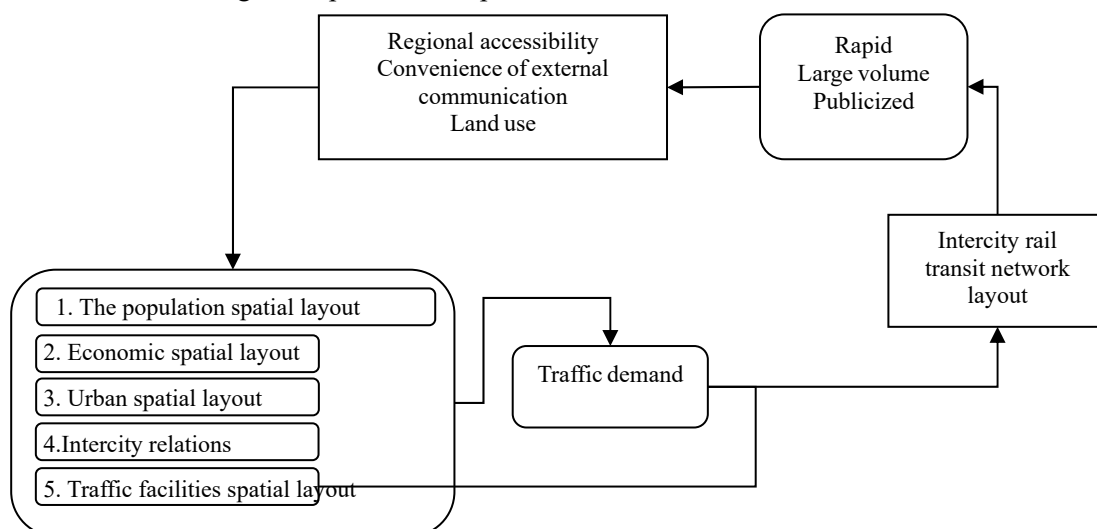


Fig.1 The graph described for the relationship between regional spatial structure and regional intercity rail transit network

3. The relationship between regional intercity and rail transit network

Economic relation intensity is a quantitative index to reflect intercity relations. In the quantitative research on regional economic relations, many scholars at home and abroad have applied the gravitational model of spatial interaction extensively [7-8]. The economical relation intensity model commonly indicates as follows .

$$F_{ij} = \frac{\sqrt{P_i G_i} \times \sqrt{P_j G_j}}{r_{ij}^2} \quad (1)$$

Tab. 1 Definition of parameters and sets

Parameter and set	Definition
$i \ j$	city i and j
F_{ij}	Economical relation intensity between city i and j
$P_i \ P_j$	City population of city i and j
$G_i \ G_j$	Gross Domestic Product of city i and j
r_{ij}	The distance from city i to j (time distance or space distance)

In the regional space system, cities form a closely linked city network, and the weights used on the networks represent different networks. When using economical relation intensity as the weight, it forms a regional urban economical relation intensity network. The urban economical relation intensity network reflects regional intercity relations. It also reflects the regional spatial structure to a certain extent.

(1) The economical relation intensity network in regional cities

In order to facilitate analysis, the urban nodes which planning population is more than 300,000 (in 2020) will be selected. According to the overall planning of Wuhan urban agglomeration, there are 13 cities, including Wuhan, Huangshi, Huanggang, Ezhou, Xiaogan, Xiantao, Xianning, Qianjiang, Tianmen, Macheng, Anlu, Hanchuan and Chibi. The economical relation intensity values between 13 cities are calculated by formula (1). They are arranged in descending order (Table 2).

Tab. 2 Sort descending of economic relation intensity in Wuhan urban agglomeration

Ranking	cities	economic relation intensity
1	Huanggang - Ezhou	792.43
2	Wuhan - Xiaogan	542.92
3	Wuhan - Huanggang	498.48
4	Wuhan - Ezhou	395.96
5	Wuhan - Huangshi	390.58
6	Huangshi - Ezhou	377.9
7	Huangshi - Huanggang	319.7
8	Wuhan - Hanchuan	245.25
9	Wuhan - Xianning	191.44
10	Wuhan - Xiantao	139.31
11	Xiaogan - Hanchuan	71.52
12	Wuhan - Tianmen	62.08
13	Macheng - Wuhan	54.52
14	Anlu - Wuhan	50.9
15	Wuhan - Qianjiang	49.26
16	Wuhan - Chibi	44.23

Note: The urban population is taken into account of the urban population predicted in the overall planning of each city, and the GDP of each city is calculated according to the average annual growth rate method.

To ensure connectivity between the 13 cities, select the top 16 in the ranking. Network diagram of the main economic relation intensity (Figure 2) is constituted. The main sorting ahead are the economic relations between the cities and Wuhan, and the relations between the other cities are weak. Ezhou, Xiaogan, Huangshi, and Huanggang are closely related to Wuhan. The economic relation intensity between Huanggang, Huangshi and Ezhou are also strong. These characteristics are basically consistent with [9].

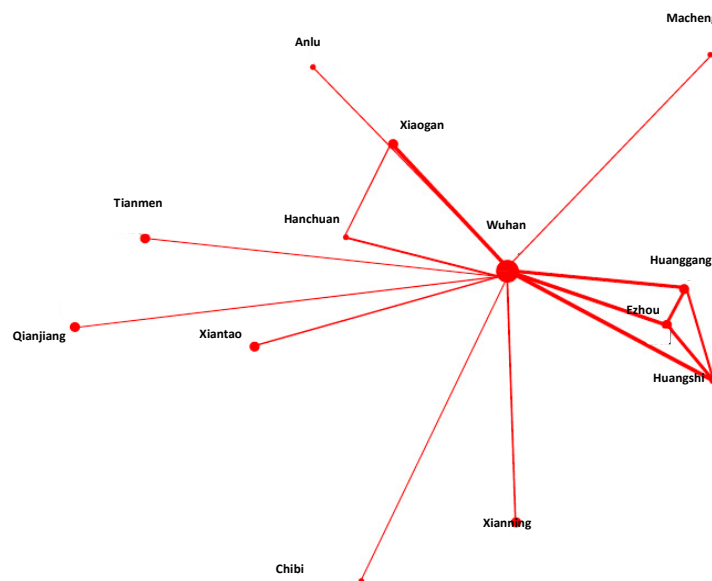


Fig.2 The network diagram of main economic relation intensity in Wuhan urban agglomeration

(2) *Correlation analysis between the main economic relation intensity network and intercity rail transit network*

① The matrix of main economic relation intensity

The main economic relation intensity network is represented by a matrix, that is, if economic relation intensity between the two cities is the main economic relation, it is represented by 1, if not, represented by 0 (Table 3).

Tab. 3 The matrix of main economic relation intensity in Wuhan urban agglomeration

Cities	Wuhan	Huangshi	Ezhou	Xiaogan	Huanggang	Hanchuan	Xianning	Xiantao	Anlu	Macheng	Tianmen	Chibi	Qianjiang
Wuhan	1	1	1	1	1	1	1	1	1	1	1	1	1
Huangshi	1	1	1	0	1	0	0	0	0	0	0	0	0
Ezhou	1	1	1	0	1	0	0	0	0	0	0	0	0
Xiaogan	1	0	0	0	1	0	0	0	0	0	0	0	0
Huanggang	1	1	1	0	0	0	0	0	0	0	0	0	0
Hanchuan	1	0	0	1	0	0	0	0	0	0	0	0	0
Xianning	1	0	0	0	0	0	0	0	0	0	0	0	0
Xiantao	1	0	0	0	0	0	0	0	0	0	0	0	0
Anlu	1	0	0	0	0	0	0	0	0	0	0	0	0
Macheng	1	0	0	0	0	0	0	0	0	0	0	0	0
Tianmen	1	0	0	0	0	0	0	0	0	0	0	0	0
Chibi	1	0	0	0	0	0	0	0	0	0	0	0	0
Qianjiang	1	0	0	0	0	0	0	0	0	0	0	0	0

② Constructing the adjacency matrix of intercity rail transit network

The recommended scheme in [10] is abstracted into a network diagram of intercity rail transit network. This network diagram takes the cities as nodes, and the intercity rail between the cities are the edges. Then the adjacency matrix of intercity rail transit network is constructed. In the matrix, 1 represents a direct connection with intercity rail transit, and 0 represents no direct connection (Table 4).

Tab. 4 The adjacency matrix of inter-city rail transit network in Wuhan urban agglomeration

Cities	Wuhan	Huangshi	Ezhou	Xiaogan	Huanggang	Hanchuan	Xianning	Xiantao	Anlu	Macheng	Tianmen	Chibi	Qianjiang
Wuhan		0	1	1	1	1	1	1	0	1	0	0	0
Huangshi	0		1	0	0	0	0	0	0	0	0	0	0
Ezhou	1	1		0	1	0	0	0	0	0	0	0	0
Xiaogan	1	0	0		0	1	0	0	1	0	0	0	0
Huanggang	1	0	1	0		0	0	0	0	1	0	0	0
Hanchuan	1	0	0	1	0		0	0	0	0	1	0	0
Xianning	1	0	0	0	0	0		0	0	0	0	1	0
Xiantao	1	0	0	0	0	0	0		0	0	0	0	1
Anlu	0	0	0	1	0	0	0	0		0	0	0	0
Macheng	1	0	0	0	1	0	0	0	0		0	0	0
Tianmen	0	0	0	0	0	1	0	0	0	0		0	0
Chibi	0	0	0	0	0	0	1	0	0	0	0		0
Qianjiang	0	0	0	0	0	0	0	1	0	0	0	0	

③ Correlation analysis between the economic relation intensity and intercity rail network

Using the social relation software UCINET, it is a software tool for analyzing complex networks. To calculate the correlation relationship these two networks using the QAP command in UCINET. QAP (Quadratic Assignment Procedure) is the study of "relationship" data, it can be used to study the correlation between the two "relationship" matrices. The results are shown in Table 5.

Tab. 5 The correlation analysis results

The results	Value
Obs Value(Actual correlation coefficient of two networks)	0.558
Significa(Significant level)	0
Average(The mean value of correlation coefficient calculated by random permutation)	-0.004
Std Dev(The standard deviation of correlation coefficient calculated by random permutation)	0.135
Minimum(The minimum value in the correlation coefficient of random permutation)	-0.167
Maximum(The maximum value in the correlation coefficient of random permutation)	0.477

Tab.6 The range judgment of correlation intensity [11]

The range of correlation intensity	correlation degree
1	Complete correlation
0.70-0.99	Highly correlation
0.40-0.69	Moderate correlation
0.10-0.39	Low correlation

<0.10

Weak correlation or irrelevant

As shown in Table 5, the correlation coefficient between the two networks is 0.558. According to the range judgment of correlation intensity (Table 6), it shows that the economic relation intensity is moderately related to the intercity rail network in Wuhan urban agglomeration. This indicates that the economic relation intensity network affects the formation and development of intercity rail network, and also shows that the regional spatial structure affects the formation and development of intercity rail network.

4. Correlation analysis between economic relation intensity and passenger flow, intercity rail transit constructing schedule

(1) Correlation analysis between economic relation intensity and passenger flow

Taking Henan province as an example, [12] studied the relationship between economic intensity and regional intercity passenger flow, and concluded that the correlation coefficient between the two is 0.922. Perform a correlation analysis between the two variables in Wuhan urban agglomeration (Figure 3). The calculating the correlation coefficient is 0.872. The result shows that the urban economic intensity is strongly correlated with the passenger flow between the two cities. So the economic intensity can better reflect the actual situation of passenger communication between cities.

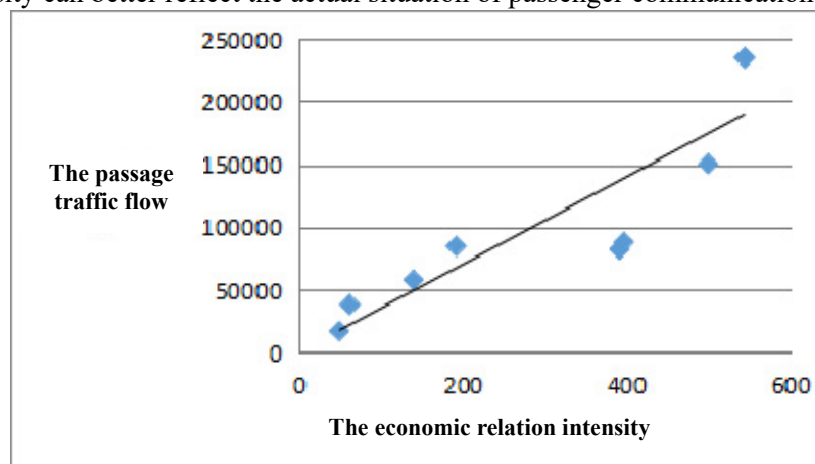


Fig.3 The correlation analysis between economic relation intensity and passage traffic flow

Note: The data are from [10].

(2) Correlation analysis between economic relation intensity and intercity rail transit constructing schedule

According to [10], the recent implementation of the line are Wuhan-Xiaogan, Wuhan - Ezhou - Huangshi, Wuhan - Xianning ge (Wuhan) – Huanggang. Compared with Table 1, these lines have strong economic intensity. They are all ranked in front of Table 2. It shows that the economic intensity is highly correlated with intercity rail transit constructing schedule

5. Conclusion

Taking Wuhan urban agglomeration as the background, it verified regional spatial structure and intercity rail transit network have internal logical relationship from a quantitative point of view. The results are as follows: (1) The main economic relation intensity network and the intercity rail transit network have a correlation. (2) The economic relation intensity between cities is strongly related to the passenger volume. (3) The economic relation intensity and the intercity rail transit construction schedule also have a high correlation. Therefore economic relation intensity is the foundation of regional intercity rail traffic network layout. In addition, the model of economic relation intensity adopted the gravitational model which is commonly used in economic geography. It only considers the urban economic scale, population size and the distance between the two cities. But many factors can

affect the economic connection between two cities. It will make the model more reasonable by appropriately modifying the model.

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