

Study on the Method of Defining the Spatial Scope of Urban Agglomeration

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Abstract. This paper researches the Chang-Zhu-Tan urban agglomerations, uses the gravitational model and the field strength model, based on the gross production of the city, the urban population, economic distance and commuting time four aspects index system, calculates the gravitational and field strength values of the core city of Changsha to the Chang-Zhu-Tan urban agglomerations, and obtains theoretically spatial extent of the Chang-Zhu-Tan urban agglomerations. The result shows that: the spatial extent of the Chang-Zhu-Tan urban agglomerations the Government establishes is consistent with the spatial extent and theoretical calculations; while the 2.4 calculation result proves that the application of gravity model and field intensity model is feasible to define the spatial extent of urban agglomeration.

In order to find a scientific method to define the spatial scope of urban agglomeration, a theoretical method for measuring the gravitational range of cities and an empirical method for analyzing element flow among the cities are used in the paper as well as considering the proximity of the regional space and the strength of the government role, taking changzhutan urban agglomeration and the changzhutan "3+5 urban agglomeration which the government is vigorously promoting as example, the spatial scope of changzhutan urban agglomeration is defined through quantitative and qualitative comprehensive analytical method.

1 Related theories of Changzhutan urban agglomeration

1.1 Relevant theories related to spatial structure of urban agglomeration

Urban agglomeration refers to a large number of cities of different nature, types and rating scale in the specific geographic range, based on a certain natural environment conditions, with one or two large or super-large city as a regional economic core and with the help of modern transportation and accessibility of the comprehensive transportation network, as well as the highly developed information network, inner links between the cities occur and develop and constitute a relatively complete city "collection"[1].

After the 1950's, the theoretical circle didn't limit the research of urban agglomeration to the method of qualitative analysis, but they started to carry on the quantitative research. For example, it used some mathematical models of mathematics, physics,

economics to research the scope and boundaries of urban agglomeration and made a series of achievements, especially on the study of urban agglomeration spatial structure, so many structural models of urban agglomeration has been produced, and the striking ones are the gravity model and field strength model [2].

1.1.1 Gravity model

Referring to Newton's universal gravitation model and based on the theory of spatial interaction, the gravity model believes that the interaction between towns is proportional to the size of the town and inversely proportional to the distance between towns, as shown in Formula 1-1:

$$I_{ij} = \frac{(W_i P_i)(W_j P_j)}{D_{ij}^b} \quad (1-1)$$

I_{ij} , D_{ij} are respectively the interaction quantity and distance between towns I and J; P_i , P_j are respectively the urban population size of the towns I and J; W_i , W_j are the weight determined by experience; b is the index to measure the friction action of distance, theoretically equal to 1.0 or 2.0, and can vary from 0.5 to 3.0. The strength of the interaction forces reflects the intensity of the connections between towns.

The gravity model can calculate a pair of expected interactions between cities, but to calculate the interaction amount between a town and all the towns in the system, including itself, The gravity model can be used to calculate the interaction amount and then the sum can be used to obtain the potential model, as shown in Formula 1-2:

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$$\sum_j^n = 1 I_{ij} = \sum_j^n = 1 \left(\frac{P_i P_j}{D_{ij}^b} \right) + \frac{P_i P_j}{D_{ij}^b} \quad (1-2)$$

D_{ij} is half the distance between town i and its nearest town, or the average radius of the area of city i , and n is the total number of towns. The potential index reflects the agglomeration capacity of the town in the system.

Divide both sides of formula 1-2 by A to get formula 1-3:

$$\sum_j^n = 1 \frac{I_{ij}}{P_i} = \sum_j^n = 1 \frac{P_j}{D_{ij}^b} + \frac{P_j}{D_{ij}^b} \quad (1-3)$$

Formula 1-3 means that the total amount of interaction in city i is expressed as the amount of interaction per person or per unit mass.

1.1.2 Field strength model

The model of urban field strength is an econometric model to calculate the urban radiation influence by using the interaction between urban and regional space. As the core of a certain regional spatial structure, the city has the functions of agglomeration and diffusion, affecting the surrounding area. Based on the hypothesis of regional homogeneity, using the concept of physics, the influence range of a city can be called the "force field" of its influence, and the size of its influence is called the "field strength". Therefore, taking the comprehensive scale of the city as the comprehensive variable to evaluate the geographical field strength of the city, a gravity model is established for a central city and any point other than it. The calculation formula is 1-4:

$$S_{ik} = \frac{F}{D_{ik}^a} \quad (1-4)$$

S_{ik} is the field strength of City F at point k ; F is the comprehensive scale of city i ; D_{ik} is the distance between city i and point k ; a is the distance friction coefficient, which is generally taken as 2.0.

1.2 Chang-Zhu-Tan urban agglomeration

The changzhutan "3+5" urban agglomeration is centered on "3" (including the changzhutan urban agglomeration within the administrative divisions of Changsha, Zhuzhou and Xiangtan); With "5" (namely the five cities of Yueyang, Changde, Yiyang, Loudi and Hengyang with changzhutan as the center commuting circle of 1.5 hours) as the main development hinterland and the urban agglomeration developed based on rapid transportation theory.

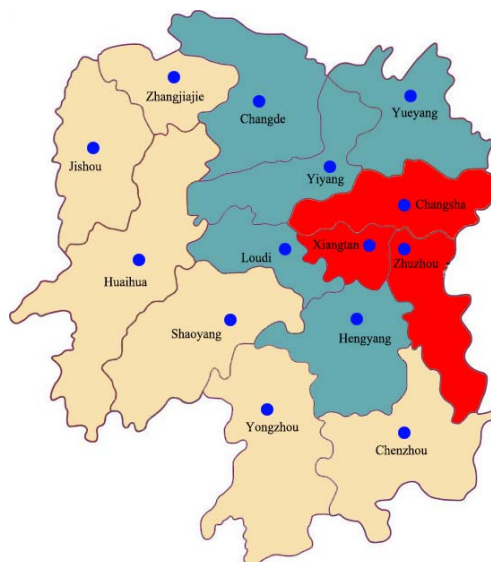


Fig.1. Geographical location of Changzhutan 3+5 urban agglomeration.

2 Define the scope of Changzhutan 3+5 urban agglomeration based on gravity model and field strength model

For a long time in the future, the development of Changzhutan 3+5 urban agglomeration will lead the regional development of Hunan Province. The determination of the core city in The Changzhutan 3+5 urban agglomeration and the determination of the economic distance between the core city and the cities within the urban agglomeration become an important factor to study the scientific spatial scope of the Changzhutan 3+5 urban agglomeration.

2.1 Determination of core cities

The core city of urban agglomeration is the city with the most developed economy and the most complete industrial development in the region. Only in this way can it attract and radiate the surrounding cities. In addition, the core city should also be the transportation core of the region, which can connect the whole urban agglomeration into a whole.

Considering China's actual situation, the selection of core cities should firstly meet the following basic conditions : (1) the size of urban non-agricultural population in core cities must be over 500,000; (2) The proportion of non-agricultural population is above 60%; (3) GDP holds the absolute lead in the region; (4) It is the city with the most convenient regional transportation [3].

For The 3+5 urban agglomeration of Changzhutan, Changsha is located in the center of the region geographically. In terms of regional functions, Changsha is the capital city of Hunan Province, leading the economic, political and cultural development of the province. In terms of urban development, Changsha has the highest non-agricultural population, urbanization rate, GDP and per capita GDP in the region. Therefore,

Changsha is undoubtedly the regional core city of Changzhutan urban agglomeration.

Table 1. Comparison of basic conditions of different cities in Changzhutan 3+5 urban agglomeration.

Cities	Urban non-agricultural population (10,000)	Urbanization rate	GDP (100 million yuan)	Per capita GDP (yuan)
Changsha	509.86	70.6%	7153.13	99570
Zhuzhou	236.54	60.12%	1949.43	49723
Xiangtan	154.26	55.10%	1443.06	51717
Yueyang	282.5	50.82%	2435.51	43953
Changde	257.64	44.38%	2264.94	39169
Yiyang	189.40	43.31%	1123.13	25773
Loudi	157.03	40.96%	1118.17	29249
Hengyang	348.73	48.1%	2169.44	30030

2.2 Determination of economic distance

According to the research of Gao Ruxi and Luo Mingyi, the calculation of inter-city distance should be based on the actual distance between cities, and the commuting distance can be obtained by taking traffic conditions as the weight and making the first revision. Then, the economic distance between surrounding cities and central cities can be obtained by taking the weight of urban gap and making the second revision [4]. The formula is 2-1:

$$E = \alpha \cdot \beta \cdot D \quad (2-1)$$

in the formula:

E is the economic distance; D is spatial distance; And α , β are the modified weights.

α is the first correction weight (commuting distance correction weight), whose value is determined by the inter-city traffic conditions, as is shown in Table 2. β is the second correction weight (economic gap correction weight), whose value is determined by the ratio of per capita GDP of surrounding cities and core cities. The specific value is shown in Table 3:

Table 2. Correction weight value of the commuting distance.

The correction weight value of commuting distance							
vehicles	train	automobile	steamer	train & automobile	train & steamer	automobile & steamer	train & automobile & steamer

Weight value α	1.0	1.2	1.5	0.7	0.8	1.1	0.5
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Table 3. Correction weight value of economic distance.

Weight of correction of economic gap				
Per capita GDP of surrounding cities	GDP of cities/core cities	>70%	70% ≥ ratio ≥ 45%	<45%
Weight value β		0.8	1.0	1.2

The economic distance between the relevant 7 cities and Changsha is calculated as shown in Table 4.

Table 4. Economic distance of 7 related cities to Changsha.

Surrounding cities	Space distance (km)	Traffic conditions	Value α	Ratio of the city's GDP to Changsha's GDP	Value β	Economic distance
Xiangtan	44.3	Railways, roads, shipping	0.5	20.2%	1.2	26.6
Zhuzhou	48.2	Railways, roads, shipping	0.5	27.3%	1.2	28.9
Yueyang	126.12	Railways, roads	0.7	34.0%	1.2	105.9
Changde	148.83	Railways, roads	0.7	31.7%	1.2	125
Yiyang	66.91	Railways, roads	0.7	15.7%	1.2	56.2
Hengyang	152	Railways, roads	0.7	30.3%	1.2	127.7

Loudi	109.7	Railways, roads	0.7	15.6%	1.2	92.1
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2.3 Modification of gravity model and determination of field strength model

Gravity model is a common measuring method to study the space between cities and urban agglomerations. Traditionally, formula 2-2 is used for calculation.

$$I_{ij} = \frac{(W_i P_i)(W_j P_j)}{D_{ij}^b} \quad (2-2)$$

I_{ij} , D_{ij} are respectively the interaction quantity and distance between towns I and J; P_i , P_j are respectively the urban population size of the towns I and J; W_i , W_j are the weight determined by experience; b is the index to measure the friction action of distance.

In order to improve the validity of the results of urban attraction, many scholars modify the gravity model.

Firstly, $(W_i P_i)(W_j P_j)$ is represented by the concept of urban quality,

P is the number of urban population and G is the gross urban product. Secondly, the distance between cities and towns is extended, concepts such as economic distance and commuting time are proposed, and the calculation model of gravity model to calculate the scope of urban agglomeration is proposed.

According to the above modified calculation of the gravity model, formula 2-2 can be expressed as 2-3:

$$I_{ic} = \frac{\sqrt{(P_i G_i)(P_c G_c)}}{E_{ic}^2} \quad (2-3)$$

in the formula: I_{ic} represents the attraction between city i and city c; P_i , P_c represents the urban population of city i and city c respectively; G_i , G_c represents the gross urban product of city i and city c respectively; E_{ic} represents the economic distance between city i and city c; i is the surrounding city and c is the core city.

In the region, the core city not only attracts the surrounding cities and regions. In the gravitational field of region, the field intensity at different positions is different, which leads to the field intensity model, whose formula is 2-4:

$$S_{ic} = \frac{\sqrt{P_c G_c}}{E_{ic}^2} \quad (2-4)$$

in the formula: S_{ic} represents the field strength of the core city, P_c represents the urban population of the core city, G_c represents the gross product of the core city, E_{ic} represents the economic distance between city i and city c, i is the surrounding city and c is the core city.

The gravity and field strength are calculated to the cities within the changzhutan 3 + 5 urban agglomeration with Changsha as the core city with above gravity model and field model. And then according to the size of the measuring results, these cities can be divided into four groups. The smaller the value of the group, the greater the number the number assigned to each city's group in the city of gravity determination value Y' and field strength determination C' , similarly to the surrounding city, according to the above calculation of the size of the cities and changsha economic distance is divided into four groups, E' is defined as economic distance fixed value.

The above E' , Y' and C' are taken as the equivalent of judgment to determine the close degree of economic connection between the 7 cities around Changsha and Changsha so as to determine whether these cities are within the spatial scope of Changzhutan 3+5 urban agglomeration. The judgment criterion is: if two of the three are less than 4, they are considered to be in the urban agglomeration. Otherwise, they are not viewed as in the urban agglomeration.

2.4 Calculation Results

Table 5. Gravity and field strength values of 7 cities related to Changsha.

Cities	GDP of municipal districts (100 million YUAN) (G)	Population of municipal districts (10,000) (P)	Economic distance (E)	Gravity value (I)	Field strength (S)
Xiangtan	1443.06	279.96	26.6	2042	3.21
Zhuzhou	1949.43	393.45	28.9	2383	2.72
Yueyang	2435.51	555.90	105.9	235.8	0.20
Changde	2264.94	580.48	125	166.8	0.15
Yiyang	1123.13	437.29	56.2	504.3	0.72
Hengyang	2169.44	725	127.7	174.8	0.14
Loudi	1118.17	383.39	92.1	175.4	0.03
Changsha	7153.13	722.14			

Table 6. Economic distance equivalent of 7 cities related to Changsha.

Number	1	2	3	4
The range of economic distance	$0 < E \leq 100$	$100 < E \leq 200$	$200 < E \leq 300$	$E > 300$
Cities	Xiangtan, Zhuzhou, Yiyang, Loudi	Yueyang, Changde, Hengyang		

Table 7. Gravity equivalent of 7 cities related to Changsha.

Number	1	2	3	4
The range of the field strength	$I > 500$	$500 > I \geq 100$	$100 > I \geq 10$	$10 > I \geq 0$
Cities	Xiangtan, Zhuzhou, Yiyang	Yueyang, Changde, Hengyang, Loudi		

Table 8. Field strength equivalent of 7 cities related to Changsha.

Number	1	2	3	4
The range of the field strength	$S > 0.5$	$0.5 \geq S > 0.1$	$0.1 \geq S > 0.05$	$0.05 > S \geq 0$
Cities	Xiangtan, Zhuzhou, Yiyang	Yueyang, Changde, Hengyang		Loudi

Table 9. Theoretical space range of 3+5 Chang-Zhu-Tan urban agglomerations.

Cities	Equivalent of judgment(E' , Y' , C')	Within the urban agglomerations limits or not
Xiangtan	(1, 1, 1)	Yes
Zhuzhou	(1, 1, 1)	Yes
Yueyang	(2, 2, 2)	Yes

Changde	(2, 2, 2)	Yes
Yiyang	(1, 1, 1)	Yes
Hengyang	(2, 2, 2)	Yes
Loudi	(1, 2, 4)	Yes

The above calculation results show that the spatial scope of Changzhutan 3+5 urban agglomeration with Changsha as the center includes Changsha, Zhuzhou, Xiangtan, Hengyang, Yueyang, Changde, Yiyang and Loudi. The spatial scope of Changsha-Zhuzhou-Xiangtan 3+5 urban agglomeration determined by the government is consistent with the theoretical calculation of spatial scope; At the same time, it is proved that it is scientific to use gravity model and field strength model to define the spatial scope of urban agglomeration.

3 Result Analysis

The above results of the changsha-Zhuzhou-Xiangtan 3+5 urban agglomeration based on gravity model and field strength model with Changsha as the central city are consistent with the current planning scope of Changsha-Zhuzhou-Xiangtan 3+5 urban agglomeration based on regional adjacency planning. The conclusion is as follows: the economic relations between the cities in the planning of Changzhutan 3+5 urban agglomeration and the central city Changsha meet the corresponding standards; This is mainly based on the following reasons: Firstly, it has been thirteen years since 2007 when Changzhutan urban agglomeration was listed as a "two-oriented" social pilot city development area, and in 2008 when Hunan Provincial Development and Reform Commission put forward the concept of Changzhutan 3+5 urban agglomeration. The influence and radiation of the central city Changsha on the surrounding cities are constantly increasing, and the economic and trade relations with the surrounding cities are relatively close, thus greatly promoting the development of the integration process of Changzhutan.

Secondly, Changsha, the central city, is a city with an urban population of 7.2214 million and a GDP of only 715.313 billion (2013 data). Regional leadership and economic radiation have been highlighted. It is relatively close to the 7 surrounding urban agglomerations (within 150 kilometers) and restricted by the central geographical location. Only Changsha has the influence of a regional center city.

Thirdly, for the cities in the 3+5 urban agglomeration of Changzhutan, according to the core-edge theory, they have been radiated by the economic and material flow of the core city. In the same way, they feed back the central city. In the state of market economy, the whole region and larger regions outside the region are included in an overall market, and they begin to have close links with

the central city, but such links are still limited in breadth and depth, and need to be accumulated over a long period of time.

Fourthly, urban agglomeration is an aggregation composed of several neighboring cities with different development directions with regional central cities as the core. The cities within the regional scope of the urban agglomeration develop together due to mutual attraction and cooperation economically. Changsha is located in the northeast of Hunan Province. Economically, Changsha has strong heterogeneity with Changzhutan 3+5 urban agglomeration. The economic radiation of Changsha to other cities is strong, thus resulting in strong economic linkage. The enhancement of absorbing power will inevitably make it get better development opportunities within the space of urban agglomeration.

Fifthly, in urban agglomeration planning, scientific and reasonable spatial scope of urban agglomeration is conducive to integrating various urban resources and promoting rapid and sustainable urban development[5]. The gravity model and field strength model can be used to scientifically define the spatial scope of urban agglomeration.

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