Assessment of Development Equilibrium of Changsha-Zhuzhou-Xiangtan Urban Agglomeration Based on Passenger Car Data

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Abstract. Urban agglomeration is a regional unit or spatial form of urbanization and economic integration development. Since governments attach more and more importance to the urban agglomeration, the development of urban agglomeration has been rapidly advanced. However, the problem of insufficient and disequilibrium development of urban agglomeration is becoming very outstanding. Therefore, scientific assessment of the urban agglomeration development equilibrium can identify problems and rationally plan for their coordinated development in the future. We use the passenger car data which can better reflect the economic interaction between urbans within an urban agglomeration as the basic data. Then we extract the origin and the destination (OD) of each car trip by combining with the point of interest data close to the road network. Each car trip can be regarded as an interaction between the OD point.

In this paper, we take the Changsha-Zhuzhou-Xiangtan Urban Agglomeration (CZX UA) as the research object. We select car interaction intensity, urban GDP per capita, urban road mileage per unit area and car ownership per capita in CZX UA as the indicators to comprehensively evaluate the development equilibrium of CZX UA. The result reflects that there is a big difference between the interaction in urbans and the development degree from the eastern to the central regions of CZX UA is gradually decreasing, which can proffer advice for the future coordination and sustainable development of CZX UA.

1.Introduction

In 1957, the French geographer Gottmann first proposed the concept of urban agglomeration. He considered that the urban agglomeration was centered on one or more central cities with strong urban functions including several surrounding areas that have intrinsic economic links with urban agglomerations and the areas where the economic attraction and radiation can reach and promote the economic development of the corresponding regions[1]. Urban agglomeration is a regional unit or spatial form of urbanization and economic integration development[2]. It is a strategic support point, a growth pole and a core node in the global productivity distribution pattern and plays a role in the convergence and diffusion of the production factors across the country and the region[3]. The national “Eleventh Five-Year Plan” clearly proposed that the urban agglomeration would be the main form of promoting urbanization, and would gradually form an efficient and coordinated urbanization spatial pattern[4]. The national “Twelfth Five-Year Plan” further clearly stated that it was necessary to strengthen the coordinated development of various regions and gradually increase the radiation power of urban agglomerations[5]. In 2018, People's Daily Online “Grasping the Future Trend of Regional
Development Space " pointed out that regional integration based on urban agglomeration would become the core driving force for future regional development[6].

With the government’s emphasis on urban agglomerations, the development of urban agglomerations has been rapidly advanced, and urban agglomerations with different levels of development have emerged. In April 2006, in the "Opinions on Promoting the Development of the Central Region" issued by the Central Committee of the Communist Party of China and the State Council, it was clarified that the CZX UA was one of the four major urban agglomerations in the six central provinces supported by the state, which indicated that the development of the CZX UA has become a national strategy. In August 2012, the State Council issued the "Several Opinions of the State Council on Vigorously Implementing the Strategy for Promoting the Development of the Central Region". The document emphasized the in-depth implementation of the comprehensive plan for the comprehensive reform of the resource-saving and environment-friendly society in Changsha, Zhuzhou and Xiangtan urban agglomerations[7]. However, the development of the CZX UA is at a medium level and needs to be improved in all aspects. There is a large gap in development between cities within the urban agglomeration. Moreover, there are few related studies on the equilibrium of the development of CZX UA and the development differences of various regions within the CZX UA are not fully recognized. Therefore, the assessment of the equilibrium of the development of the CZX UA is of great significance for future development and can provide theoretical basis and reference suggestions for future development.

2. Research objects and data sources

2.1 Research object

The CZX UA, located in the central and eastern of Hunan Province, is centered on Changsha, Zhuzhou and Xiangtan, and including Yueyang, Changde, Yiyang, Loudi and Hengyang. The total area is 96,800 km², accounting for 45.8% of the area of Hunan Province. Among them, the central areas of Changsha, Zhuzhou and Xiangtan are less than 50 km and the margin is less than 10 km, which is known as the “Golden Triangle” of Hunan.

2.2 Data sources

The research data in this paper is about 115,000 passenger car GPS data from October 17 to 23, 2016. The average interval of vehicle track data recording is about 20 seconds. We first match these trajectory data with China road network. Then we extract the origin and the destination (OD) of each car trip by combining with the point of interest data close to the road network. In the last, 21,000 vehicle trajectory data within CZX UA are separated. Considering that the precise passenger traffic data is difficult to obtain, this paper assumes that the passenger volume of the bus is consistent and regards the total number of direct bus between cities in the CZX UA as the level of passenger interaction. In addition, this paper takes the bus operations once from the origin to the destination as one city interaction. The urban population, area, GDP per capita, car ownership and road mileage data mentioned in the paper are all derived from the 2016 Hunan Statistical Yearbook.

3. Assessment indicators and analysis

3.1 Assessment indicators

1. The total passenger interaction

   Passenger traffic flow is the main carrier of logistics, capital flow, information flow, technology flow and other data. The point-to-point direct intercity passenger traffic is efficient and fast and can reflect the business communications and commuting between urban nodes within the region[8]. The Passenger traffic data between the two cities within the urban agglomeration can fully reflect the level of interaction between the regions. The total passenger traffic can reflect the overall external interaction of the city, the level of urban development and the equilibrium of urban agglomeration development[9]. By preprocessing the passenger interaction data of each city in the CZX UA, extracting the passenger car ID,
Latitude and longitude and time, an interaction is recorded when the trajectory data with a round-trip regularity is detected. Count all the trajectory data and get the travel OD shown in figure 1.

2. GDP per capita

Real GDP per capita is an effective tool for people to understand and grasp the macroeconomic performance of a region. It is one of the most important macroeconomic indicators and often used as an indicator of economic development[10]. The GDP per capita of each region is analyzed to measure the development level of all the cities, and the results are shown in figure 2. The deeper the color of the region represents the per capita GDP of the city is higher.

3. Road mileage per unit area

The assessment indicator of development level of urban agglomeration should comprehensively reflect the development of it, not only the economic development, but also the social development indicators need to be fully reflected[11]. This paper analyzes the road mileage of each city in the CZX UA to analyze the urban social development level. In order to evaluate the urban transportation infrastructure more fairly and reasonably, this paper analyzes the development of each city with the road mileage per unit area because of the big difference in the area of each city, as shown in figure 3.
4. Car ownership per capita

The level of people's living standards can fully reflect the development level of the urban agglomeration. With the continuous development of the society and the improvement of people's living standards, every household has a private car basically. Therefore, this paper measures the level of people's living to reflect the development level of the CZX UA by the number of car ownership per capita. The number of car ownership per capita of cities in CZX UA is shown in Figure 3.

3.2 Assessment Method

1. Standardization

Due to the large difference in the dimension and numerical value of the assessment indicator, this paper uses the normalization method to make the data comparable. The indicators are standardized as in equation (1) and (2) so that all indicators take values between 0 and 1[12].

Positive indicator: 
\[ X_{ij}^* = \frac{x_{ij} - \min_j}{\text{Max}_j - \min_j} \]  
(1)

Negative indicator: 
\[ X_{ij}^* = \frac{\text{Max}_j - x_{ij}}{\text{Max}_j - \min_j} \]  
(2)

where \( x_{ij} \) is the original value of the indicator \( i \) in city \( j \); \( X_{ij}^* \) is the standardized value of \( x_{ij} \); \( \text{Max}_j \) and \( \min_j \) are the maximum value and minimum value of \( i \) indicator in the original data for all cities.

2. Coefficient of Variation

The coefficient of variation is a dimensionless coefficient that is suitable for comparing two sets of data and different mean values, which can eliminate the influence of inter-group spacing caused by the difference in the development level of urban agglomeration[13]. The greater the coefficient of variation is, the more disequilibrium of the development of the CZX UA is. This paper evaluates the coefficient of variation of each indicator in each region to measure the equilibrium of the development of the CZX UA. It is defined as the ratio of the standard deviation to the mean[14] as in equation (3).

\[ CV = \frac{\sigma}{\bar{x}}, \quad \sigma = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (x_i - \bar{x})^2} \]  
(3)

Where \( \sigma \) is the standard deviation, \( CV \) is the Coefficient of Variation, \( n \) is the total number of districts within the CZX UA, \( x_i \) the corresponding indicator of each region within the CZX UA, \( \bar{x} \) is the average value of each indicator within the CZX UA.

3.3 Assessment results

The coefficient of variation of the indicators for each city within the CZX UA is shown in Table 1.

| indicator                  | total passenger interaction | GDP per capita | road mileage per unit area | car ownership per capita |
|----------------------------|-----------------------------|----------------|----------------------------|--------------------------|
| Coefficient of Variation   | 1.31                        | 1.11           | 1.05                       | 0.69                     |

It can be seen from Table 1 that except for the coefficient of variation of car ownership per capita, the other coefficients of variation are bigger, which indicates that there is a big gap between the four indicators in the CZX UA. In particular, the values of the indicators of Changsha, Zhuzhou and Xiangtan are higher than other cities in the CZX UA. Changsha City is particularly prominent and plays a leading role. However, as an economic consortium, the development level of the CZX UA should depend on the common development of the CZX UA. Therefore, the core cities within the CZX UA should enhance their capabilities of agglomeration and radiation. They need to promote the common development of other regions to improve the overall development level of the urban agglomeration, and finally achieve regional coordinated development.
4. Assessment of the Equilibrium of the Development

4.1 Assessment Method
In order to facilitate the calculation of the data, each indicator data should be normalized firstly because of the large gap between the above four indicators. The normalized values of the indicators in the CZX UA are shown in Figure 4.

Based on the above four indicators, it is equally important to judge the coordinated development of CZX UA. Therefore, this paper combines the four indicators into a comprehensive indicator by using the average weighting method to reflect the development level of the CZX UA as in equation (4).

\[ F = 0.25X_1 + 0.25X_2 + 0.25X_3 + 0.25X_4 \]  

(4)

Where \( F \) is the assessment value of the development level of CZX UA, \( X_1, X_2, X_3 \) and \( X_4 \) are representing the normalized passenger interaction, GDP per capita, road mileage per unit area, car ownership per capita of each urban in CZX UA.

4.2 Assessment Results
We obtain the assessment values of the development level of each city in the CZX UA by substituting the indicators of each city into the formula (1), the result is shown in Table 2.

| city     | value | rank | city     | value | rank |
|----------|-------|------|----------|-------|------|
| Changsha | 0.268 | 1    | Changde  | 0.105 | 5    |
| Xiangtan | 0.137 | 2    | Hengyang | 0.095 | 6    |
| Zhuzhou  | 0.128 | 3    | Loudi    | 0.082 | 7    |
| Yueyang  | 0.115 | 4    | Yiyang   | 0.071 | 8    |

4.3 Classification of development level in CZX UA
The assessment values of development level of each city are obtained through the above method. The assessment values are clustered and divided into five categories to understand the development level of each region and the gap between cities more clearly as shown in Figure 5.
5. Summary
Base on the assessment method, this paper allows us to have a deeper understanding of the equilibrium of the development of CZX UA, and we can see that there is a big difference between the interaction in cities. The development level from the eastern part of Hunan Province to the central part is gradually decreasing. The characteristic of the coordinated development pattern centered on the Changsha, Zhuzhou and Xiangtan City is so obvious. Changsha, Zhuzhou and Xiangtan, as the core cities of CZX UA, should improve the radiation power, drive power and competitiveness to improve the development level of the hinterland cities. They should play a leading role to help other regions by making full use of the resources of the UA and try to narrow the gap between cities to improve the overall development level of the CZX UA.

Cities in less developed areas should strengthen infrastructure construction, improve transportation convenience to promote and strengthen economic interaction and ties with other regions. They should detail industry division of labor and layout, develop characteristic industries, transfer high-cost and non-dominant industries, and consider adjusting the regional industrial structure while not neglecting regional resources, environment and other factors. All the cities should strive to narrow the gap with other areas of the CZX UA and achieve regional coordinated development.

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