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Gis-based Urban Density on the Impact of Travel Demand Analysis

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Abstract. Urban density is one of the important factors to measure the occurrence of traffic in a region. It can not only reflect the intensity of traffic demand well, but also provide a way to quantitatively analyze the influencing factors of urban traffic demand. Take Nanchang and Jiujiang, cities with different geomorphic features, for example. The spatial analysis technique of GIS is used to calculate the urban density that can reflect the density difference. According to the characteristics of urban traffic demand, urban density is divided into single density and compound density. Through spatial statistical analysis, the impacts of various urban densities on traffic occurrence, travel distance, travel time and travel mode are analyzed. The research shows that different urban density corresponds to different traffic demand characteristics; In a certain threshold range, there is an obvious monotonic relationship between urban density and traffic demand.

1. Introduction

Urban density reflects the intensity of human social activities within the urban space, and it can reflect the indicative information of city-related activities. Urban density is an effective way for us to understand the law of urban development and change, so it can be used as an important index to study traffic demand. There are many factors affecting traffic demand, and most of these data are obtained mainly through mathematical statistics. In addition to this way, spatial statistical analysis based on density influencing factors can better reflect the spatial nature of interaction[1,2].

In general, the average density is used to represent the urban density, but the average density cannot describe the spatial difference of factors within the statistical range in detail, leading to a large deviation in the results. GIS can transform the discrete data obtained from statistics and surveys into continuous spatial distribution data according to a certain spatial calculation method, which can reflect the spatial difference. In this paper, GIS technology is used to divide the research area into grids with certain resolution to improve the calculation accuracy of urban density. Then, the traffic demand components and influence factor values are assigned to each grid to discuss the influence of various densities of cities with different landforms on traffic demand[3].

2. Date

Urban spatial form and urban traffic demand are affected by natural conditions, because natural conditions, to a certain extent, determine the scope, intensity and concentration of urban development space[4,5]. Therefore, this paper selects two cities with different topographic and geomorphic conditions as the research objects, namely Nanchang, a plain city, and Jiujiang, a hilly city. The data are from the 2018 resident travel survey of the two cities.

Urban density is divided into two types: single density and compound density. Single density includes population density, commuting density and income density. The compound density includes residential - commuting entropy density, residential - school entropy density and residential - shopping entropy density. Traffic demand includes residents' travel times, travel modes, travel distance and travel time[6]. In order to overcome the average density and spatial discontinuity and reflect the actual characteristics of various density spatial distribution more truly, the urban density was obtained by using GIS spatial analysis technology.

2.1. Single Density Calculation Method
In this study, single density includes population density, commuting density and income density, and the calculation method is spatial interpolation-inverse distance weight method[7]. The calculation formula is as follows:

$$C=\frac{\sum_{i=1}^{n}\frac{1}{\left(D_i\right)^p}\bullet C_i}{\sum_{i=1}^{n}\frac{1}{\left(D_i\right)^p}} \tag{1}$$

In the formula: C —Estimated density value;
C_i—Actual density value;
D_i—The value of the space distance between two points;
n—Points of known actual density values.

2.2. Calculation Method of Compound Density
Residential factor is the source of traffic occurrence and attraction, while commuting, going to school and shopping are three important aspects of residents' daily activities. Therefore, this paper mainly reflects the spatial distribution balance of residents' travel by using the three compound densities of residence, commuting, school and shopping. The concept of information entropy is used to calculate the compound density[8,9] .The specific calculation method is as follows:

$$H=-\sum_{i=1}^{n}\sum_{j=1}^{n}P_{ij}\ln\left(P_{ij}\right) \tag{2}$$

In the formula: H—Residential commuting entropy, school entropy and shopping entropy;
Pij—Commuting probability, going to school probability and shopping probability in traffic community i to j.

The compound density mainly reflects the spatial distribution relationship between population and three travel purposes.

3. Analysis
Before statistical analysis, the data is preprocessed to generate GRID data with a certain spatial resolution, so as to achieve spatial superposition analysis and spatial statistical analysis[10]. For specific analysis, different spatial resolutions are selected in this paper, including the GRID with a spatial resolution of 150 meters in Nanchang and the GRID with a spatial resolution of 100 meters in Jiujiang, and the mean and sum values of densities are considered respectively.

3.1. Influence of Single Density on Traffic Demand

3.1.1. Population density
Since Levinson and Wynn first studied the impact of urban density on traffic demand in 1963, population density has been an important reference factor for urban traffic analysis[11,12]. The influence of population density on traffic attraction is analyzed by using GIS spatial superposition analysis function, and the relationship between population density after spatialization and traffic

occurrence, travel distance and travel time is calculated. The population density and traffic occurrence in Jiujiang city are shown in Figure 1. On the whole, the change trend of "low-high-low" is presented. The population density is around 10,000, the peak area of traffic occurs, and the number of trips concentrates within 40,000. When the population density is less than 10 000, it increases monotonically. Greater than 1,000, the monotony decreases. The relationship between population density and traffic occurrence is basically monotonously increasing in Nanchang. With the increase of population density, the number of residents' trips also increases. When the population density is within 3 000, the traffic behavior is relatively concentrated, while after 3 000, the overall traffic behavior increases, but presents radiation and dispersion.

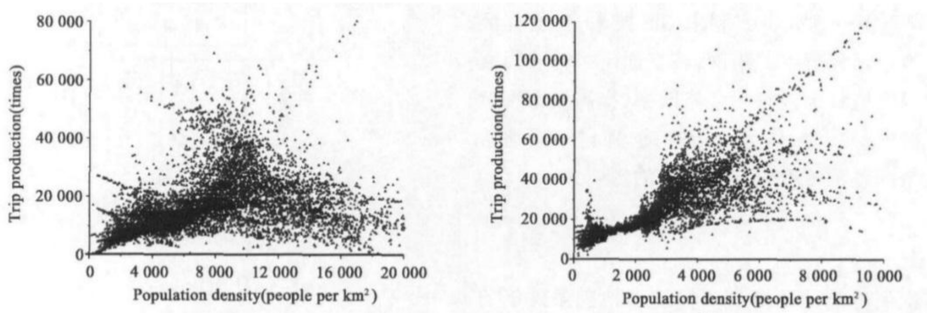

Figure 1. Population density and traffic occurrence

The relationship between population density and travel distance. Generally speaking, the travel distance of residents in the two cities decreases with the increase of population density. The travel distance of residents in Jiujiang is concentrated in 2 000 meters to 4 000 meters, while that of residents in Nanchang is concentrated in 2 000 to 6 000 meters, which is directly related to the radius of the city. With the change of population density, the travel distance of residents in Jiujiang is concentrated. Nanchang, on the other hand, showed a divergence and decrease at 0~500 meters and above 3 000 meters, while a concentration decrease at 500~3 000 meters (Fig. 2).

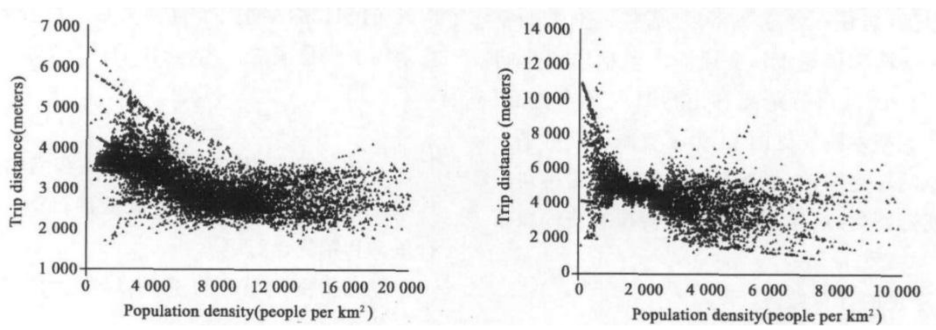

Figure 2. Population density and travel distance

According to the general cognition, with the increase of population, the corresponding number of residents will also increase. However, from the example of Jiujiang, a relatively obvious parabolic curve appears, indicating that with the growth of population density, the number of residents' trips does not simply show a monotonously increasing trend. Nanchang residents travel with the growth of population density and growth. The results show that there is no absolute monotonic relationship between the growth of population density and the occurrence of traffic in different urban forms[13].

3.1.2. Post density

Limited by the data, the research area of post density is Nanchang, and the calculation method of post density is consistent with the population density method. Figure 3 for the curve of the change relationship between post density and traffic occurrence in Nanchang. The change trend of job density and traffic in Nanchang is similar to that of population density and traffic. Generally, with the increase of job density, the number of residents' trips also increases. When the job density is before 750, it mainly increases in a centralized way, while after 750, it increases in a divergent way.

The change of job density and travel distance in Nanchang shows a trend of "high-low-high", among which 750 is the turning point. Before 750, the travel distance of residents decreased, and the change slope was large. The travel distance was concentrated in 2 000~10 100 meters. However, after 750, with the increase of post density, the travel distance of residents gradually increases, with a small change slope, and the travel distance is concentrated in the range of 2,000 ~ 6,000 meters.

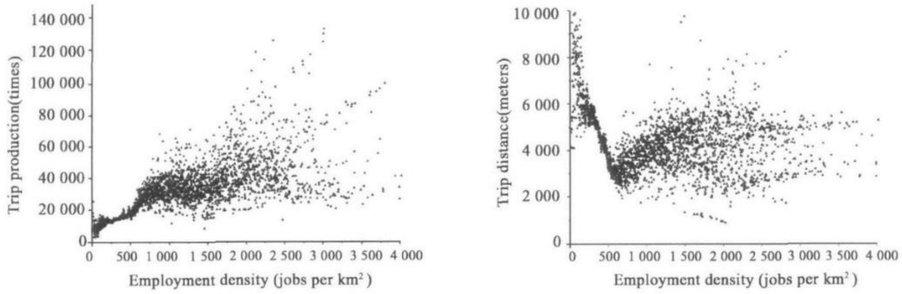

Figure 3. Nanchang post density and travel time

3.1.3. Income density

Under normal circumstances, the increase of income will affect the number of trips, travel distance and travel time of residents, especially the impact on the choice of travel modes. The research area of income density is Nanchang. With the increase of income density, the occurrence of income density and traffic showed a complex change trend without obvious regularity. After the income density was 700, the occurrence of traffic showed an obvious divergence and distribution trend. The study on travel mode selected five kinds of walking, bicycle, bus and electric motorcycle. With the increase of income density, Changes in five ways: income density at 400 and 650 places, minimum travel, maximum density at 550 places, basically presenting a "high-low-high-low-high " development pattern (Fig. 4).

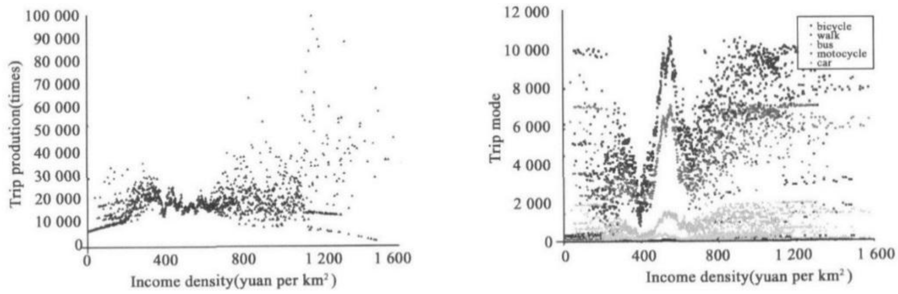

Figure 4. Nanchang income density and traffic demand

3.2. Influence of Compound Density on Traffic Demand

The compound density mainly involves residential - commuting entropy density, residential - school entropy density and residential - shopping entropy density. The relationship between the three densities and the total amount of traffic is discussed. Going to work, going to school and going shopping are the three main daily activities of residents, and the coordination between them and residence largely determines the effectiveness of urban traffic and land use integrated planning. In view of the influence of compound density on traffic, the average entropy value and the total entropy value are selected in the study, where the average entropy value is expressed as: Calculate the average value of the traffic occurrence of the grid with the same compound entropy; The sum entropy is expressed as the sum of the grid traffic occurrences with the same composite entropy.

3.2.1. Mean entropy value and traffic occurrence

The relationship between the compound entropy and traffic occurrence in Jiujiang and Nanchang is obviously different. With the increase of the compound entropy, the traffic occurrence in Jiujiang presents a monotonous increasing trend on the whole; Different compound entropy and traffic occurrence in Nanchang have different growth relationship. The relationship between residential - commuting entropy and traffic occurrence in Nanchang is more complex. The residential - commuting entropy has a minimum value at 0.9 and 2, and a maximum value at 1.1 and 1.7. The rest places generally have a monotonous relationship. After the residential commuting density of nanchang reaches 2.75, there are two branches: one growing and the other decreasing.

The residential - school entropy and traffic occurrence in Nanchang generally show a "high and low" development trend, and the dividing line is 1.5. When the entropy is less than 1.5, the amount of traffic occurs increases with the increase of the entropy of residence and schooling. When the entropy is greater than 1.5, the amount of traffic occurs decreases with the increase of the entropy of residence and schooling.

Before the residential - shopping entropy of Nanchang was 0.65, the traffic appeared a trend of decreasing with the increase of the residential - shopping entropy, which reflected the law that the greater the proximity was with the increase of the entropy. After 0.65~1.5, residential - shopping entropy increases. After exceeding 1.5, with the increase of entropy, the traffic has a trend of partial increase and partial decrease.

According to the basic principle of compound entropy, residents' nearby travel activities will increase greatly with the entropy value. However, Jiujiang does not show such a rule, but on the contrary, which shows that the layout of living and commuting in Jiujiang city has a serious leap, and the proximity is poor. The relationship between the three compound entropy values and the occurrence of traffic in Nanchang is not the same, and the changes are more complex and violent, the regularity is not very obvious. This shows that the relationship between the average entropy value and the occurrence of traffic is not invariable, and only within a specific range, the monotonic relationship between the two is valid, and the curve changes under different urban forms are not the same[14].

3.2.2. Total entropy and traffic occurrence

The sum of traffic occurrences corresponding to a certain entropy value of residential - commuting entropy, residential - school entropy and residential - shopping entropy is calculated respectively. The results show that the traffic occurrence in Jiujiang city and Nanchang city presents a parabolic trend of "low-high-low", indicating that the relationship between the total entropy of the composite density and the traffic occurrence is not invariable. It's only within a certain range of entropy that this relationship exists. Therefore, the current reasonable entropy range of a city can be obtained through statistical research on the relationship between residential - travel entropy and traffic demand (Table 1).

Table 1. Change of the composite entropy value and traffic in Jiujiang and Nanchang

	Jiujiang	Nanchang
	Maximum occurrence	Maximum occurrence
Residential - Commuting entropy	1.8	0.75
Residence - School entropy	1.75	0.50
Residential - Shopping entropy	2.1	0.75

4. Conclusion

By using GIS technology, urban density GRID and traffic demand factor GRID reflecting spatial distribution differences are calculated and obtained, and spatial statistical analysis is conducted on these two factors to find the interaction between them. Because it avoids the homogeneous characteristic of average density, it can better reflect the difference of spatial distribution of elements.

Urban density reflects the intensity of human production and life, and is also an important source of traffic demand. Starting from single density and compound density respectively, especially from the three compound densities closely related to traffic demand, the relationship between them is studied. It is found that the monotonic relationship between urban density and traffic demand parameters has a certain permissible interval, and different cities have different intervals. By calculating the relationship parameters between urban density and traffic demand of a city, the current development status of urban traffic demand can be clearly understood and scientific and reasonable reference indexes can be provided for traffic planning.

5. Acknowledgments

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