Research on Characteristics of Hefei Road Traffic Flow Based on GIS

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Abstract. Taking the whole road network traffic system in Hefei as the research object, based on GIS (Geographic Information System) traffic flow big data, this paper analyzes and compares the van aerde traffic flow model. The characteristics of urban road traffic flow are compared and analyzed according to road grades, working days, holidays and seasonality, which lays a foundation for further research on driving conditions and travel rules of automobile users in Hefei.

1. Introduction
With the rapid growth of vehicle ownership, traffic congestion in Hefei is becoming more and more serious. There are often long-time queue congestion, unreasonable traffic distribution and untimely network supervision in morning and evening rush hours. In order to grasp the temporal and spatial law of traffic flow and speed distribution in advance, it is necessary to build a traffic flow relationship model through big data mining and analyze the characteristics of traffic flow, so as to lay a foundation for the division of urban road service level, the distribution of network traffic and the evaluation of traffic quality.

The sample size of the traffic flow model proposed by Greenshields in 1935 is insufficient, which is not suitable for the study of expressway traffic flow and high-density traffic flow. The logarithmic velocity density model proposed by Greenberg in 1959 is suitable for traffic congestion, but not for free flow traffic. In 1961, undefood proposed a speed density exponential model for small density traffic flow. In 1995, van aerde derived the classical four parameter single segment continuous model, which is suitable for various traffic states. In 2012, sun Xu et al. Compared and analyzed the fitting effect of Greenshields, Greenberg and Underwood models on the traffic flow of Hefei Expressway Based on a large number of measured data in queuing congestion and unblocked state [5]. In 2018, Jing Lizhu and others analyzed the impact of truck mixing rate on average driving time of vehicles for basic sections of expressway, and concluded that the higher truck mixing rate, the longer driving time of vehicles. The research on traffic flow characteristics by scholars at home and abroad mainly focuses on expressways and expressways. Due to the influence of complex factors such as intersections, traffic lights and pedestrians, there are few studies on the traffic flow characteristics of main roads and secondary branches based on the actual road. Based on the big data of traffic flow, this paper constructs the traffic flow model by road level, and deeply studies the characteristics of traffic flow and speed.
2. Data sources
The data are from the big low frequency data of vehicles running in Hefei whole road network, 2019 to June 30, 2020. The traffic information collection combines GPS (Global Position System) and GIS (Geographic Information System). The refresh frequency of data is 5min, that is, the running data of all road vehicles is refreshed once in 5min.

As shown in Figure 1, the data covers the entire administrative region of Hefei city. According to the urban planning outline, urban roads are divided into the following four grades according to road types [7]:
- Road grade 1: expressway, such as Hefei ring expressway. No traffic lights;
- Road level 2: closed roads such as expressway and ring road in the city, such as Fangxing Avenue, urban management, no traffic lights;
- Road grade 3: the main trunk road in the city is the ground road in the city, with traffic light intersections;
- Road class 4: link roads.

3. Traffic flow model

3.1. Building Traffic Flow Model
VAN AERDE model is a single structure model with four parameters, which takes into account the characteristics of Greenshields model and pipes model. It has the characteristics of single structure model and multi structure model. The model has sufficient degrees of freedom in the process of construction, and is suitable for all kinds of traffic states. The structure is simple and easy to calibrate. The specific formula of the model is as follows:

$$k = \frac{1}{c_1 + \frac{c_2}{u - u_f} + c_3u}$$  \hspace{1cm} (1)

$$c_1 = u_t / k m / h$$
$$c_2 = u_t(u_t - u_m)^2 / k m / h$$
$$c_3 = 1 / q_c - u_t / k m / h$$  \hspace{1cm} (2)

Where: k is the density of traffic flow; u is the spatial average speed; U_f is the free flow speed, which refers to the running speed of traffic flow, km / h, when there are almost no vehicles on the road, which is not affected by the upstream and downstream conditions; Q_c is the capacity, which refers to the maximum number of vehicles that may pass through a certain section of the road in unit time, also known as the road capacity, pcu / h; u_m is the critical speed, which refers to the corresponding speed when the road flow reaches the capacity, km / h; k_f is the blocking density, which refers to the density when the vehicles on the road are unable to drive and the speed approaches zero, pcu / km; C_1, C_2 and C_3 are the intermediate variables [8-9].

The relationship model between speed and density can be calculated by calibrating the parameters of each grade road model. According to the relationship q = k × u between the three parameters of traffic flow, the traffic flow information of the whole road network can be obtained according to the big data of GIS traffic flow.

3.2. Traffic flow model validation
In order to verify the accuracy of speed calculation of traffic flow, considering the danger of manual counting of expressway. Typical expressways, trunk roads and secondary roads are selected to compare the calculated flow of the whole lane model with the actual investigation flow. The investigation time is June 6, 2018, and the investigation method is manual counting. The expressway takes the main road of Beijing North Fourth Ring Road as the verification object, and Figure 1 shows the calibration diagram of the measured data and each traffic flow model. It can be seen from the comparison that the VAN AERD model is the most consistent with the measured data, and the construction of the traffic flow model is more reasonable and accurate.
The average value of relative error and the average value of absolute error can be calculated by numerical analysis[10].

\[ \varepsilon = \frac{1}{24} \times \sum_{i=0}^{23} \frac{|Q_i - q_i|}{Q_i} \times 100\% \quad Q = \frac{1}{24} \times \sum_{i=0}^{23} |Q_i - q_i| \] (3)

Where: \( \varepsilon \) is the average value of relative error; \( q \) is the average value of absolute error; \( Q_i \) is the actual traffic flow in the ith hour of the whole year; \( q_i \) is the traffic flow calculated by the ith hour Model of the whole year.

As can be seen from Figure 2, from the overall point of view, the trend of model flow and survey flow is consistent, and the error is small, so the model construction is more reasonable. According to the comparative analysis in Table 1, the error of the hourly traffic flow of the expressway is larger than that of the main road and the secondary road, \( Q \) is 157.59pcu/h, and \( \varepsilon \) is 12.17%. However, considering the large base of the traffic flow of the expressway, the factors related to human factors and the contingency of the investigation time, etc. Generally speaking, the road traffic flow model of each grade is reasonable, the model parameters are calibrated accurately, and the traffic flow data can be used for the analysis of road traffic flow characteristics.

### Table 1. Comparative analysis of full lane flow

| Investigation section         | Road length/m | Starting section    | End section            | Absolute error average \( (Q_{\text{ave}} \times 10^{-2}) \) | Average value of relative error g/% |
|------------------------------|---------------|---------------------|------------------------|----------------------------------------------------------|-----------------------------------|
| Expressway (North Fourth Ring Road) | 18089         | Landingchang North Road | Xingqiao Airport Expressway | 157.59                                                   | 12.17                             |
| Main road (Zi Yun Road)       | 1219          | Four rings          | South Fourth Ring Road East | 90.31                                                    | 13.93                             |
| Secondary branch road (Tang Kou Road) | 7646          | Malian Road         | Four rings             | 113.18                                                   | 14.35                             |

4. Analysis of traffic flow characteristics

The characteristics of traffic flow and speed can be used to evaluate the level of service of the road and intuitively measure the operation of vehicles, which is the most critical part of the research on the characteristics of road traffic flow. The average speed of vehicles in the selected road section can be directly obtained from the GIS traffic flow big data, and the traffic flow information of the whole road network and the whole lane can be calculated through the traffic flow model[11].

By observing Figure 3, it can be found that the traffic flow has an obvious change trend, showing M-shaped or saddle shaped overall. The traffic flow from 6:00 to 22:00 accounts for about 85.81% of the whole day traffic flow, and the traffic flow during the day is maintained at 4000-7000 PCU / h. There is morning and evening peak phenomenon, the morning peak appears quickly and lasts for a
long time, generally from 7:00 to 9:00; the evening peak appears slowly and subsides for a long time, generally from 17:00 to 19:00. There will be a trough from 12:00 to 13:00 at noon, and the traffic flow has a small downward trend.

The speed range of 0-130 km / h in the whole road network is divided into 2 km / h intervals, and the VHT frequency distribution and cumulative distribution curve are drawn. It can be seen from Figure 4 that the average speed of the whole road network is roughly distributed between 20 km / h and 40 km / h, and the average speed of vehicles reaches the peak at about 30 km / h, accounting for 9% of the total number of vehicle travel hours; the frequency distribution of the speed between 50 km / h and 70 km / h is relatively stable, accounting for 10% of the total number of vehicle travel hours. According to the cumulative distribution curve, the average speed of the road network above 40 km / h grows slowly, and the vehicles are mainly distributed in the low-speed and medium speed regions, which is consistent with the situation that the vehicles in China are mainly distributed in the low-speed regions, and is different from the European and American countries.

Figure 3. Full network traffic diagram  
Figure 4. VHT frequency distribution and cumulative distribution

4.1. Analysis of traffic flow characteristics of different road grades
The overall trend is consistent with that of the whole road network, showing saddle or M-type. During 22:00-4:00 at night, the traffic flow is relatively stable and in a free flow state; the morning and evening peak phenomenon of expressway is not obvious, and the traffic flow of 9:00-19:30 during the day is relatively stable; the traffic flow of 6:30-9:00 and 19:30-20:00 will increase and decrease rapidly. There are obvious morning and evening peaks on expressways, and the peak at night is greater than that at morning. The traffic flow of trunk road and secondary road is low, the driving conditions are similar and stable, and the road service level is high. It can be found that the expressway and expressway are mainly responsible for the traffic and transportation task of Hefei City, with large traffic flow. The daily average traffic flow accounts for 48.54% and 29.83% of the total traffic flow respectively, and the road load is far higher than that of the main road and the sub branch road.

Figure 6 shows the cumulative distribution of each speed interval, and the distribution difference of each speed interval is obvious. The corresponding values of main speed intervals of expressway, expressway, main road and secondary branch road decrease in turn. When the speed is higher than 100km / h, the proportion of VHT distribution is close to 0, which indicates that the actual road vehicles in China mainly drive at low and medium speed, which is related to the large number of vehicles and large population in China. Expressway mainly undertakes the task of long-distance transportation, mainly distributed in the high-speed section. Expressways are mainly responsible for the morning and evening peak transportation tasks, and the cumulative distribution curve grows rapidly in the speed range of 50-60km / h. The cumulative speed distribution of main road and secondary road is similar, and vehicles mainly drive in low speed section.

Figure 7 shows the frequency distribution of each speed interval of VHT, and there are obvious differences in the speed distribution of vehicles on different grades of roads. The speed range distribution of Expressway and expressway is scattered, and the maximum proportion is less than 6%. The average speed of expressway is mainly distributed around 80km / h, and there will be a sub peak
near 40km/h, and the vehicle speed is mainly concentrated in the high-speed section; the average speed of expressway is mainly distributed around 60km/h, and the vehicle speed is in the medium speed section. The speed range distribution of trunk road and secondary branch road is relatively concentrated, mainly in the low speed range, with the maximum value of nearly 14%, and the abscissa corresponding to the peak value is around 30km/h.

4.2. Analysis Of Traffic Flow Characteristics On Weekdays, Weekends And Holidays
According to the traffic sequence diagram of the whole railway network in Figure 8, there are double peaks on weekends and holidays. The morning peaks on weekends and holidays appear later than those on weekdays, with shorter duration, but there is no obvious change in the morning peak. The evening peaks on weekends and holidays appear earlier, with longer duration, with smaller peak than those on weekdays. This phenomenon is mainly related to the driving habits of travelers, irregular vehicle travel on weekends and holidays, drivers' early rising time goes back, the evening peak lasts longer, and the time for going out activities is longer. According to the integration of traffic flow, the total daily average traffic flow of the road network on weekdays is 1129466pcu, and the total daily average traffic flow of the road network on holidays is 1115213pcu. The traffic flow on weekdays is larger than that on holidays, which is in line with the general travel law.

According to the cumulative distribution diagram of VHT in Figure 9, when the speed is below 40km/h, the cumulative distribution proportion of VHT on weekdays is 81.24%, and that on holidays is 76.96%. The cumulative distribution of VHT on medium and low speed sections of roads on
weekdays is higher than that on holidays, which indicates that the average speed of vehicles on weekdays is lower than that on weekends and holidays. Hefei has a large number of working population, and the flow of boarding and alighting buses is dense, which is easy to cause traffic congestion Traffic jam, slow speed phenomenon.

According to the comparison of VHT frequency distribution map of the whole road network between weekdays, weekends and holidays in Figure 10, the overall form of speed interval distribution on weekdays is basically consistent with that on non-weekdays, and the speed interval corresponding to the peak value of frequency distribution is close, all around 30km / h; the VHT frequency value corresponding to the average speed around 60km / h on weekdays is slightly higher than that on weekends and holidays.

Figure 8. Timing diagram of full network traffic on weekdays, weekends and holidays

Figure 9. Shows the cumulative distribution of VHT on weekdays and weekends

Figure 10. Differentiating the distribution of VHT frequencies on weekdays and weekends

4.3. Analysis Of Seasonal Characteristics Of Traffic Flow

Figure 11 is the traffic flow sequence chart of Hefei in the four seasons. It is found that the traffic volume of Hefei city is the highest in the middle and summer, the lowest in winter and the trend of the traffic flow in spring and autumn is similar. In the four seasons, there are double peaks in the traffic volume in the first day, and the late peak is higher than the early peak. The main reason is that the weather is suitable in summer, which is favorable for travel and the traffic flow is generally high; in winter, the air conditioning is needed to be turned on to drive, the fuel consumption of vehicles is too large and the traffic flow is generally low.

Figure 12 shows the cumulative distribution of VHT in spring, summer, autumn and winter. On the whole, the cumulative distribution trend of each speed range in four seasons is consistent, and the medium and low speed range accounts for a larger proportion. When the speed is lower than 40km / h, the cumulative proportion of each speed range in four seasons is 79.96%, 84.10%, 81.20% and 76.66% respectively. By analyzing the cumulative distribution map, it can be concluded that the proportion of middle low speed range in summer is the largest, and that in winter is the smallest, and the distribution of each speed range in spring and autumn is similar. Analysis reasons: the traffic volume is the largest in summer, the vehicles are congested, and the average road speed is small.
Figure 13 shows the VHT frequency distribution of different speed intervals in different seasons. The overall form of VHT frequency distribution in each speed interval is similar. The abscissa corresponding to the peak value in spring and autumn is roughly the same, which is around 30 km/h; the abscissa corresponding to the peak value in summer and winter is larger, which is around 35 km/h; the peak value of VHT frequency distribution in summer exceeds 10%, which indicates that the average road speed in summer is concentrated around 35 km/h.

Figure 11. Seasonal changes in traffic flow timing diagram
Figure 12. Distinguishes the seasonal VHT cumulative distribution
Figure 13. Distinguishes seasonal VHT frequency distribution

5. Conclusion
It is of great significance to build traffic flow model according to road grade and study the characteristics of urban road traffic flow for improving road capacity, controlling commuter road traffic and improving intelligent transportation information function. Based on the annual GIS traffic flow data of Hefei City, this paper constructs the flow velocity model and verifies the model. This paper analyzes the influence of road grade, working days, holidays and seasonal changes on the change law of traffic flow and the change of VHT speed interval proportion. In order to further study the driving conditions of Hefei City, the paper analyzes and verifies the travel rules of Chinese automobile users and the actual traffic big data, and lays a foundation for the control of urban vehicle fuel consumption and emission.
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