Traffic Flow Model Based on Power Flow

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Keywords: Evaluating System of Traffic Conditions, CA, Overtaking Model, TFPF.

Abstract. The article is research on the traffic rules of freeways. We analyze factors like traffic flow and safety performance respectively, and propose the theory basis for making more reasonable rules of the road. We first establish an evaluation system of traffic flow, which can be designed based on the average speed, the traffic density, the following ratio and the overtaking ratio. And we separately calculate the average speed and traffic density in heavy traffic and the opposite. Meanwhile, we obtain a relation of traffic flow and overtaking ratio or following ratio via fitting. We next construct an assessment system, based on IHSDM, and reach the conclusion that the more different the speed of vehicles is, the higher the relevant accident rate will be. As the accident rate reflects the safety performance directly, combining the conclusion with the overtaking model, we can probe into safety performance of freeways under different traffic rules. Afterwards, we compare the freeway network to power network to find a solution, and establish a traffic flow model based on power flow (TFPF). It calculates power flow. We utilize cellular automata (CA) method to simulate traffic circulation, and verify the accuracy of the above model with the obtained data. The verification shows the model is feasible in certain degree. Finally, the intelligent control of urban traffic flow applies to both light and heavy traffic. And it cannot only reduce the required time controlled by human factor, but also guide and schedule reasonably through the network monitoring, so as to ease traffic congestion and traffic accidents, and improve the efficiency of transportation.

Introduction

The rule for right-hand drive vehicles in multi-lane freeway is defined as drivers must drive in the rightmost, except in which case they needed to overtake, first drove to the left side of the high-speed lane, overtaking and then returned to their former travel lane.

The reason for passing another vehicle when driving is that the driver on the road hope to maintain their desired speed, but the complexity traffic compositions, differences in the type of vehicles and driver personalities lead people-expect great speed vehicle unit differences produce overtaking demand.

Setting up the Modeling

Construct an evaluating system of index of traffic flow.

The average speed varies from under different degrees of crowdedness. The average speed can be described as:

$$v = \frac{L}{\Delta t}$$

Traffic density refers to the dense degree of vehicles on a driveway, also known as traffic density ρ is defined as follow:

$$\rho = \frac{N}{L}$$

Using Matlab to do the curve fitting, we can get the approximate relationship between traffic flow and following ratio. The results are presented as follow:

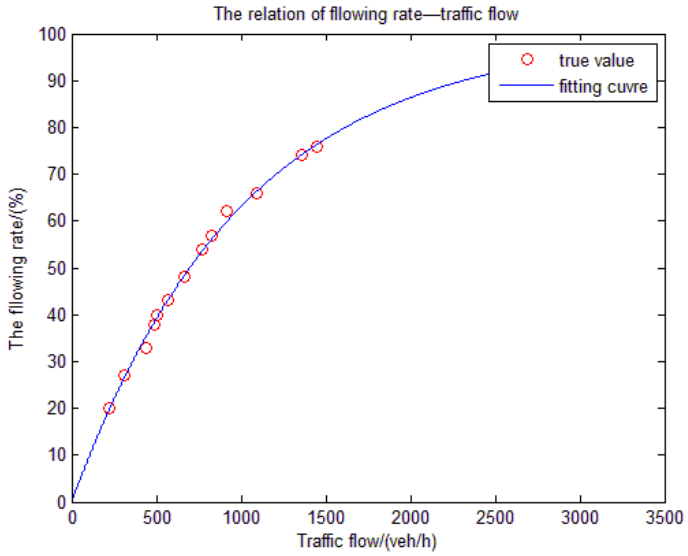


Fig.1 Curve Fitting Result

The degree of fitting is 0.993 which shows that the result is available to a certain extent. From the figure, we can know there isn't a clear relationship between overtaking ratio and traffic flow. When the traffic flow is small, as the same as the load of road is low, the overtaking ratio is big.

Construct an Evaluation System of the Safety.

There are many index contributing to safety, fig.2.

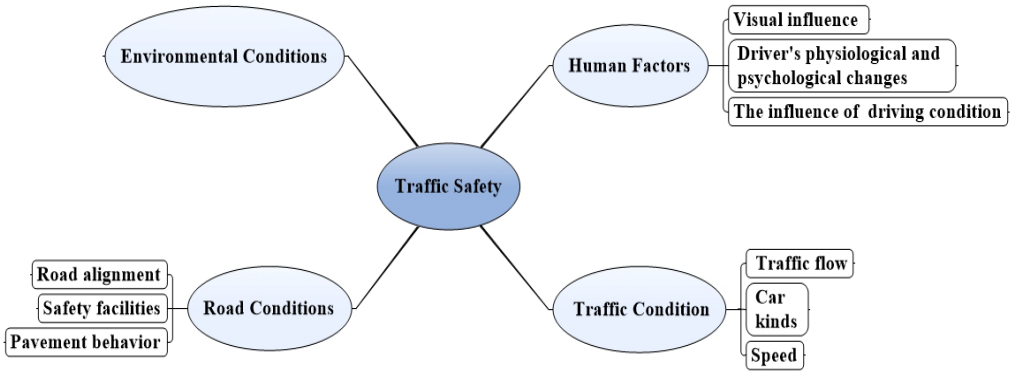


Fig.2 Factors Contributing to Traffic Safety

According to the requirements given by the problem, we ignore secondary factor, and only take the traffic condition into account.

Type of vehicles is also an influence, we don't talk about it either because we convert different types of vehicles into a unified standard.

Based on the overtaking model established, we analyze both safe factors and unsafe factors in the process of overtaking.

Drivers hope to maintain their desired speed on the road, but the complexity traffic compositions, differences in the type of vehicles and driver personalities lead people - Vehicle units vary greatly desired speed.

Some of the vehicles are slower, a part of the vehicles are faster. When the faster vehicle is behind the slower vehicle, the faster one hope to maintain desired speed, which produce overtaking demand.

The vehicles with overtaking demand begin to overtake into the left lane, when they find the lane to the traffic flow has a certain gap between the lane to the vehicle, and then return to their former travel lane, as shown in Fig.3.

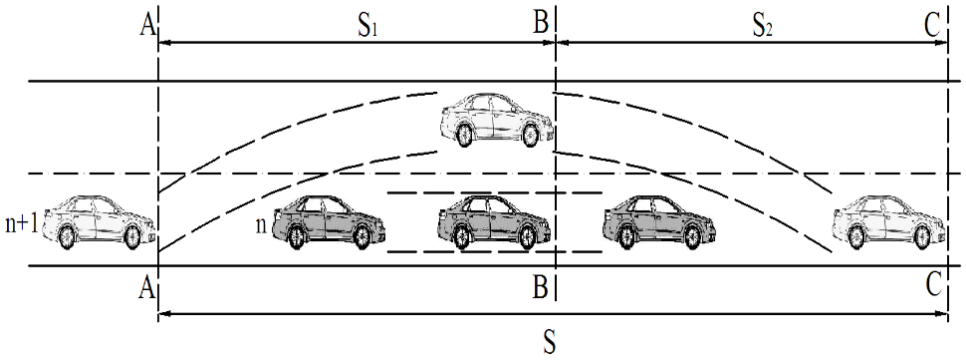


Fig.3 Sketch map of overtaking

The safe distance:

$$S = S_1 + S_2 = \frac{x_{n+1}'(t)}{3.6} \cdot t_a + \frac{1}{2} a t_a^{\ 2} + \frac{x_{n+1}'(t+t_a)}{3.6} \cdot t_y$$

Construct Traffic Network Model Based on Power Flow.

The expression of transmission line voltage deviation is:

$$\Delta U = \frac{PR + QX}{U} = \frac{S \cdot R\cos\theta + S \cdot X\sqrt{1-\cos^2\theta}}{U}$$

Analogy to traffic models, add a correction factor c:

$$\Delta v = c\frac{\eta Rf + Xf\sqrt{1-\eta^2}}{v}$$

Then, replace the above expression with an equivalent transformation:

$$a = \frac{\Delta v}{\Delta T} = c\frac{\eta Rf + Xf\sqrt{1-\eta^2}}{v\Delta T} = c\frac{\eta Rf + Xf\sqrt{1-\eta^2}}{l} \approx 0.66$$

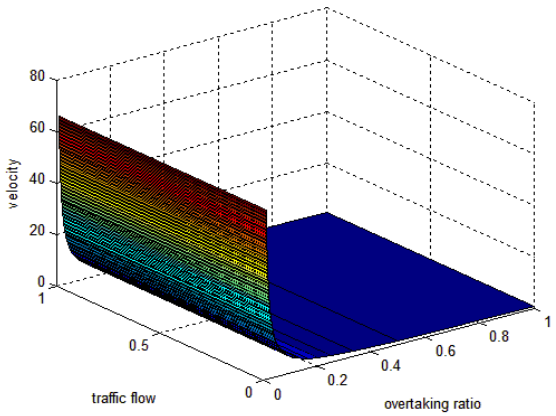


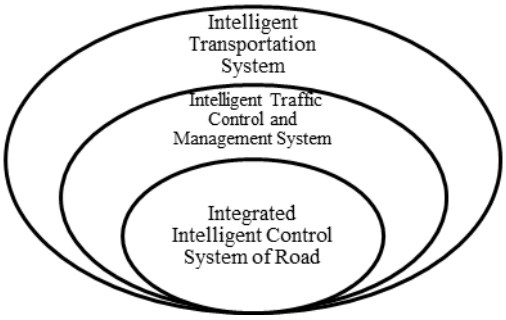
Fig.4 3D Plot of Traffic Model

When traffic is light, namely the ρ is less than a threshold value ρ_1, we can consider overtaking ratio as a constant, and overtaking doesn't influent the traffic flow. On the other hand, when traffic is heavy , namely ρ is more than a threshold value ρ_2, process of overtaking would contribute to the road resistance so that overtaking ratio vary under different traffic density($\eta \propto \frac{1}{\rho}$). Eq.5 is equivalent to the following equations:

$$f = \begin{cases} \dfrac{0.66l}{c \cdot (\eta \mathrm{R} + X\sqrt{1-\eta^2})} & \rho < \rho_1 \\ \dfrac{0.66l}{c \cdot (\eta(\rho) \mathrm{R} + X\sqrt{1-\eta(\rho)^2}} & \rho > \rho_2 \end{cases}$$

When $\rho > \rho_2$, we can get Fig.4 as follow.

Intelligent traffic system



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