Research on vehicle overtaking behavior under right-hand traffic rule

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Abstract. We address establishing a comprehensive mathematical model to analyze the performance of right-hand rule in right and heavy traffic. First, we build the overtaking model by considering some retricted conditions including the safe distance, speed limitations and human judgment. Next, we take account of several uncertain factors, such as traffic density and overtaking frequency to improve the comprehensive model. On the basis of the comprehensive model, we simulate the right-hand rule under different traffic conditions, we find that with the number of vehicles increasing, the average passing time increases, traffic flow increases. According to human judgment, we can calculate the possibility of overtaking to decide whether to tag or overtake. Finally, we make the sensitivity analysis. We change the speed of the vehicle and we find that two different speeds have the same variation tendency which can explain that the model is very robust. Our model can be applied to other traffic rules with a simple change of parameters.

1. Introduction

We are discussing the problem basing on the problem A in 2014MCM. With the development of the ecomic economy, more and more vehicles walk into people's lives. We build and analyze a mathematical to analyze the performance under the right-hand rule in light and heavy traffic. In countries where driving automobiles on the right, multi-lane freeways often employ the same rule. On the basis of an abstract general principle of psychology PIEV model [1] and an Australian TRARR model [2], we develop our model to analyze the influence of the right rules, including traffic flow, traffic safety, vehicle speed, safety and so on. According to the recent study, we synthetically add several factors to the model.

The focus of this rule is overtaking, while overtaking behavior will affect traffic. Therefore, we mainly research the effect of overtaking behavior of traffic flow and safety. In order to provide a reasonable evaluation strategy, this paper first set up the comprehensive model. Then we complementally analyze the relationship between the total number of vehicles and the lenght of the highway and the time cost. It turned out that our model is feasible and scientific.

2. Vehicle overtaking model

2.1 Model establishing

In the transportation model, according to the driver’s psychological state, we find an abstract general principle of psychology PIEV model. PIEV model has the following specific elements:

(1) When overtaking, we consider the relative position between four cars. When a vehicle intends to overtaking, he has to think of the distance between him and the back of the car in order to avoid collision.

(2) Safety distance is no longer a constant, but a speed-related variable.

The overtaking process is showed as the following figture:

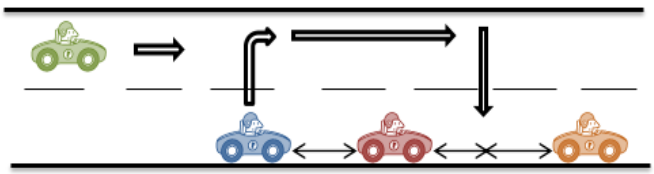

Fig.1 Overtaking process

The driver in the process of moving away has to decide driving maneuver. If the distance is large enough, he can speed up. Otherwise, he should consider slowing down.

The required safe distance G_s is related to the present speed, theoretically safe distance relationship is

$$\frac{1}{2}mv_i^2 = f \times (G_s - G_0) \tag{1}$$

Where f represents vehicle suffered friction when braking, G_s represents the safe distance, G_0 represents the minimum distance between the overtaking vehicle and the in front car when the car slows down and stop.

Since (1), we have:

$$G_s = \frac{mv_i^2}{2f} + G_0 \tag{2}$$

where $G_0 = v_i^2 / 2g\mu$.

According to the distance from the front car, we make our decisions:

- When the distance from the front car is larger than G_s, the vehicle will keep up the distance, so we consider it maintains its speed.
- When the distance from the front car is larger than G_s, the vehicle has two operations. First, we should make a judgment to decide whether it can overtake according to the distance between it and the back of the car.

We call the orange car a, the red car b, the blue one c, the green one d.

(1) If the distance between b and c is greater than the safe distance between b and c, car c can speed up to overtaking.

(2) If the distance between b and c is less than the safe distance between b and c, we should make further calculations.

The distance between b and a is

$$L_{CB} = (v_{ci+1} - v_{bi}) \times t_c \tag{3}$$

where t_c represents overtaking time.

When car c intends to overtaking, the back of car is overtaking, it must guarantee that they won't collide. Since:

$$t_c \times (v_{di+1} - v_{bi}) \le L_{BC} + L_{CD} \tag{4}$$

We have:

$$L_{CD} \ge \frac{v_{di+1} \times L_{BC}}{v_{ci+1} - v_{bi}} - L_{BC} \tag{5}$$

Furthermore, we also need to consider the safe distance problems after overtaking. Not only car c should keep safe distance with a, but also with b.

Exactly,

$$L_{AB} \ge G_{BC} + G_{AC} \tag{6}$$

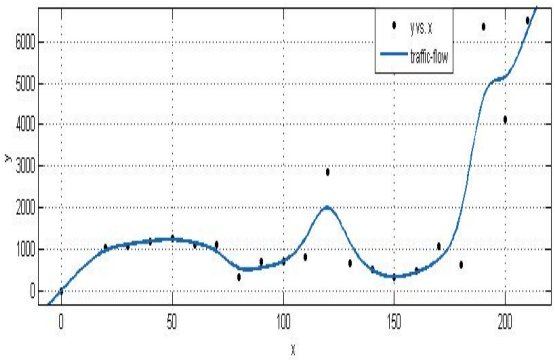

Fig.2 The relationship between traffic flow and passing time

We can see that with the increase of the number of cars, cars passing time increased. Further analysis, vehicle numbers reflect the traffic flow. Cars passing time reflects traffic degree of fluency. Therefore, as for the right rules, traffic congestion will affect the car through time. 180 is a tipping point. As the number of cars is in a certain range, the performance of this rule is in light. When surpass the critical value, the traffic is in heavy.

2.2 Supplementary factors of comprehensive model

On the basis of the model, we consider traffic flow [3] and overtaking frequency [4] to improve comprehensive model. This model considers not only speed limits, but also human factor. Therefore, it is comprehensive and general.

3. Analyzing the comprehensive model

3.1 Analyzing the relationships

In our model, we arbitrarily give road length and the total number of cars to make a two-dimensional plan. We used MATLB pcolor toolbox, and made the following picture. However, this plan is actually a three-dimensional map. X-axis represents the total number of cars, Y-axis represents road length. Z-axis is dummy. It represents average time which all vehicles spent. Here, we regard different color as Z-axis.

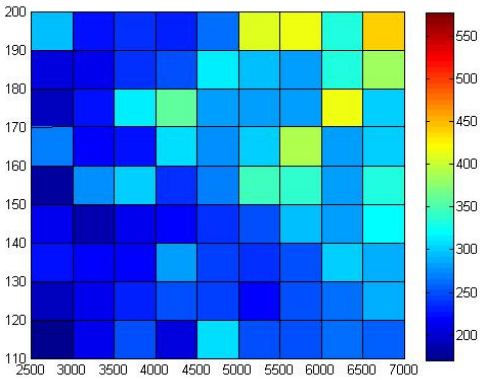

Fig.3 The relationship between traffic flow and time cost and road length

In the fig.2, horizontal ordinate forms different colors of the square. Different colors represent different average time. Red represents the maximum traffic flow and blue represents minimum flow. They transit from big to small. From the figure, we can find that with the speed of the car decreasing, the flow of the traffic decreased. If the speed of the car reaches a high level, the traffic is smooth. Fig.2 has no transition and differentiation phenomenon is serious. Therefore, comprehensive model is more reasonable and scientific.

3.2 Stability and Sensitivity Analysis

As for our model, we change the average speed in our model. We get figure3:

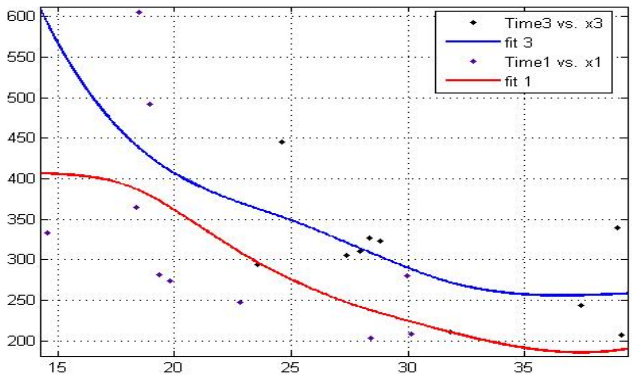

Fig.4 The text of sensitivity

From the figure, we find that as for a vehicle, the length of the highway is different, the cost of the time is different. Then we change the speed of the vehicle, we find that, two different speeds have the same variation tendency. This can explain that the model is very robust.

4. Conclusions

According to our analysis, we find that with increasing of the traffic flow, the safety of traffic decreases rapidly, the average of passing time increased quickly. When the traffic flow is heavy enough, it swings around a certain value. So the traffic flow influence the average passing time. After analyzing all the factors, the changing of speed limits is the most significant variable that affect the average time. As the over-posted speed limits increase, the accident rate increases while the average time decreases. Otherwise, we add human judgment into our paper. The driver can decide whether he will overtake.

Reference

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