Preventing Road Rage by Modelling the Car-following and the Safety Distance Model

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Abstract. Starting from the different behaviours of the driver's lane change, the car-following model based on the distance and speed and the safety distance model are established in this paper, so as to analyse the impact on traffic flow and safety, helping solve the phenomenon of road anger.

1. Introduction

When the driver sees the sign at the end of the right lane (the right lane is going to end), he can choose between lane-changing left and going straight. When approaching the road closure point to see the roadside marked with the distance to the end of the right lane, it is also necessary to make a decision between the left lane and the straight lane where the left lane is already crowded. Signs indicate the distance of the lane closure as it nears (e.g. 1 mile, 1/2 mile, 500 ft.).

For the various actions taken by the driver on the main highways in the case of trunk closure, we classify as the following：.

Table 1. Various actions taken by the driver on the main highways

1 Change lanes to the left		Left lane/right lane
	2.1 slow down	right lane
2 Go straight	2.2 accelerate	right lane
	2.3 Keep the original speed	right lane
3 parking		right lane

The behaviour of the driver impacts from the traffic flow and safety of two aspects. The above five kinds of behaviours, the left lane, acceleration and deceleration, the original speed, parking will bring the traffic flow changes, and security is mainly affected by the left lane. The following will be from the traffic flow and safety aspects of the two models were established to discuss the driver's behaviours.

2. As For Traffic flow

2.1 Traffic Flow Change Model

Analysis of the impact of traffic flow, we are based on the theory of Green Schils, as shown in Figure 1, the first establishment of the relationship between vehicle speed – flow model.
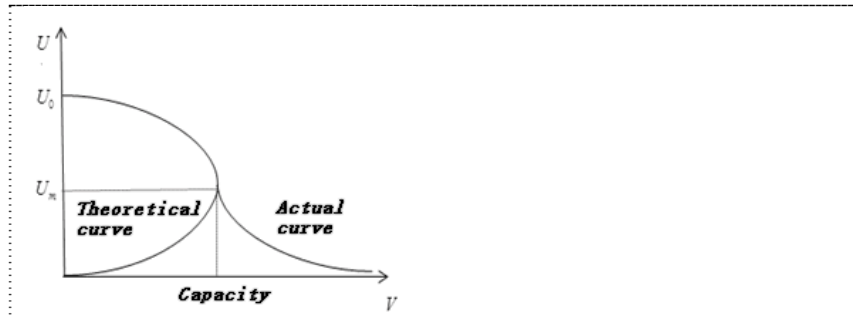
Figure 1. Green Shields theoretical schematic diagram.

The average travel speed of a vehicle that arrives in a unit time $\bar{v}=\dfrac{U_0}{1+\dfrac{V}{C}}$, in expression , U_0

represents the average traveling speed of the vehicle when the traffic volume is zero，V represents the traffic volume of the road，C Indicates the lane capacity。But this expression is in the road vehicles under the assumption of uniform dissipation, So need to introduce α 、 β two correction

factors，we can get the traffic impedance model $\bar{v}=\dfrac{U_0}{1+\alpha\left(\dfrac{V}{C}\right)^{\beta}}$ 。In order to obtain accurate

prediction results，make $V/C<0.8$ ，$\gamma=1$, further refine the model to $\bar{v}=\dfrac{\alpha_0 U_s}{1+\gamma\left(\dfrac{V}{C}\right)^{\beta}}$ ，in

expression，U_s is the designed speed for the lane. β is V/C 's nonlinear function，express like

$\beta=\alpha_2+\alpha_3\left(\dfrac{V}{C}\right)^{3}$.

2.2 Car-following Model
So that our attention to road traffic is converted to the calculation of road speeds，The following focus on solving the vehicle to the left after the lane into the target road after the speed. Select the target vehicle to the left lane to the left lane，follow the car on the road，in figure $x_{j-1}\left(t_w\right)$ and

$x_j\left(t_w\right)$ respectively front car and the target car through t_w 's reaction time (generally take 1.5～2 s) 's displacement，the schematic diagram is as follows:
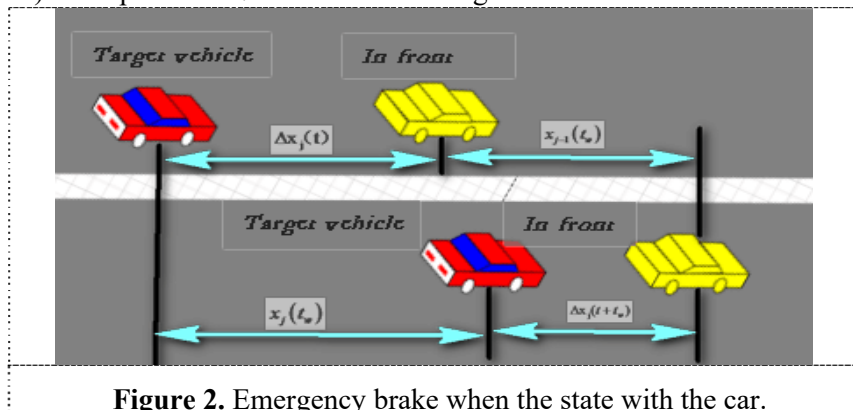

Figure 2. Emergency brake when the state with the car.

The speed of the target vehicle is not only related to the front-to-back vehicle distance, but also to the speed of the preceding vehicle (car-following), then the car-following model based on the distance and velocity is established.

$$
\begin{cases}
v\left(\Delta x_j\left(t\right)\right) = \dfrac{dx_j\left(t+\Delta t\right)}{dt} = \dfrac{v_{\max}}{2}\left[\tanh\left(\Delta x_j\left(t\right)-h_c\right)+\tanh\left(h_c\right)\right] \\[4mm]
a\left[v\left(\Delta x_j\left(t\right)\right)-\dfrac{dx_j\left(t\right)}{dt}\right] = \dfrac{d^2 x_j\left(t+\Delta t\right)}{dt}
\end{cases}
\tag{1}
$$

At the same time, we also get the driving distance of the front car $x_{j-1}\left(t+\Delta t\right) = -\dfrac{\left[v_{j-1}\left(t\right)\right]^2}{2a_{j-1,\min}}$,

and the target car $x_j\left(t+\Delta t\right) = v_j\left(t\right)t_w - \dfrac{\left[v_j\left(t\right)\right]^2}{2a_{j,\min}}$, We define a desired vehicle spacing

$$
h_c\left(t\right) = \max\left\{h_{c,\text{stop}}, v_j\left(t\right)t_w - \frac{v_j\left(t\right)^2}{2a_{j,\min}} + \frac{v_{j-1}\left(t\right)^2}{2a_{j-1,\min}} + h_{c,\text{stop}}\right\}
\tag{2}
$$

among them，$v_{j-1}\left(t\right)$ is the speed of the front car at t time，$a_{j-1,\min}$ is the maximum deceleration of the preceding vehicle，$a_{j,\min}$ is the maximum deceleration of the target vehicle.

3. As For Safety

As we all know, the driver of the lane always in a safe distance conditions make sense. Different drivers take different lane tracks, the first step is to do the classification of the lane. Next, to determine whether a safety distance has been violated and a traffic hazard has arisen, we set a minimum safety distance as a threshold, which will be established by modeling. Finally, the actual distance and safety distance are given to judge whether to change lane.

3.1 Classification of Lane Changes

Take vehicle M as the research object，If you select the left lane, it will travel roughly along the arc. The initial position of the vehicle is shown in the following figure:
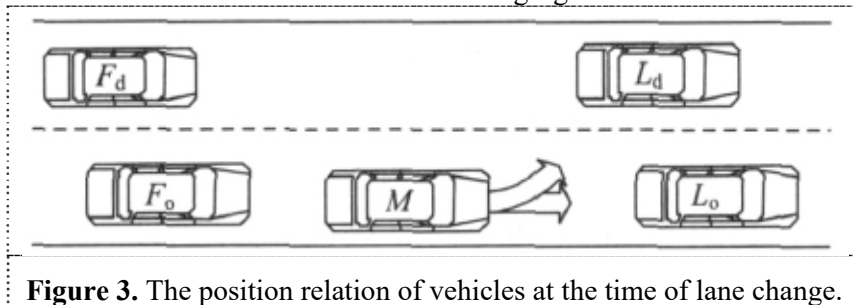

Figure 3. The position relation of vehicles at the time of lane change.

Diagram shows the positional relationship of the vehicle at the time of lane change. In figure 2, M is changed lane vehicle，L_0 is the front vehicle in driveway，L_d as the target lane before the car，F_0 is the after vehicle in driveway，F_d is the after vehicle in target driveway.

Assume the speed of lane changing vehicle M is V_M，the Speed of the vehicle F_d after the target lane is V_{F_d}，the lane changing behavior includes the following.
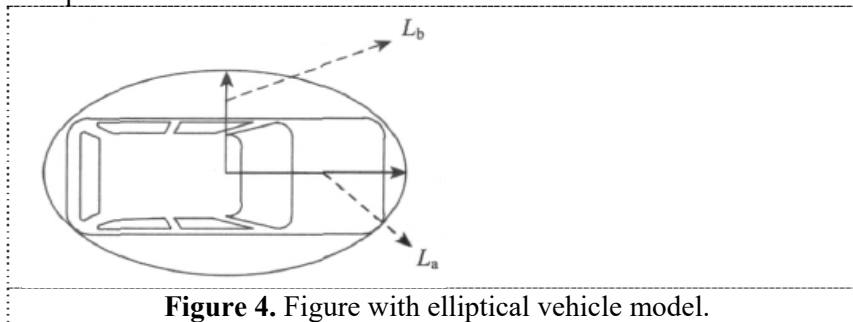
Table 2. Various actions taken by the driver on the main highways

The size relationship of V_M and V_{F_d}	The relative position between lane changing vehicle M and the vehicle F_d after the target lane	Lane change mode
$V_M < V_{F_d}$	M in front，F_d in the back	Accelerate
$V_M < V_{F_d}$	F_d in front，M in the back	Constant speed
$V_M > V_{F_d}$	M in front，F_d in the back	Constant speed
$V_M > V_{F_d}$	F_d in front，M in the back	Slow down or wait

3.2 Model of Safety Distance for Lane Changing
After classifying the four lane changing behaviors above, the safe distance of the lane changing vehicle is solved.

Because small vehicles are the majority of vehicle types, we believe that the use of ellipses to cover the vehicle area, through the use of the longitudinal axis and the horizontal axis of the short half-axis to express different potential hazards.

Figure 4. Figure with elliptical vehicle model.

Take the major axis of the ellipse model which has a great influence on the safety distance of the lane，we have $L_a = \dfrac{L}{2} + (1-T_d)^{\frac{L}{W}} \dfrac{V_{L_0}}{V_M}$，$L$ is vehicle length，W is vehicle width，V_{L_0} is the front vehicle in driveway，V_M is change land vehicle speed，T_d is driver type.

If the front vehicle speed is greater than the lane change speed, as time increases, the spacing will be expanded, the two vehicles will not collide，minimum safe distance $D_{MSS} = 0$；

If the relative speed of two vehicles is equal, with time, spacing remains the same, the minimum safe distance $D_{MSS} = (1-T_d)^{\frac{L}{W}} \dfrac{V_M}{V_{L_0}}$；

If the speed of the changed land vehicle is greater than the speed of the front vehicle, the spacing will decrease as time increases. The minimum safety distance should take into account not only the relative speed and acceleration of the two vehicles, but also the different types of drivers and the initial speed of the lane changing. It is assumed that the driver decelerates at the maximum deceleration after the reaction is $-a_{max}$，τ is drivers reaction time，t_p is the time when the lane change vehicle arrives at the collision point. So

$$D_{MSS} = V_M(0)\tau - \int_0^{\tau} V_{L_0}(\xi)d\xi + (1-T_d)^{\frac{L}{W}} \dfrac{V_M(t)}{V_{L_0}(t)} + \int_0^{t_p} \int_0^{\sigma} \left[a_M(\xi) - a_{L_0}(\xi) \right] d\xi d\sigma \quad (3)$$

Based on the above three points, the elliptical vehicle model is

$$D_{MSS} = \begin{cases} 0 & V_M < V_{L_0} \\[2ex] \left(1-T_d\right)^{\frac{L}{W}} \dfrac{V_M}{V_{L_0}} & V_M = V_{L_0} \\[2ex] V_M\left(0\right)\tau - \int_0^\tau V_{L_0}\left(\xi\right)d\xi + \left(1-T_d\right)^{\frac{L}{W}} \dfrac{V_M\left(t\right)}{V_{L_0}\left(t\right)} + \\[2ex] \int_0^{t_p}\int_0^\sigma \left[a_M\left(\xi\right)-a_{L_0}\left(\xi\right)\right]d\xi d\sigma & V_M > V_{L_0} \end{cases} \qquad (4)$$

The distance between the lane changing vehicle and the preceding vehicle is expressed as d, if $d \geq D_{MSS}$, Then the lane change is safe; if $d < D_{MSS}$, Then the lane change vehicle may be have a collision with target vehicle in front , choose to continue straight.

4. An example

Solving the Model in Part 1:

Through the road traffic monitoring equipment to measure the left and right lanes of the 100 vehicles of the instant vehicle distance, Using car-following model to solve the instantaneous speed of left and right lanes. And then by the traffic flow rate model to calculate the left and right road traffic change .Finally, the safety model is used to evaluate whether the vehicle is suitable for lane changing.

As shown in the table below, the driver's behaviour affects traffic flow to the traffic：

Table 3. The effect of driver's behaviours to the traffic flow

Driver 's behaviour	Left lane traffic flow changes	Right lane traffic flow changes
Change to the left	-168.85pcu/h	-265.34pcu/h
Accelerate forward	0pcu/h	+186.53pcu/h
Slow down forward	0pcu/h	-202.86pcu/h
Uniform forward	0pcu/h	+50.12pcu/h
Parking	+48.76pcu/h	-73.35pcu/h

Table 4. Safety Assessment of Driver 's Lane Change

Before and after the vehicle distance	safe distance（Td：0.1）	Whether to change lanes
96.93270665	9.424118075	No
92.91902499	80	No
62.29179783	110.2365167	YES
83.20724832	91.56832676	YES
84.84192773	63.36780192	No
88.29435245	80	No
71.95123574	80	YES
79.69884213	172.5204096	YES
88.79767746	15.86841843	No
82.78356137	31.84986113	No

5. Conclusions

From the results can be seen, the driver of the lane change will make the left and right lane of traffic decreased, but the reasons for the decline is different, the left is because the right lane vehicle insertion reduces the overall speed, the right is because the overall vehicle is reduced. While the acceleration and deceleration will only have an impact on the right side of the traffic flow, the left side traffic flow

unchanged. Uniform speed and parking on the traffic flow impact is not obvious.

As for the safety of road operation, the results can be seen, only about 40% of the vehicles for lane, in real life, if the vehicle lane change rate is too high, it may lead to traffic accidents.

6. Guidelines for Policies and Practices

When a motorized vehicle meets a roadblock, it must comply with the following provisions:

There are obstacles in the road with motor vehicles seeing signs identified obstacles when under conditions permitting, should be done in a timely and safe lane change;

With the driveway of motor vehicles, the car should be in front with the vehicle to maintain adequate safety measures to take the emergency braking distance, and according to the distance before and after, adjust their own speed;

Motor vehicles in preparation for lane, should be observed before and after the vehicle and the car from the distance to determine whether it is suitable for changing, and timely adjustment of their speed;

Forbidden motor vehicles in preparation for lane, forcibly inserted into the gap, should indicate the intention to change lanes, and follow the car lane change, as far as possible to achieve co-lane;

When the vehicle encounters a lane change vehicle, change speed to increase the lane gap when the conditions permit, and the lane change vehicle is started when the lane changing car can meet the requirements of the safety lane change;

Passenger traffic on the route should give priority to traffic in its road, should not be forced to change lanes, or not in the lane, the non-stop by the speaker vent dissatisfaction;

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