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Research Article

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Application of multiple linear regression model in the performance analysis of traffic rules

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ABSTRACT

Nowadays, the traffic safety problem has become the focus of attention and making a sound and reasonable traffic rules and regulations is the trend. The current study mainly discusses the overtaking and lane-changing problem in highway, the differences between traveling on the left and on the right lane. In order to promote traffic smooth effectively, overtaking model is constructed. The left lane changing rule considers its influence on human heart, and then multiple linear regression models. In the country with the cars driving on the left, this model is especially suitable for the near S shaped highway. By studying the joint influence of the curve radius of curvature, steering angle and the road friction coefficient on the driving speed of the curve and the obtained speed is within the speed limit. Therefore, after improving the overtaking model, the left lane vehicle also applies to the lane-changing rule.

Keywords: overtaking model, multiple linear regression model, variance analysis, regression coefficient

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INTRODUCTION

Nowadays, traffic safety problem has become the focus of attention, and stipulating sound and reasonable traffic rules is an important part of traffic safety. In most countries, driving on the right side is a common traffic rule to be abode by, and drivers are required to be on the right lane in highway with many lanes unless they want to overtake other cars. When overtaking happens, the driver should move to the left lane to surpass other cars and return to the original lane after it is over. However, it cannot be ignored that some countries require driving on the left side, which is regarded as a common traffic rule. Therefore, it is of necessity to establish a model to analyze the traffic rules of driving on the right side, and improve it to make the model play a more effective role in stimulating traffic smooth. Then make the improved traffic rules applied to the countries with driving on the left side as the common law, and consider whether it is effective in these countries and optimize the results.

Overtaking model

Model Hypothesis

(1) assume that the vehicle model is of unification, and the vehicles in the team are of the same braking strength and efficiency, namely the braking distance is only related to its own speed;
(2) ignore the influence of weather, slope, road conditions, and other environmental factors on the speed;
(3) assume that the drivers' identification of the surrounding environment is consistent.

Constant speed overtaking model

From the perspective of modeling, overtaking can be classified into constant speed overtaking and accelerating overtaking, and other overtaking behavior is a combination of the two categories. Constant speed overtaking refers to the overtaking vehicle finishes the overtaking process with constant or near constant speed; accelerating overtaking refers to the fact that the overtaking vehicle follows the front vehicle, and wait for the suitable moment to speed up to accomplish the overtaking process. Figure 1 is the sketch map of the overtaking process.

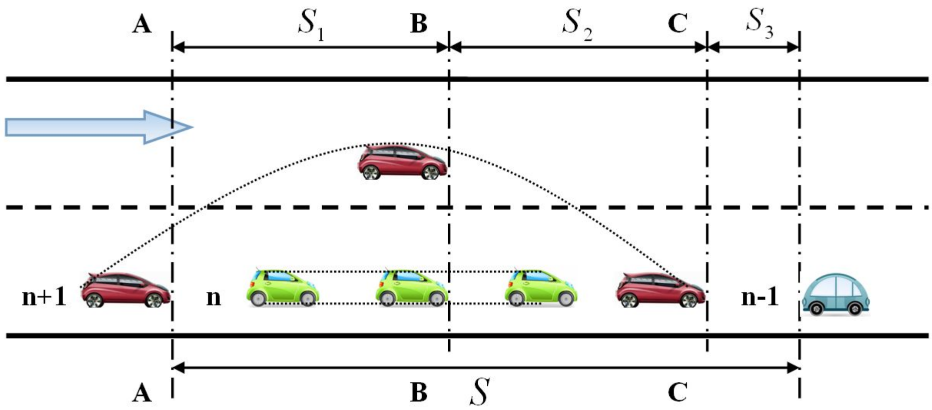

Figure 1 Sketch map of overtaking

Model description
Constant speed overtaking is the simplest situation, namely the overtaking car, the surpassed car and the vehicle on the left lane have the same speed.

Establish a simplified graph shown in Figure 1. The car $n+1$ is the overtaking car, the car n is the surpassed car. A-A position marks the place when the overtaking car changes the lane and begins to overtake. B-B position marks the overtaking car catches up with the surpassed car in the opposition lane. C-C position marks the position when the overtaking car returns to the original lane.

At the time of t, the car $n+1$, n, $n-1$ drive at constant speed. Set t_C as the total time for the overtaking car to accomplish the overtaking process, that is, the time required for the car $n+1$ to move from A-A to C-C. During this time, the driving distance of the car $n+1$ is S_1+S_2, the driving distance of the car n is S_4, the safe distance between the car $n+1$ after overtaking and the car $n-1$ is S_3. Then the computation formula of the overtaking distance S is shown in (1).

$$S = S_1 + S_2 + S_3 = \frac{\dot{x}_{n+1}(t)}{3.6} \cdot t_C + S_3 \qquad (1)$$

In the formula S——overtaking distance (meter);

t_C——the total time requirement for the car $n+1$ to accomplish overtaking (second);

$\dot{x}_{n+1}(t)$——the speed of the car $n+1$ (kilometer/hour).

It is known from the previous research that when the time headway is between 2 to 8 seconds, the vehicle will be influenced and restricted by the front car. At that time, the vehicle has an overtaking requirement, and an overtaking likelihood may occur. By analyzing the result, the time headway range is given when the overtaking will judgment begins. When analyzing the vehicle comprehensive movement state and the total feature of the driver, it is recommended to adopt 3.1 seconds[1].

In the highway, drivers hope to drive at the expected speed. But due to the complexity of the road and traffic condition, the different vehicle type and performance, together with the drivers' different temperament, it leads to the gap of the expected speed between driver and vehicle in the formed people-vehicle unit. Therefore, when the faster car is driving behind the comparatively slow car, the faster car hopes to main its expected speed, so the overtaking willingness comes into being.

Overtaking acceleration model
Based on the referred material [2] when the overtaking accomplishes, the safety distance model between the overtaking car and the car $n-1$ is:

$$S_{加} = v_a \cdot (t_a + t_y) + \frac{1}{2} \cdot a \cdot t_a^2 + a \cdot t_a \cdot t_y$$

$S_{加}$——the safety distance in the process of accelerating overtaking;

v_a ——the speed of overtaking car A when it begins to overtake;

t_a ——the time for accelerating driving;

t_y ——the time for constant driving;

v_b ——the constant speed of the surpassed car B.

Based on the pertinent literature and investigation on experienced drivers, only when the spacing distance between the overtaking car A and the surpassed car Bis bigger than 20m, overtaking is allowed[3].

MULTIPLE LINEAR REGRESSION MODEL

Model preparation

Based on lane changing rules of cellular automata traffic flow model constructed in Problem Two, it applies to the highway road, no matter the vehicle is on the left or right. The obvious difference is the body's physiological factors. As is known to all, when we are running, we are used to doing it counterclockwise, this is because the clockwise running can cause oppression to the heart, and is not conducive to human health. Similarly, when vehicles on the left lane change the lane, it will produce a part of clockwise driving. Because of inertia, the heart will be on right avertence. In order to optimize this, we design the approximate "S" shape curve of highway, as shown in figure 2. We mainly consider the influence of the radius of curvature, steering angle and road friction coefficient on the car when it drives on the curve. Through the establishment of multiple regression analysis model, we study the common effect of several factors on the curve driving[4].

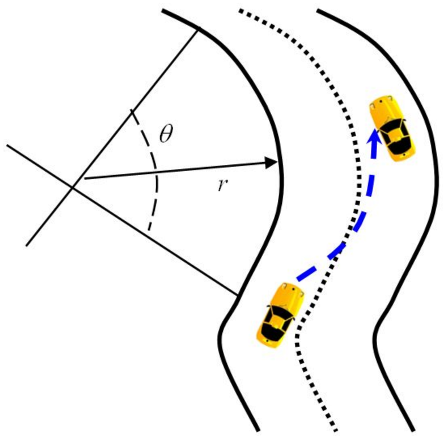

Figure 2 highway graph of the near S shaped curve

Table 1 the radius of curvature, steering angle, road friction coefficient and vehicle speed

speed（km/h）	Radius of curvature	Steering angle	Friction coefficient
65.45	20	120	0.15
80.04	50	60	0.20
90.42	80	40	0.25
101.02	120	30	0.30
109.64	150	20	0.35
116.89	180	16	0.40
123.01	220	12	0.45
127.28	250	8	0.50

Model Establishment and Solution

Assume dependent variable y and independent variable x_1, x_2, x_3 have the following relational expression[5]:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon$$

Among it, y is observable random variable, β_0, β_1, β_2, β_3 are unknown parameter； ε is unobservable random error, satisfying the condition of $E_\varepsilon = 0, D(\varepsilon) = \sigma^2$ （σ^2 unknown）, but the random error is ε slim，therefore it can be omitted in actual investigation.

Setting the regression equation by establishing the relationship between vehicle running speed y and radius of curvature x_1, steering angle x_2, road friction coefficient x_3 :

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3$$

Evaluate the unknown parameter β_0, β_1, β_2, β_3.

According the least square method, use SPSS software to work out the unknown parameters[6]:

$$\begin{cases} \beta_0 = 81.546 \\ \beta_1 = 0.163 \\ \beta_2 = -0.188 \\ \beta_3 = -17.133 \end{cases}$$

Therefore, the equation of linear regression is:

$$y = 81.546 + 0.163x_1 - 0.188x_2 - 17.133x_3$$

◆ analysis of the model result:

(1)It is known in Table 2, the multi-correlation coefficient of 3 independent variables and dependent variable R is 0.998, the determination coefficient R^2 is 0.995, the adjusted R^2 is 0.99. Due to the adoption of the enter method, there is only one regression model. It is seen in Table 2 that the changing volume of R^2 and determination coefficient R^2 is consistent. At the same time, the three variables can explain the speed dependent variable has 99.5% variation value.

Table 2 Model Summary[b]

Model	R	R Square	Adjusted R Square	Std.Error of the Estimate
1	.998[a]	.995	.992	1.96778

a. Predictors:(Constant),V4,V3,V2
b. Dependent Variable:V1

(2) Variance analysis [7]

Table 3 is the analysis of variance table of the regression model, F is 283.692, the corresponding Sig.is the actual significance probability of F. That is the value p. When it is less than 0.05 significance value, the linear relation of the regression equation is obvious.

Table 3 ANOVA[b]

Model		Sum of Square	df	Mean Square	F	Sig.
1	Regression	3295.494	3	1098.498	283.692	.000[a]
	Residual	15.489	4	3.872		
	Total	3310.983	7			

a. Predictors:(Constant),V4,V3,V2
b. Dependent Variable:V1

(3) Significance testing of regression coefficient

Table 4 Coefficients

Model		Unstandardized Coefficients		Standardized Coefficientts	t	Sig.
		B	Std.Error	Beta		
1	(Constant)	81.546	27.745		2.939	.042
	V2	.163	.301	.611	.542	.616
	V3	-.188	.045	-.322	-4.174	.014
	V4	17.133	205.481	.096	.083	.938

a. Dependent Variable:V1 [8]

From the three variables in table 4: the Sig of radius of curvature, steering angle and road friction coefficient is respectively: 0.616, 0.014, 0.938.its corresponding Sig. is the actual significance level of the value t, namely the value p , if given $\alpha = 0.05$, then

$p_1 = 0.616 > \alpha$ so refuse H_0 , thinking the regression coefficient of independent variable "radius of curvature" is not obvious.

$p_2 = 0.014 < \alpha$ so refuse H_0 , thinking the regression coefficient of independent variable "steering angle" is obvious.

$p_3 = 0.938 > \alpha$ so refuse H_0 , thinking the regression coefficient of independent variable of "road friction coefficient" is not obvious.

(4) examine the normal distribution of sample observation:

Table 5 Residuals Statistics[a]

	Minmum	Maximum	Mean	Std.Deviation	N
Predicted Value	64.7695	129.3852	101.7250	21.69758	8
Residual	-2.10517	2.14368	.00000	1.48750	8
Std.Predicted Value	-1.703	1.275	.000	1.000	8
Std.Residual	-1.070	1.089	.000	.756	8

a.Dependent Variable:V1

Table 6 relative error

Actual speed	Calculated value	Relative error%
65.45	64.82	-0.9626
80.09	81.84	2.1850
90.42	91.35	1.0285
101.02	100.61	-0.4059
109.64	108.233	-1.2833
116.89	114.73	-1.8479
123.01	122.86	-0.1219
127.28	129.36	1.6342

From Table 6, the absolute value of the relative error between calculated value and actual value is small; multiple linear regression analysis meets the following four conditions[9]:

★ linear relationship exists between independent variable and dependent variable;

★observed values are independent from each other;

★residual e obeys normal distribution $N(0, \sigma_2)$;

★ e doesn't change according to different variable values, that is homogeneity of variance.

Therefore, multiple linear regression model is suitable for the study of curvature radius, steering angle and the variable relationship between road friction coefficient and vehicle speed.

The model is applied to the country with driving on the left as the rule, such as Britain, its scope of the highway speed limit is $64.4/128.8\ km/h$ [10].The actual value and the calculated values are in the range. Therefore, based on overtaking model after modification, the left lane vehicles are also suitable for lane changing rules of driving.

In addition, we also consider the driving rules different areas around the world distribution, as is shown in Figure 3.We find that 34% of the countries are driving on the left, 66% of the countries are driving on the right. And countries with traffic rules of driving on the left are mostly island countries, such as Hong Kong, Australia and other regions. Therefore, it is related to the geographical position whether it is the rule to drive on the left or right[11]. Through further analysis, most of the countries keep left for the invasion of the British, is only required by Britain and has not changed. And take Hong Kong and China for example, traffic rules are different, but the difference between the geographical positions is few. Thus, we conclude that different location of vehicle driving rules do not have too big effect, therefore, this study does not consider this factor seriously.

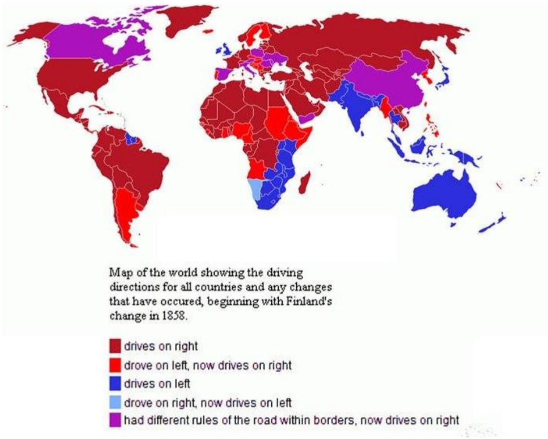

Figure 3 regional distribution of the traffic rules for different countries in the world

CONCLUSION

To sum up, in the country with the car driving on the left, the improved lane-changing rules meet the function of the human body comfort, perfect the vehicle lane changing rules based on overtaking model, especially applicable to the near "S" shaped curve of highway.

future work

Based on the overtaking model established in current study, its main study object is the double-lane changing situation. Hereby, we aims to promote the overtaking model and apply it to the three lane model.

Assume the three lanes as the carriageway, and vehicles driving in the lanes have the same performance and vehicles are allowed to overtake other vehicles at any lane. Based on the above condition, establish model by determining the first lane as the accelerating lane, and the rest two lanes as the driving lane. The stimulated result shows that under the same condition, three lanes with the managed traffic flow model have similar traffic stream characteristics with that of the three lane traffic without regulation. However, the system lane-changing frequency and the lane utilization ratio vary. In this way, it is demonstrated that the three lanes with managed traffic flow model enhance the drive safety.

Acknowledgements

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