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Research of two-factor optimization model of a multi-lane freeway traffic rules

Aimin Yang[1]*, Shujuan Yuan[2], Yingna Zhao[1], Qingpeng Ding[1], Longge Yan[1]

[1]Hebei United University, Tang Shan, (CHINA)

[2]Qinggong College, Hebei United University, TangShan, (CHINA)

E-mail: aimin_heut@163.com; yuanshujuan1980@163.com

ABSTRACT

Under circumstances of left-driving rule, from both internal and external causes, to consider the difference of driving on the left or right, and we found that the person of driving at left side is slower by 0.5s than that of the right side, and therefore affect the safe distance between vehicles thus further affecting the safety factor and traffic flow. Then in combination with the two-factor optimization model based on performance problems of a multi-lane freeway traffic rules to calculate the optimal solution when driving at left side, that is an average speed of vehicles in the second lane should be maintained as $v = 80\text{km/h}$, the second lane speed limit is 85 km/h, the minimum speed limit is 75 km/h, the maximum speed limit for the first lane is 95 km/h, the minimum speed limit is 85 km/h, and we use actual data to verify the conclusion.

Intelligent system response time is negligible, we obtained that the response time can be reduced therefore to shorten safe distance between vehicles. Then according to two-factor optimization model based on performance problems of a multi-lane freeway traffic rules, and the optimal speed for the second lane should be 94km/h, and the second lane minimum speed limit is 84 km/h; highest speed limit of first lane is 104km/h, the lowest speed limit of first lane is 94 km/h. Finally, the traffic properties under this case are analyzed; we found the impact on traffic performance from intelligent system can be improved by 11%.

KEYWORDS

Traffic rules performance;
Two-factor optimization;
Safety factor evaluation system.

MODELING FOR THE TRAFFIC FLOW CALCULATION

v_3, v_4 are the mean value of speed upper limit and lower limit in the lane. x_{11}, x_{12} are the vehicle-following safety speed in different lanes respectively. At this time, the maximum traffic flow in single lane is:

$$C_{imax} = \frac{L}{l + x_1} / \frac{L}{v} = \frac{v}{l + x_1}, i = 1,2 \quad (1)$$

The total maximum traffic flow in both lanes is:

$$C_{max} = \frac{v_5}{l + x_{11}} + \frac{v_6}{l + x_{12}} \quad (2)$$

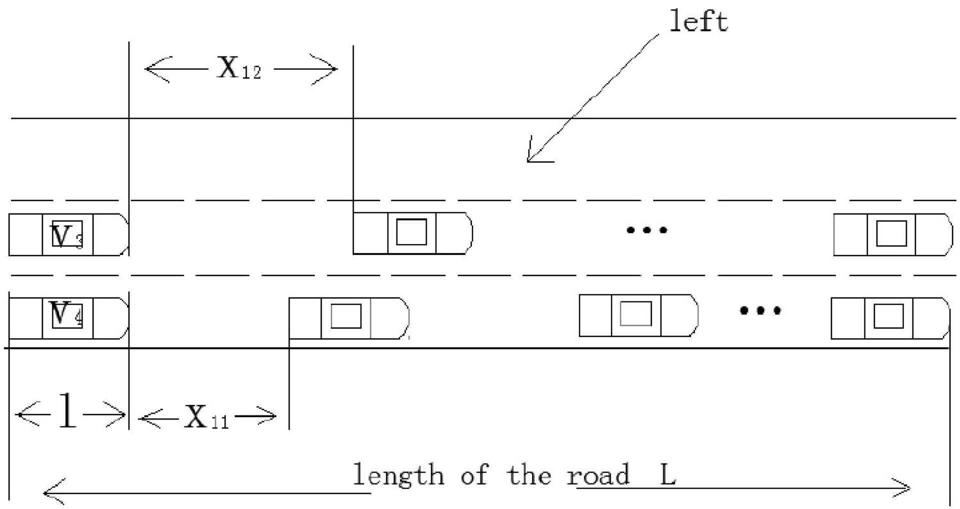

Figure 1 : Sketch map of ideal road condition

To determine the length of the vehicle body[1]

This problem mainly researches the influence from vehicle speed and in-between distance, the influence of vehicle length on traffic flow[2] is very small. And in China, 80% of the vehicles on the highway are medium size, which is relatively concentrated. To simplify the model, all vehicle can be seen as the same length. Mid-size vehicle length is less than 6 m, and taking into account the existence of a large vehicle, so we assume that the average vehicle length is 5 meters.

In reality, many factors such as road width, slope, lateral clearance, conditions along the road will affect the traffic capacity of the road. Assuming the correction factor for road influence factoras:

①lane width correction coefficient r_1; ②clear width of the lateral correction factor r_2; ③vertical slope correction factor; r_3; ④ sight deficiency correction factor r_4; ⑤ conditions along the correction factor r_5 ⑥ The fix of traffic conditions mainly refers to the composition of the vehicle, especially under mixed traffic conditions[3], many types of vehicles, large and small, the area occupied by different roads, different properties, different speeds, mutual interference, are all seriously affecting road traffic capacity, general correction factor for the traffic conditions is r_6.So, we take an overall correction factor as K, then:

$$\mathbf{K = r_1 r_2 r_3 r_4 r_5 r_6} \quad \mathbf{(3)}$$

The chosen highway is in the same part of the road, so K is constant.

Therefore, the traffic flow calculation formula is:

$$\mathbf{C = KC_{max}} \quad \mathbf{(4)}$$

Assuming pavement width is not less than 3.75 m with roadside lateral width of no less than 1.75 m, and a gentle longitudinal slope. According to the reference[4], to obtain correction factor: take $r_1 = 1.0$, $r_2 = 1.0$, $r_3 = 1.0$; due to an open road conditions, the correction factor for the lack of sight is $r_4 = 0.85$; according to the size of the speed limit, you can guess the road in some cities of the region. So take correction factor along the road as $r_5 = 0.95$; the better the road condition, the better the traffic condition, taking traffic conditions correction factor $r_6 = 0.85$; in summary, correction factor available $K = 0.696$.

Therefore, the traffic flow calculation formula is

$$\mathbf{C = 0.696\left(\frac{v_3}{5 + x_{11}} + \frac{v_4}{5 + x_{12}}\right)} \quad \mathbf{(5)}$$

TWO-FACTOR OPTIMIZATION MODEL BUILDING

According to the safety distance calculation formula, we know the speed of vehicles traveling directly determines the size of the safe distance. Therefore to decided speed traffic flow and safety. According to overtaking traffic models and model, you can build a traffic and safety optimization model.

Based on traffic flow model, the relationship between speed and traffic flow can be obtained:

$$C = 0.696\left(\frac{v_4}{5 + x_{11}} + \frac{v_3}{5 + x_{12}}\right)$$

the relationship between speed and safety factor can be obtained according to the overtaking model:

$$\eta = \frac{\sum_{i=1}^{3} \eta_i}{3}$$

To weight the impact of speed on both traffic flow and safety, so the traffic condition can be optimized. When the traffic flow is too large, it will cause a declined safety. Therefore, the relationship between traffic flow and security is mutual restraint. We believe that traffic flow and safety are equally important, and therefore their weight is the same, assigning each of them as 0.5 respectively, you can create an object function, to make:

$$Z = \frac{1}{2}(C + \eta) \quad (6)$$

When Z is the largest, the traffic condition is the best, so the speed at this time is an optimized value.

And v_4, v_3 are average speeds in first lane and second lane respectively.

$$v_4 = \frac{v_{1\max} + v_{1\min}}{2},\ v_3 = \frac{v_{2\max} + v_{2\min}}{2} \quad (7)$$

According to the single lane, the speed limit values are 20 km / h. According to the second model overtaking equation (9), (10), (11), relationship between v_3 and v_4 can be obtained and. According to the equation (7), v_4 can be used to replace $v_{1\max}$, $v_{1\min}$, $v_{2\max}$, $v_{2\min}$ and v_3.

According to the optimization model, we can obtain the relationship between v_3 and the object function Z. And the chart relationship between v_3 and Z can be obtained as shown by Figure 2.

Figure 2 shows that when $v_3 = 22\text{m/s}$, the optimized solution is obtained.① Evaluation to current traffic rules.Under the current traffic rules, $v_3 = 19.5\text{m/s}$. From Figure 2, we can see the disparity when the value of Z is compared with the optimal value. This shows there is a big optimization space to the current traffic rules.When the traffic condition is sparse, the vehicle speed v_3 is larger (but smaller than lane speed upper limit). Therefore the driving distance between vehicle is too large. According to Figure 2, the traffic performance is 1.3. With the englarging of traffic flow, the vehicle speed v_3 decrease, and traffic performance is declined.② The chosen of optimized solution According to Figure 2,

when $v_3 = 22\text{m/s} = 79.2\text{km/h}$, there is a maximum

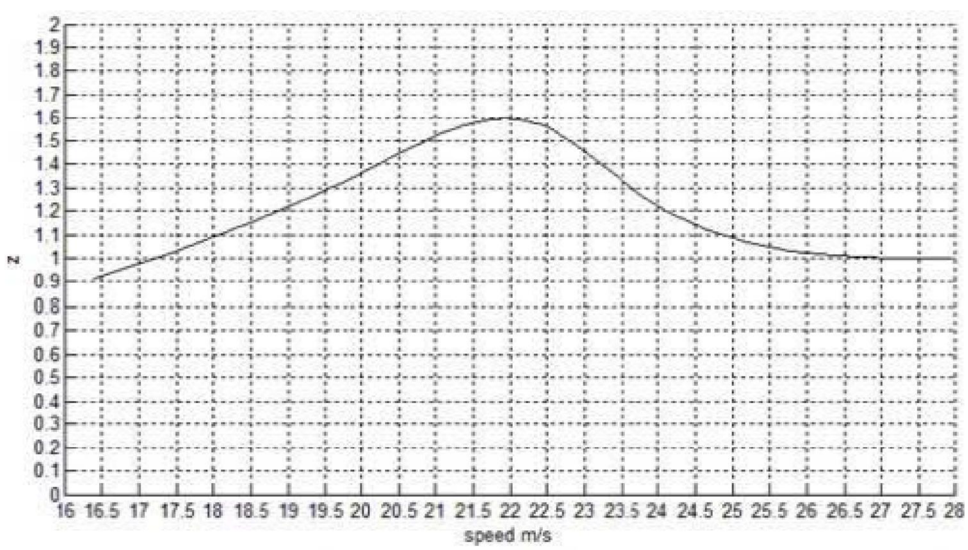

Figure 2 : Relationship chart between v_3 and object function

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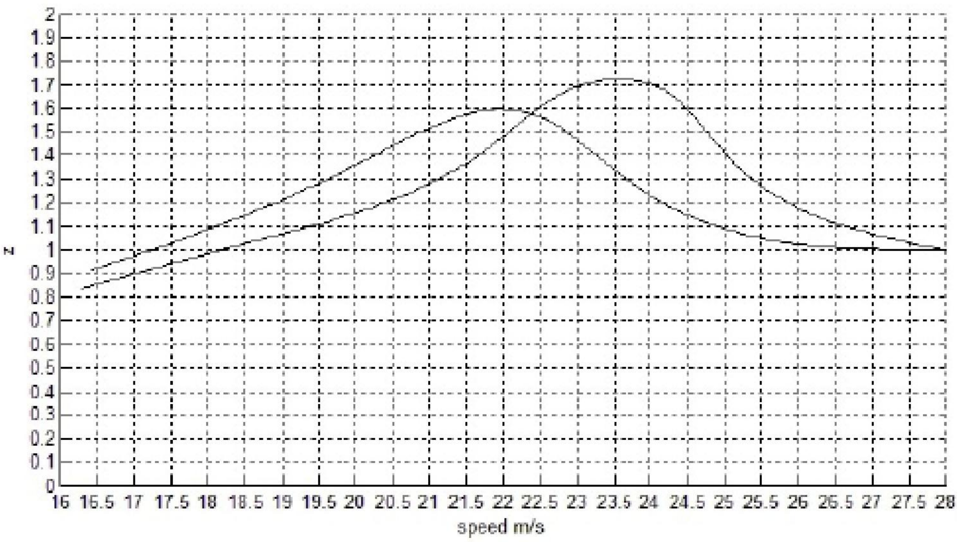

Figure 3 : The relation chart between improved v_3 and object function Z

for Z , and then the best traffic performance appears. Also known differences between maximum and minimum speeds under current traffic circumstances is 20 km / h. After optimization, take the second lane minimum speed of 69.2 km / h, the maximum speed of 89.2 km / h. At this point, the first lane minimum speed limit is 89.2 km / h; the maximum speed is 109.2 km / h.

Under the current rules of the road, the speed gap between the upper and lower limits is 20 km / h. Greater speed difference and greater influence each other result in reduced traffic flow and poor safety performance. Accordingly, we speculate that if this difference is reduced, it will improve traffic performance. In the driving process, speed is changed. Different vehicle performance also influences vehicle speed. Taken overall consideration, we define speed limit as 10 km / h. to validate the assumptions, we made the relation graph between v_3 and Z , as shown by Figure 3:

Images show the difference value between the speed limits is 10 kilometers, the object function is better than the solution of the speed limit of 20 kilometers. At this speed value $v_3 = 23.5\text{m/s} = 84.6\text{km/h}$. To get a round value for v_3 , the optimized solution is: second lane speed limit is 90km/h, the minimum speed limit is 80km/h; first lane upper speed limit is 100km/h, the

Figure 4 : Distribution of left driving and right driving countries

minimum speed limit of 90km/h. This solution is the best one of this highway speed limit.

LEFT DRIVE WITH OPTIMIZATION

To analyze whether the optimization solution in problem one can be used to left-driving traffic rules, you need to analyze the differences between left-driving and right-driving system. In this regard, we discussed both from internal and external cause.

Analysis to external cause

External factors are discussed from both the origin and driving conditions

Discussion of the origin[4,5]: There are now about 34% of the world's countries have adopted the system of left driving traffic system, as shown in Figure 4[6].

Left driving or right driving is not fixed at the begining, but the result of long-term evolution. "Left" in general stands for the United Kingdom, Japan,For Britain, their left driving system can be traced back to the Roman Empire. In medieval Europe, left or right habit is always according to the knight's habits. Japan's left-habit historical reason for this is similar. Samurai long knife in the left hand to facilitate pulling the sword, the left side of the body is vulnerable.No mutual influence between the origin of the 'left system' and traffic rules. Discussion on the driving conditions[7]: the left and right drive pedal of vehicle is all in the same order. Driving the processes of both sides are also identical. There is no mutual influence between the left or right driving and the traffic rules.

Analysis to internal cause

Through search information[8], we found that humans have an instinct to avoid its evils: in the case of rapid human movement, when a possible danger is found, he or she will tilt to the left or turn instinctively. When cars drive on the left, the left lane is low speed. If a person in danger occurs in two situations: one is turn left to escape. Then the car will turn to the low speed lane, which is very easily lead to accident; second, escape to right after the reaction. In daily life, most people are right-handed. When this group of people in an emergency situation, you need to force the left to make the car turn right. This will extend the time to change lanes or overtaking time, and brake response time. The time difference between two hands is 0.5 seconds[9,10], which can be added to the brain reaction time in the model 1, then the brain reaction time is 2 seconds.

It can be seen left-driving rules need to increase the safety distance x_1 between vehicles. To put $t = 2$ in $Z = \frac{1}{2}(C + \eta)$ of optimization model built in problem one, you can get the optimal solution for maximum speed limit of 85km/h, the minimum speed limit of 75km/h; first lane speed limit of 95km/h, the minimum speed of 85km/h.

Application of the model in the left driving test

In 2012, cases of traffic accidents accounted for 20.3% [5] of Britain's total vehicles.At the end of 2012, China's vehicles are 233 million. Police department reported road traffic accident cases are 3,906,000[9]. China traffic accident occurrence rates was 18.1% [10]. British accident occurrence rates was 2.2 percentage points higher than that of China. Obviously, the human instinct to avoid its evils and left-hand drive have lower safety factor than that of right-handed, so the speed limit should be reduced.

we can obtain the proportion between casualties and total vehicles, as shown in Figure 5

From Figure 5 we know that right driving is safer than left driving.

Intelligent systems with optimization

With the development of science and technology, transportation systems[11] are becoming more intelligent.

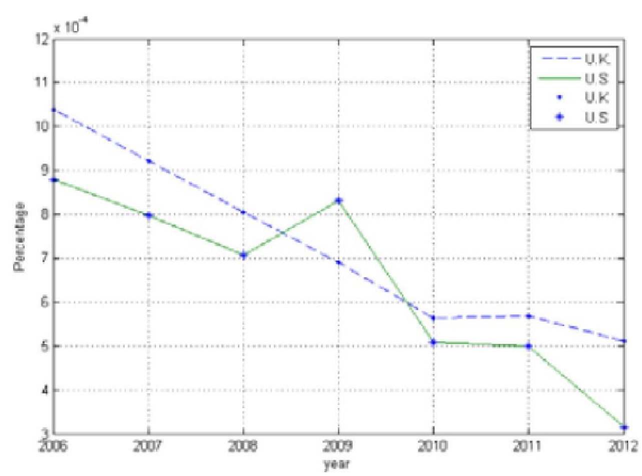

Figure 5 : The proportion between casualties and total vehicls

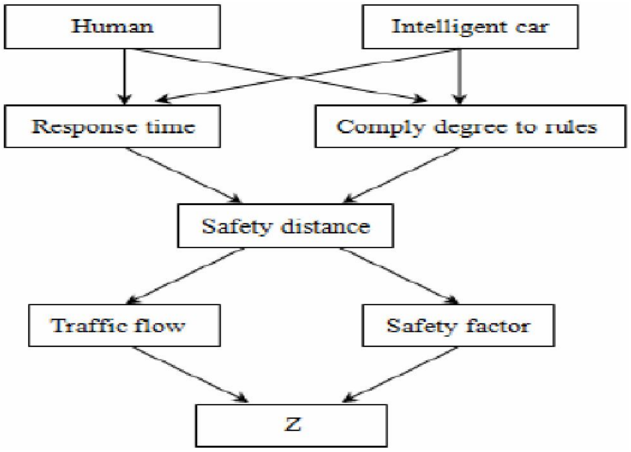

Figure 6 : The relation chart of intelligent vehicle in model

Such as electronic monitoring, intelligent navigation, smart cars, all of them reduce the incidence of traffic accidents and increase traffic flow. There is a big difference between intelligent electronic traffic control and human control; the optimized traffic rules will be affected. We have smart cars as an example to study optimization of traffic rules.

Smart Car is the latest scientific and technological achievements, such as the computer product in combination with modern automobile industry, the intelligent vehicle refers to the use of varied types of sensors and smart highways to realize auto driving, which usually have the autopilot function, automatic transmission and automatic identification of road. The vehicle also has a variety of auxiliary computerized facilities.

First of all is to assume that the vehicles in certain highway are installed with intelligent control system. The differences between intelligent driving and human driving are mainly that: human reaction speed is slower than that of the computer; and human do not fully comply with the traffic rules;

The relationship[12] between intelligent vehicle in the model and the influencing factor is shown in Fig.8. The arrow direction indicates the previous factor influences the next facto.

As shown in Figure 6, the impact of human and intelligent systems for the proposed model in this paper lie in the vehicle safety distance. In the calculation of the safety distance between vehicles, intelligent systems do not need to consider the reaction time. Therefore, the optimization model can be improved by removing response time. Equation (6) can be used to obtain Figure 7.

Optimal solution can be known that second lane speed limit is 94 km / h, the minimum speed limit of 84 km / h; first lane speed limit is 104 km / h, the minimum speed limit of 94 km / h.

In this case the object function $Z_3 = 1.91$, the optimal solution in the original program $Z_2 = 1.72$

So traffic performance is improved as $\frac{Z_3 - Z_2}{Z_2} \times 100\% = 11\%$. This factor can be known to improve transport performance by 11%

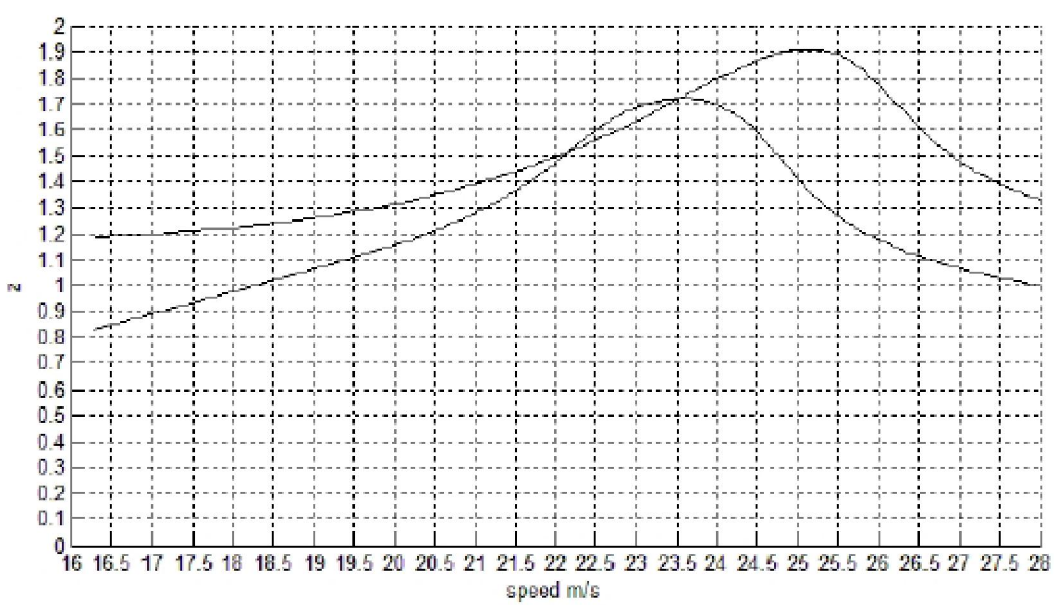

Figure 7 : The relationship between speed and Z

CONCLUSION

This paper created three models interconnected, the traffic flow and safety is optimized by varying the speed with the unique variable. Therefore optimal traffic rules are obtained.

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