Research on Reasonable Design of the Front View Triangle Area of the Front Side of the Road Mixing Nose Based on Driving Safety

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Abstract. In order to improve the limitation of formulation for sightline triangle area in Design Rules of Highway Grade Separation JDG/TD-2014, which is 100 meters before confluence nose for the main line and 60 meters before that for the ramp, this paper analyzes the driving and vision characters considering the driving safety. The reasonable design sizes of sightline triangle area for different mainline driving speeds are given, using the available sightline model.

1. Introduction
The intersection of the freeway ramp is in the intersection of two driving states, usually a frequent occurrence of traffic accidents. The main line vehicle travels faster, and the driver has a large psychological load during the high-speed driving. If the situation of the vehicle that is suddenly converging from the ramp is improperly handled, serious traffic accidents are likely to occur, and the risk of driving is extremely high.

In terms of traffic safety at the junction of the roads, there have been relatively few studies at home and abroad. The US Green Paper [1] Chapter 10 Stereo In the application description of the Y-type interchange of the full-orientation ramp, it is mentioned that the entrance and exit of the full-directional ramp should be designed as the main line branching and joining joint. The "Code Design Code for Highways" (JTG D20-2006) [2] specifies the design conditions for the main line branching and confluence. One-way lane of one expressway is divided into two multi-lane ramps to connect the branches of another expressway. The branching department divided into two expressways by one expressway shall be designed according to the main line, and vice versa. "Three-way cross-design rules for highways" (JTG T21-2014) [3] (hereinafter referred to as "the rules") formulate for the triangle zone of entrance ramps nose. The appropriate distance of main line is 100m from the nose, and that of ramps is 60m from the nose. The space between the main line and the ramp should meet the requirements of the vehicle mutual view in the triangle area, as shown in Figure 1.
Figure 1. Schematic diagram of the front view triangle of the combined nose

The triangle is the front of the nose, the main line is 100m from the nose, and the triangle is 60m from the nose. It is important for the main line and the vehicle on the ramp to recognize each other and take timely deceleration measures to avoid collision. The guarantee function ensures that its certain viewing area is of great significance to the driving safety at the combined nose. However, the values of 100m and 60m specified in the "Rules" do not explain the reasons in the relevant description. In the actual selection process, they are only in the stage of empirical application. The relevant research has not elaborated and clarified this. When the design speed of the main line is 120km/h, 100m can only guarantee the 3s stroke of the main line vehicle. According to the theoretical calculation model of the parking line of sight, the response time of the driver to see the obstacle is generally taken as 2.5s. After the driver judges and takes the braking measures, it is obvious that the distance of 100m does not guarantee sufficient time for the driver to slow down or change lanes. Based on this, this paper intends to analyze the driving characteristics of the main line and the ramp vehicle, and select the appropriate line-of-sight model to classify the reasonable value of each side length of the general-purpose triangle area under different main line design speed states.

2. Analysis of driving characteristics of main line and ramp vehicles

2.1 Analysis of driving characteristics of mainline vehicles

The main line vehicle has priority to pass the vehicle in the ramp that is expected to flow into the main line, and the traveling speed is high. When the driver is driving in a free-flowing road state, he will comprehensively judge his desired vehicle speed $v_2$ according to the actual road conditions, actual traffic conditions, vehicle operating conditions and vehicle performance, and compare the desired vehicle speed $v_2$ with the actual vehicle speed $v_1$, according to the comparison results take corresponding measures to adjust the actual speed of the vehicle. When $v_1>v_2$, the deceleration operation is performed; when $v_1<v_2$, the acceleration operation is performed, as shown in Fig.2. Therefore, the greater the difference between the actual speed and the expected speed, the more emergency measures the driver takes in the event of an emergency, the greater the risk, the more likely it is to cause a traffic accident.
2.2 Analysis of driving characteristics of ramp vehicles

The ramp is the link that connects the main line and acts as a transitional connection. Acceleration lanes are connected at the end of the entrance ramp, mainly to provide space for the ramp vehicles to increase the speed of travel, to achieve a reasonable speed to flow into the main road traffic, and to reduce the intrusion disturbance. The vehicle can generally be divided into five stages: the diversion driving process, the deceleration driving process, the constant speed or variable speed driving process, the acceleration driving process and the confluence driving process. The tunneling process involved in the Tongwei triangle area explored in this paper is mainly the latter three processes.

The constant speed or variable speed driving process refers to the driving process of the car from the exit to the entrance. During this process, the car should travel at a constant speed. However, due to the influence of the speed of the deceleration travel end and the actual driving speed of the driver according to the road conditions, the shifting driving state, that is, the deceleration or acceleration to the entrance speed is often occurred. The acceleration driving process is the driving process before the vehicle accelerates from the entrance to the front line when the vehicle enters the acceleration lane. The confluence driving process refers to the driving process in which the car starts to traverse from the acceleration lane to the full-flow straight traffic.

3. Reasonable size design of the viewing triangle

3.1 Selection of main line of sight model

Wu Chaoyang [6] carried out detailed analysis and selection of the characteristics of the main line confluence process and the safety line of sight calculation model. However, the design of the main triangle part of the intersection of the tunnel merged with the main line has similar characteristics. Therefore, the line-of-sight model established by this paper is selected as the basis for calculating the length of the main line of the general-purpose triangle.

Usually, when the main line vehicle finds that the vehicle in the ramp is about to enter the main line, there are two processes that are subjected to deceleration braking or lane change measures: 1 reaction distance l1; 2 lane change distance l2 or deceleration distance l3.

(1) Reaction distance l1

When the driver finds that there is a remitted vehicle in the ramp, he will observe the driving situation of the other vehicle and make a judgment. The reaction distance l1 of this process is considered to be the driving speed of the original vehicle speed. The reaction time includes the
observation time $t_1$ and the judgment time $t_2$. With the preparation time $t_3$, the formula for calculating the distance is as follows:

$$l_1 = \frac{vt}{3.6} \quad (t = t_1 + t_2 + t_3)$$

Where: $l_1$ — reaction distance (m);
$V$ — main line design speed (km/h);
$t$ — Travel time (s), take 2.5s.

The reaction distance of the main line vehicle is shown in Table 1.

| Speed (km/h) | 120 | 100 | 80 | 60 |
|--------------|-----|-----|----|----|
| Reaction distance $L_1$ (m) | 83  | 69  | 56 | 42 |

(2) Lane change distance $L_2$

Confluence connection, if the outer vehicle wants to change lanes to the inner lane, find a suitable traffic safety clearance. Since the lane change behavior is unnecessary to change lanes, the driver can take a lane change or deceleration, when the driver decides to change lanes. When the left side does not have an instantaneous change of lane clearance, it is not necessary to change the lane, so this lane change behavior does not need to wait for the insertable gap. It takes 3 seconds for the vehicle to change lane behavior. During this time, the outer lane vehicles will wait in the original lane to enter the inner lane. The vehicles on the outer lane must ensure that they enter the inner lane before the merged nose. During the lane change, the outer lane is not considered. The speed changes, the distance the vehicle changes lanes in this process is:

$$L_2 = \frac{vt_4}{3.6}$$

Where: $L_2$ - change lane distance (m);
$V$ — main line design speed (km/h);
$T_4$ - the time required to change lane behavior, usually takes 3 seconds.

The distance required for the vehicle to change lanes at each design speed of the main line is shown in Table 2.

| Speed (km/h) | 120 | 100 | 80 | 60 |
|--------------|-----|-----|----|----|
| Lane-change distance $L_2$ (m) | 100 | 83  | 67 | 50 |

(3) Vehicle deceleration distance $L_3$

Decelerate when the vehicle is driving without a suitable insertable clearance, or if no lane change is taken. Avoiding the vehicle encountering the vehicle on the other side is a critical condition: one side of the vehicle is to reduce the speed to the speed of the vehicle before the other side of the vehicle enters. The vehicle change lane entrance speed is generally 0.76 times of the main line design speed. After deciding that the speed needs to be decelerated, the driver brakes the vehicle and reduces the speed before the nose point of the confluence connection. This process can be divided into brake preparation, phase and braking phase are two parts. The braking phase can be in two more phases, the braking transition phase and the stationary braking phase.

Wu Chaoyang carried out a detailed analysis of the vehicle deceleration process, and finally got the formula for calculating the vehicle deceleration action distance as follows:

$$L_3 = l_1 + l_2 + l_3 = \frac{Vt_3}{3.6} + \frac{Vt_4}{3.6} - \int_0^t \int_0^t xdxdt + \frac{v_1^2 - v_2^2}{25.92a}$$

Where: $l_1$ — the distance traveled by the vehicle during the braking preparation phase (m);
$L_2$ — the distance travelled by the vehicle during the braking transition (m);
$L_3$ — the distance travelled by the vehicle during the stationary braking phase (m);
$T_3$ — Brake preparation time, take 0.3s;
$T_4$ — the duration of the braking transition phase (s);
V2——The speed at which the vehicle enters the joint nose (km/h), taking 0.76 times the design speed of the main line.

The calculated braking distance to the vehicle is shown in Table 3.

| Speed (km/h) | 120 | 100 | 80 | 60 |
|-------------|-----|-----|----|----|
| Deceleration distance (m) | 84  | 60  | 40 | 24 |

3.2 Algorithm for calculating the length of the viewing triangle in the ramp section

The design speed of the ramp is generally 50%~70% of the design speed of the main line. For vehicles with fast driving on the main line, the vehicles in the ramp should choose to wait for the waiting mode to enter the main line. The vehicle traveling in the ramp is intended to travel at a constant speed at the ramp design speed. The length of the viewing section of the triangle should be equal to the uniform driving distance of the ramp in the main line braking or changeover time. The main line braking or lane change time t is about 5.5 seconds, so the length of the through triangle of the ramp section is calculated as shown in Table 4.

| Main line design speed (km/h) | 120 | 100 | 80 | 60 |
|--------------------------------|-----|-----|----|----|
| Ramp design speed (km/h)      | 70  | 60  | 50 | 40 |
| Side length value (m)         | 106.9 | 91.6 | 76.4 | 61.1 |

The value of the length of the viewing triangle in the ramp section should also meet the requirements of the Rules for the parking line of the ramp. The Rules and Regulations for the parking distance of the ramps are shown in Table 5.

| Ramp design speed (km/h) | 70  | 60  | 50  | 40 |
| General area parking line of sight (m) | 95  | 75  | 65  | 40 |

3.3 Establishing a reasonable size reference table for the viewing triangle

Through the above analysis and calculation, the lengths of the reserved line segments of the main line segment and the ramp section that meet the driving safety requirements are summarized in Table 6.

| Main line design speed (km/h) | 120 | 100 | 80 | 60 |
|--------------------------------|-----|-----|----|----|
| Main line segment (m)         | 185 | 155 | 125| 95 |
| The length of the tunnel section (m) | 105 | 90  | 75 | 60 |

4. Conclusions and prospects

4.1 By analyzing the driving characteristics of the main line and the vehicle in the ramp, this paper selects the corresponding line-of-sight calculation formula, and classifies and calculates the classification of the length of each side of the front-end triangle of the tunnel nose, and gives the classification and calculation under different main line design speeds. The recommended values for each side length are given.

4.2 In the calculation of the side length of the tunnel in the tunnel section, the vehicle is designed based on the uniform driving speed of the ramp design. In fact, the driver's driving state also receives the driver's psychology, age, vehicle starting braking sensitivity, and observes the main line. The time of the vehicle is related, so the calculated accuracy of the length is subject to further study.

4.3 For the difference in the influence of the direct ramp and the parallel ramp on the main line, this paper does not analyze and distinguish accordingly, and further research is needed.
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