Research on identify stadia of interchange exit ramp in mountainous urban freeway

TAN Hai
(School of Civil Engineering and Architecture, Chongqing Jiaotong University, Chongqing, China)

Abstract
The identify stadia of interchange exit ramp has great influence on capacity and safety levels of urban expressway, combining with car psychological theory and drivers' characteristics, based on design speed and driver's reaction time, drivers' operating characteristics and the cause of the accident on interchange exit ramp was analyzed and the identify stadia threshold under different design speed was determined. The result indicates that: the requirements of specification for identify stadia has some limitations, it should be modified appropriately.

Keywords: expressway; interchange exit ramp; identify stadia

1. Introduction
With the sustained economic and social development, urban population and car ownership is increasing, the number of road traffic accidents also increased year by year. There are always a large quantity of interchange in mountain city, with complex form, low alignment index, a small road width, and the interchange typically contains a short length of weaving section, traffic run complexly in this section. There are many traffic conflict points, inadequate identify stadia, easy to cause traffic accident.

After a review of domestic and foreign research, I have rarely found domestic and international research for the identify stadia of Interchange export, and they focused on the relationship between exit ramp alignment and highway safety, there is no experimental study, and not fully consider the actual operation of the vehicle and the combined effects of various factors.

2. The classification of interchange exit ramp

2.1 General ramp
In terms of the whole interchange system, due to a variety of restrictions of the terrain, feature, there are different requirements of traffic function, the layout form of the exit ramp is complicated. Its basic requirement is not complicated, however, in addition to have linear function, the right side of the shunt, the left side of the shunt traffic function should be added, namely the right shunt ramp and left shunt ramp.

2.1.1 Right shunt ramp
Shunt vehicles separated from the on-ramp traffic, leave the on-ramp diversion area through the right shunt ramp. Its feature is, right-turning shunt lane have little influence on the straight lane, shunt is convenient, clear direction, the speed is high, use more widely.

2.1.2 Left shunt ramp
Shunt vehicles separate from the inner side of the ramp driveway, through the left shunt ramp, leave the on-ramp diversion area. Its feature is, left-turning shunt lane have big influence on straight lane, directly affect the traffic efficiency.
of diversion district.

2.2 Successive shunt ramp

In accordance with the order of right shunt and left shunt, the left split, the combined mode of interchange successive exports can be divided into first left then the right, first right then left, first left then left, first right then right these four types.

2.3 Mainline constraint export

Mainline constraint export refers to the interchange export restricted by terrain conditions and have to set in the lower index sections of main or segments hard to identify or unfavorable to vehicle decelerate on. The mainline constraint exports mainly have problems to identify export position, according to different export identify factors, mainline constraint export can be divided into the mainline horizontal alignment constraint export and mainline vertical alignment constraint exports.

2.3.1 Mainline horizontal alignment constraint export

Mainline horizontal alignment constraint export refers to interchange export position at horizontal curve section, the export position blocked by motorways obstacles, the driver is not easy to identify the export position, prone to rear-end collision, side collision, hit fixtures and other accidents.

2.3.2 Mainline vertical alignment constraint export

The mainline vertical alignment constraint export include interchange export locate behind curve slope point of smaller Convex vertical curve, the driver always miss the export or emergency braking near the export in this section, easily lead to traffic accident.

3. Traffic flow characteristic analysis in the process of car shunting

Because the vehicle was designed for running from high speed mainline to the low speed ramp, in this process, the driver must complete the driveway transform, and it is mandatory lane change. In order not to affect the main line, drivers need to change to the outer lane within a certain distance in front of the deceleration lane, and then in the transition section and slow lanes, reduce the running speed of the vehicle within the safe driving speed of ramp, so within the original lane, the velocity of the front car is greater than the speed of back car, therefore, it is almost impossible to rear the end, in this study to ignore the situation, but in the process, the safety of the car is still restricted by other conditions, due to the front car within the target lane is slower, and the high speed when cars changing lanes, the lane changing car easily rear the end with the front vehicles within the target lane; Due to premature brake or brake acceleration too large, vehicle speed reduce too fast, leading to the vehicle within original lane crash. In both cases, therefore, constitutes the vehicle security constraints of safely change lanes. Only both cases are satisfied at the same time, the vehicle can be safely change lanes.

4. Accident analysis

The road alignment index in mountain city is generally low. When the car approach the overpass weaving section, pulled out of the exit freeway interchange intertwined; the car, since the interleaving length is short, confluence of vehicle import and distribution vehicles out of lead to more traffic conflict and more speed discreteness, easy to produce collisions, rear-end accidents; Since exit sometimes behind a smaller radius convex vertical or horizontal curve, the driver is difficult to detect exit signs and markings, the export position was found when close to exit, the driver will be forced to take emergency brake and change lanes, prone to rear-end collisions and side collisions; Due to the unreasonable exit sign set position, distance and information overload, drivers fail to understand the information, emergency braking or parking read symbol meaning, when miss exports, will back into the target export, these behaviors are prone to crash.
5. Specification provisions on identify stadia of interchange exit ramp

According to 《Design Specifications for Highway Alignment》 JTG_D20-2006, in the exit of interchange, identify stadia is the distance required for safe operation; it is mainly used to detect something that may cause visual clutter, or the information source difficult to perceive, danger signs or its potential, select the appropriate speed and route, safe and effective to complete the trip. The specification stated that identify stadia should be guaranteed before the mainline shunt nozzle judge the export, identify stadia value should be more than the prescribed in Table 1, under limited conditions, the identify stadia value should be greater than 1.25 times the main line stopping sight distance (as shown in Table 2).

<table>
<thead>
<tr>
<th>Table 1</th>
<th>The identify stadia of interchanges export</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design speed (km/h)</td>
<td>120</td>
</tr>
<tr>
<td>Identify stadia (m)</td>
<td>350~</td>
</tr>
<tr>
<td>Identify stadia (m)</td>
<td>460</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2</th>
<th>The limit value of interchange exit identify stadia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design speed (km/h)</td>
<td>120</td>
</tr>
<tr>
<td>Stopping sight distance (m)</td>
<td>210</td>
</tr>
<tr>
<td>Identify stadia (m)</td>
<td>262.5</td>
</tr>
</tbody>
</table>

6. Identification stadia of expressway interchange exit ramp

The process of vehicle left the freeway exit ramp involves identifying the exit and vehicle deceleration process, and thus identify stadia can be decomposed into export identify distance and deceleration distance (as shown in formula 1), identify stadia L calculated value is as follows:

\[ L = L_1 + L_2 + L_3 \]  \hspace{1cm} (1)

Where:
- \( L \) —— identify stadia required for freeway exit (m);
- \( L_1 \) —— driving distance when the driver identify export (m);
- \( L_2 \) —— deceleration traveling distance on ramp (m);
- \( L_3 \) —— safe distance (m)

Among these, the export recognition distance is made up of reading distance and judge distances and safe distance.

6.1 Reading distance

Reading distance is related to reading time, according to the related research, take a picture of time 3 s, because the slow action hasn't been used in the process of reading, so the speed of reading distance (as shown in formula 2 and formula 3), can be calculated according to the mainline design speed:

\[ L_1 = l_1 + l_2 \]  \hspace{1cm} (2)
\[ l_1 = vt_1 \]  \hspace{1cm} (3)

Where:
- \( l_1 \) —— reading distance;
- \( v \) —— the main line design speed;
- \( t_1 \) —— time for reading logo.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Reading distance under different design speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (km/h)</td>
<td>Reading distance(m)</td>
</tr>
<tr>
<td>120</td>
<td>100</td>
</tr>
<tr>
<td>100</td>
<td>83</td>
</tr>
</tbody>
</table>

Judgedistances is the vehicles travel distance that drivers make a judgment after reading traffic sign information. This process judge distances (as shown in formula 4) is:

\[ l_2 = vt_2 \]  \hspace{1cm} (4)

Where:
- \( l_2 \) —— judge distances;
- \( v \) —— the main line design speed;
- \( t_2 \) —— time for judge

The time required for driver to judge signs 2.0 ~ 2.5 s in this study, we take 2.5 s. By the above formula can be concluded that the judge distance under different design speed is as shown in table 4.
6.2 Action distance

Action distance is the distance traveled by cars exported from expressway to slow down amid, generally includes two phases: the first stage is the driver loosen the accelerator pedal, without using brake deceleration and transferred to the deceleration lane, the phase using engine slow down, the speed change from \( v_0 \) to \( v_1 \); The second stage is to use the brake to slow down, when arrive at interchange export, the speed change from \( v_1 \) to \( v_2 \). Therefore, vehicle action distance is the sum of the two stages in the car distance (as shown in formula 5 to formula 8)

namely

\[
L_2 = l_1 + l_2
\]  \hspace{1cm} (5)

\[
l_1 = v_0 t_1 - \frac{1}{2}a_1 t_1^2
\]  \hspace{1cm} (6)

\[
v_0 = v_0 - a_1 t_1
\]  \hspace{1cm} (7)

\[
l_2 = \frac{v_1^2}{2a_2} - \frac{v_2^2}{2a_2}
\]  \hspace{1cm} (8)

Where:

- \( l_1 \) —— driving distance in the first stage process of deceleration;
- \( l_2 \) —— driving distance in the second stage process of deceleration;
- \( t_1 \) —— the time needed for the first stage process of deceleration, apply 3 s;
- \( a_1 \) —— the acceleration in the first stage process of deceleration, the values shown in table 5;
- \( v_1 \) —— vehicle speed after the first deceleration phase;
- \( v_2 \) —— the speed in the process of vehicle leave mainline export;
- \( a_2 \) —— the acceleration in the second stage process of deceleration, the values shown in table 5;

Table 5 The acceleration values under different design speed

<table>
<thead>
<tr>
<th>Speed (km/h)</th>
<th>Judge distance (m)</th>
<th>Speed (km/h)</th>
<th>Judge distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>83</td>
<td>80</td>
<td>56</td>
</tr>
<tr>
<td>100</td>
<td>69</td>
<td>60</td>
<td>42</td>
</tr>
</tbody>
</table>

6.3 Safe distance

According to the related research, researchers usually take safe distance for 15 ~ 100 m, in this paper, we take a median of 50 m.

Table 7 Identify stadia of interchange exit ramp

<table>
<thead>
<tr>
<th>Design speed (km/h)</th>
<th>Identify stadia (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mainline</td>
<td>ramp</td>
</tr>
<tr>
<td>120</td>
<td>60</td>
</tr>
<tr>
<td>120</td>
<td>50</td>
</tr>
<tr>
<td>120</td>
<td>40</td>
</tr>
<tr>
<td>100</td>
<td>60</td>
</tr>
<tr>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>80</td>
<td>60</td>
</tr>
<tr>
<td>80</td>
<td>50</td>
</tr>
<tr>
<td>80</td>
<td>40</td>
</tr>
<tr>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>
7. Conclusion

Through comparison, we can know that the calculate identify stadia value of interchange exit ramp is bigger than the specification given value. This indicates that in interchange design, in order to ensure traffic safety, we should try to adopt bigger identify stadia value than the value specified. But in mountain cities, there are interchanges with complex form, low linear index, a small road width, and the interchange typically contains a short length of weaving section, traffic run complexly in this section, the identify stadia value can't satisfy the requirement of safe operation. Under the condition, we should strengthen the traffic safety facilities setting.

Reference


