

Adjusting the length of acceleration lane about MaJuQiao Interchange

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ABSTRACT

An acceleration lane should have sufficient length to enable a driver entering a highway from a turning roadway in a safe and comfortable manner. Studies of road safety show that many accidents happen due to the shortage of the length. So, it is to confirm the appropriate length is necessary for safety of interchange design and operation. According to active standard of China, the distance is governed by the speed differential between the operating speed on the entrance curve of the ramp and the operating speed of highway. The design specification suggests that the length of single-lane acceleration lane is not less than 200 meters. However, traffic volume on major roadway has high influence on the length. The value (200 meters) is lower because of neglecting the effect of traffic volume. Based on the traditional method on calculating the length of acceleration lane, the paper takes MaJuQiao Interchange as the research target to stress the effect by major roadway traffic volume. After analysis the vehicle operating characteristic on acceleration lane, the condition of vehicle merging from ramp to major roadway resembles the condition of vehicle crossing the non-signal intersection. Then, the paper resorts to the theory of non-signal intersection merge and presents the new formula applied into confirm the length, which considers the delay caused by traffic volume of major roadway during merging into the highway. The length calculated by new formula is longer than recommend by the standard. After investigate and compare, the former can meet the demand better than the latter.

Key word: acceleration lane; traffic volume adjustment; the theory of merge

1 BACKGROUND

Jingjintang Highway is the one of earliest construction. Located at the node of 12.865 kilometer, Majuqiao Interchange takes an important part in highway operation. Recently, many people focus on the problem of Jingjintang Highway Safety. And Majuqiao Interchange is paid attention because there is more accidents than the average degree of Jingjintang highway. An investigate had been organized in order to analysis the condition of Jingtang highway in 2005. During the investigate, many drivers reflected the insufficient length of acceleration lane may cause accident. Some experts also pointed out that the shortage of the length made the vehicle have not enough time to finish merging into the major roadway. The acceleration lane about MaJuQiao Interchange belong to parallel type. After measured the length of acceleration lane about MaJuQiao Interchange, it is 200 meters long. According to active standard of China, the distance is coincident. In fact, the value neglects the effect of traffic volume. How much the distance is appropriate? Based on the background, the paper tries to resolve the problem.

2 METHODOLOGY

The distance needed for acceleration in advance of this point of convergence is governed by the speed differential between the operating speed on the entrance curve of the ramp and the operating speed of the highway. The parallel-type entrance provides an added lane of sufficient length to enable a vehicle to accelerate to near-freeway speed prior to merging. The length of a parallel-type acceleration lane is generally measured from the point where the left edge of the traveled way of the ramp joins the traveled way of the freeway to the beginning of the downstream taper. Whereas, in the case of the tape type entrance, acceleration is accomplished on the ramp upstream of the point of converge because of the two roadway, acceleration usually takes place downstream from this point in the case of the parallel type. However, a part of the ramp proper may also be considered in the acceleration length, provided the curve approaching the acceleration lane has a long radius of approximately 300 m or more, and the motorist on the ramp has an unobstructed view of traffic on the freeway to his or her left. The minimum acceleration length for entrance terminals are given in Technical Standard of Highway Engineering (JTG B01-2003), and the adjustments for grades also are given in it. The value is gained without concerning on the traffic volume of major roadway. This section resorts to the theory of non-signal intersection merge and presents the new formula applied into confirm the length, which considers the delay caused by traffic volume of major roadway during merging into the highway.

Traditional method on calculating the length of acceleration lane takes the following form:

$$L = \frac{v_1^2 - v_2^2}{2.6 a}$$

where

v_1 = operating speed of highway,

v_2 = operating speed on the entrance curve of the ramp,

a = average acceleration of vehicle from ramp to major roadway.

Adjustments for traffic volume of major roadway:

The following is assumed: The time gap (expressed by the "H") of major roadway follows the Erlang regression.

Erlang regression is: $f(t) = \lambda e^{-\lambda t} \cdot \frac{(\lambda t)^{k-1}}{(k-1)!}$

When $H \geq \alpha$ vehicle in the acceleration lane can merge in major roadway. So, the probability of accept gap which merge in highway is:

$$P(H \geq \alpha) = \sum_{i=0}^{k-1} (\lambda k \alpha)^i \frac{e^{-\lambda k \alpha}}{i!}$$

However, the probability of decline gap which merge in highway is:

$$P(H < \alpha) = 1 - \sum_{i=0}^{k-1} (\lambda k \alpha)^i \frac{e^{-\lambda k \alpha}}{i!}$$

Then the distribute of probability of decline gap is:

$$G(t) = P(H < t / H < \alpha) = \frac{P(H < t, H < \alpha)}{P(H < \alpha)}$$

Based on above formula, we can deduce the formula as follow:

$$G(t) = \frac{\int_0^t \lambda e^{-\lambda t} \frac{(\lambda t)^{k-1}}{(k-1)!} dt}{1 - \sum_{i=0}^{k-1} (\lambda k \alpha)^i \frac{e^{-\lambda k \alpha}}{i!}} \quad 0 < t < \alpha$$

Express \bar{h} as the average decline gap, then
$$\bar{h} = \int_0^\alpha td \left(\frac{\int_0^\alpha \lambda e^{-\lambda t} \frac{(\lambda t)^{k-1}}{(k-1)!} dt}{1 - \sum_{i=0}^{k-1} (\lambda k \alpha)^i \frac{e^{-\lambda k \alpha}}{i!}} \right)$$

At this time, if the vehicle in acceleration lane accepts the gap $j+1$ then all of gap j ahead of gap $j+1$ is less than α so the probability of decline j gaps which merge in highway is:

$$p_j = [P(H < \alpha)]^j P(H \geq \alpha) = \left(1 - \sum_{i=0}^{k-1} (\lambda k t)^i \frac{e^{-\lambda k t}}{i!}\right)^j \sum_{i=0}^{k-1} (\lambda k \alpha)^i \frac{e^{-\lambda k \alpha}}{i!}$$

Express \bar{n} as the amount of average decline gap, then

$$\bar{n} = \sum_0^\infty j p_j = \sum_0^\infty j \left(1 - \sum_{i=0}^{k-1} (\lambda k t)^i \frac{e^{-\lambda k t}}{i!}\right)^j \sum_{i=0}^{k-1} (\lambda k \alpha)^i \frac{e^{-\lambda k \alpha}}{i!}$$

Express \bar{w} as the average waiting time caused by the traffic volume of major roadway., then

$$\bar{w} = \bar{n} \times \bar{h} = \left[\sum_0^\infty j \left(1 - \sum_{i=0}^{k-1} (\lambda k t)^i \frac{e^{-\lambda k t}}{i!}\right)^j \sum_{i=0}^{k-1} (\lambda k \alpha)^i \frac{e^{-\lambda k \alpha}}{i!} \right] \int_0^\alpha td \left(\frac{\int_0^\alpha \lambda e^{-\lambda t} \frac{(\lambda t)^{k-1}}{(k-1)!} dt}{1 - \sum_{i=0}^{k-1} (\lambda k \alpha)^i \frac{e^{-\lambda k \alpha}}{i!}} \right)$$

In the end, gains the extend length of acceleration lane caused by the traffic volume of major roadway:

$$L' = \bar{w} v_1$$

Owing to incertitude of parameter of Erlang regression, it is difficulty in integral and calculation the value of the average waiting time caused by the traffic volume of major roadway. In order to predigest calculation, evaluate k as 1 then can draw the conclusion as follow:

$$\bar{w} = \bar{n} \times \bar{h} = \frac{e^{\lambda \alpha} - \lambda \alpha - 1}{\lambda} \quad (2)$$

According to Equation 2, then the Equation of Adjustments for traffic volume of major roadway is:

$$L = \frac{v_1^2 - v_2^2}{26a} + \bar{w} v_1 \quad (3)$$

where

v_1 =operating speed of highway,

v_2 =operating speed on the entrance curve of the ramp,

a =average acceleration of vehicle from ramp to major roadway.

\bar{w} =average waiting time caused by the traffic volume of major roadway

3 APPLICATION

The length of acceleration lane is not only linked with the speed differential between the operating speed on the entrance curve of the ramp and the operating speed of highway, but also with the traffic and road condition. Through investigate and measure in practice, such as the values of speed, traffic volume, the width and length of acceleration lane acquire. The data are follow as:

$$v_1 = 70 \text{ km} \cdot \text{h}^{-1}, v_2 = 40 \text{ km} \cdot \text{h}^{-1}, Q = 1800 \text{ pcu} \cdot \text{h}^{-1}$$

Taking them into the Equation 3, then the length of Majuqiao Interchange acceleration lane should reach 240~280 meters.

4 RESULT

The length of acceleration lane should consider synthetically. Resorted to the theory of non-signal intersection merge and presents the new formula applied into confirm the length, which considers the delay caused by traffic volume of major roadway during merging into the highway. The length calculated by new formula is longer than recommend by the standard, and it should reach 240~280 meters. The value can meet the demand of road safety better than the fact.

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