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Passing Segment Length Determination on Two-Lane Highways

Chiu Liu, Zhongren Wang

1120 N Street, MS-1, Caltrans, Sacramento, CA 95814
2389 Gateway Oaks Drive, MS-91, Caltrans, Sacramento, CA 95833

Abstract

Passing lane has been often constructed to dissipate traffic queues growing behind slow moving vehicles. These queues may appear randomly on a two-lane highway depending on geometry, traffic volumes, location and vehicle performance. For example, on the uphill side of a highway with relatively high AADT, a transient queue can rapidly grow behind a slow leading heavy vehicle. Aggressive drivers in the queue, losing patient of coasting along at a low speed, may make unsafe passing maneuver at occasions with limited passing sight distances in the presence of double-yellow centerline. Since passing sight distance may not be sufficient at many spots along a two-lane highway, installing a passing lane becomes necessary to relieve recurrent transient queues and avoid traffic collisions due to passing. The purpose of our study is to determine the passing segment length that is sufficiently long to dissipate the foreseeable traffic queues. Based on the criterion for dissipating a traffic queue behind a slow leading vehicle, we derive the passing length by integrating vehicle performance, driver characteristics, roadway geometry, traffic flow volume, and queue size into one realistic and analytic equation. All parameters introduced into this study can be adjusted for any highway project to fit anticipated design scenarios for enhancing traffic operational safety on two-lane highways. Interesting consequences from this study will be presented to showcase the usefulness of this multi-parameter framework. Practitioners can easily apply this framework to estimate or check the potential project scope and make long-lasting smart decisions for improving safety and operation and potentially reducing emissions on two-lane highways

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1. Introduction

It wouldn't be safe driving on a long stretch of no-passing two-lane rural highway since aggressive drivers would potentially take the risk of crossing the double yellow centerline when his or her patience of driving behind a slow vehicle runs out, for instance, on a hilly curved road, where a slow vehicle moves even slower; on the other hand, a traffic queue, usually growing fast behind the slow vehicle at daily peak hours, brings down the operational capacity

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of the roadway. For a rural two-lane highway with unlimited sight distance and low daily traffic volume, most economical solution would be restriping the centerline with the dashed yellow lines [MUTCD, 2009]; but this type of road, usually with a traffic collision rate well below average, doesn't call for an expensive safety or operational improvement. Thus, to improve safety and operational efficiency for a no-passing two-lane highway is to allow passing to occur at least for various spots along the roadway where proper engineering solution becomes feasible. A few conventional engineering strategies for improving a two-lane highway have been known, such as, constructing vehicle turnouts along roadside, constructing straight long segments with sufficient passing sight distance (PSD), constructing 3-lane segments where a passing lane is provided alternatively to traffic moving in opposite direction, and expanding the 2-lane highway to a 4-lane highway, where passing can be accommodate on the fast/inside lane. Since PSD can be several thousand feet long for a two-lane rural highway [Liu and Herman, 1996], providing a segment with sufficient PSD with realignment of the roadway, could be a costly solution on a curved hillside road. Moreover, increasing the number of lanes to three or four, requiring a new geometric design, better alignment, more right of way, and a wider road bed for pavement to meet new design criteria or standards, will be very costly. In order to provide drivers with safe passing option, it becomes necessary to add a lane at some locations along a two-lane highway with insufficient PSD. Subsequently, the passing segment length should be determined with analysis based on an engineering framework, which would be set up and discussed in this paper with anticipated passing scenarios.

2. Formulation

The physical pictures for passing as shown in Figure 1, including three maneuvers, at first, the slow leading vehicle moves to the outside lane over the diversion transition section, and then the fast vehicles behind accelerates on the inside lane and pass the slow the vehicle in the passing lane section, and finally the slow vehicle merges back into one-lane highway segment over the merge transition section. In Fig. 1, the diversion section, the merge section, and the nominal passing lane length are respectively denoted as L_d, L_m, and L_0. The entire passing segment length L_T, should be the sum of these three section lengths, namely,

$$L_T = L_0 + L_d + L_m \tag{1}$$

By the way, the passing lane section design isn't unique, and a mirror image of the Figure 1 design also exist but such a design is less user friendly especially for drivers in the overtaking vehicles since the passing lane is provided for smooth passing purpose. Additionally, two passing lanes, one for each travel direction, at times are provided at the same location, making the passing lane segment a 4-lane road section. Parameter L_H represents the length of the slower leading vehicle, usually a heavy one; and parameter L_P is the length for the faster following vehicle, usually a passenger car. In order to find the passing segment length, we will proceed to determine above three section lengths one by one. Let's determine the passing lane length L_0 first with physical reasoning of the passing process.

At the beginning of the tapered diversion section, the slower vehicle with a speed v_H steers to the right and readily switches into the outside lane, and the driver in the following vehicle with a 'safe' headway 'α' seconds behind observes the slower vehicle movement and decides to accelerate with a perception-reaction time-lag of 'δ' seconds from its initial speed close to the speed v_H toward a higher speed v_P, expected to be greater or equal to the posted speed limit or the advisory speed. By the time, the slow vehicle touches the end of the passing lane section as shown in Fig. 1, the rear end of the first passing vehicle is at a distance 'D' ahead of the slow vehicle. Distance 'D', a parameter independent of the merging section length, is introduced to account possibly for the length of platoon of vehicles following behind the slow vehicle at the beginning of the diversion section; namely the length parameter 'D' will depend on the traffic flow rate, the uphill grade, the number of passing locations provided on a long two-lane road, and the number of vehicles in a platoon that would be allowed passed the slow vehicle. With this in mind, we can write down an equation integrating together the parameters shown in Fig. 1 below.