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Partially limited access control design for special-use freeway lanes

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ABSTRACT

Most special-use freeway lanes, such as High Occupancy Vehicle (HOV) lanes, have traditionally been designed with either limited access or continuous access control from the adjacent general-purposed (GP) lanes. Studies have shown the advantages and disadvantages of each design in terms of safety, mobility, environment, and enforcement, among other factors. With a focus on improving the operational performance of HOV facilities, this paper proposes a new design called partially limited access control where the continuous access is mostly designated along the freeway to achieve higher travel speed while buffers between the HOV lane(s) and the adjacent GP lanes are strategically placed on selected freeway segments to accommodate higher throughput on those segments. The placement of buffers primarily aims to reduce the impact of HOV cross-weave flow on the capacity of GP lanes. In this research paper, a methodology for determining the location and length of buffers in the partially limited access control has been developed. A case study is performed along a 13-mile section of HOV facility on SR-210 E in Southern California, which is coded and evaluated in traffic microsimulation. The results show that the partially limited access control increases the throughput (represented by total vehicle miles traveled or VMT) and decreases the delay (represented by total vehicle hours traveled or VHT) of the freeway as compared with either the limited access or continuous access control. As a result, the overall efficiency (represented by average travel speed calculated as VMT/VHT) of the freeway with partially limited access HOV facility is 21% and 6% higher than that of the freeway with limited access and continuous access HOV facility, respectively, under the baseline traffic demand.

1. Introduction

Special-use freeway lanes, including High-Occupancy Vehicle (HOV) lanes, are an integral part of many freeway systems. Traditionally, HOV lanes have been designed with either limited access or continuous access control (see Fig. 1(a) and (b)). Over the last several years, the performance of limited access and continuous access HOV facilities in terms of safety (Chung et al., 2007; Jang et al., 2008, 2009; Du et al., 2012), mobility (Chang et al., 2008), environment (Boriboonsomsin and Barth, 2006, 2008; Shewmake, 2012), enforcement, etc. have been extensively compared through empirical and simulation studies.

Based on data from the Freeway Performance Measurement System (PeMS) in California, Chen et al. (2005) found that the

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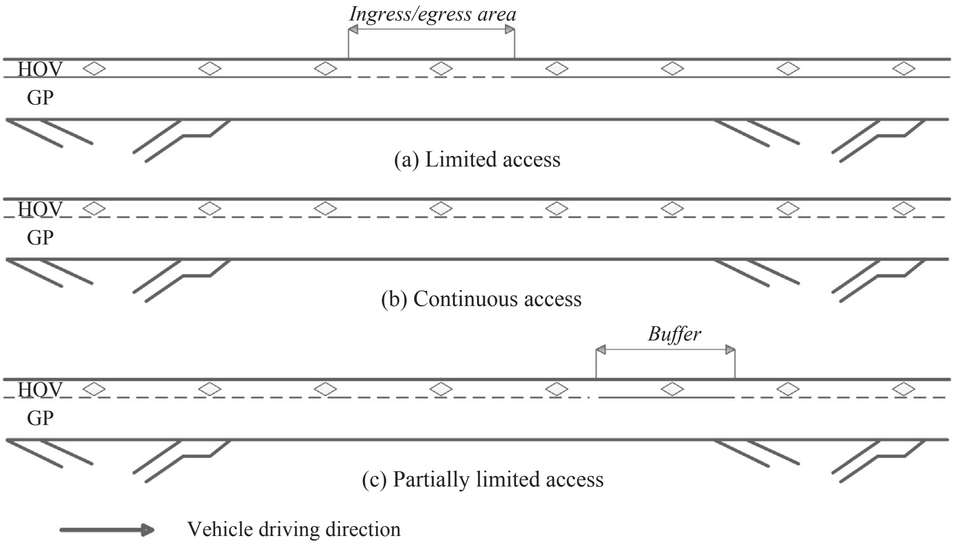

Fig. 1. Different configurations of HOV lanes.

general-purposed (GP) lanes suffer a congestion penalty due to the capacity drop, and the HOV lanes suffer a capacity penalty as the speed in single HOV lanes is governed by the low speed vehicles. On the contrary, Menendez and Daganzo (2007) theoretically showed that HOV lane implementation diminishes the lane changes between the HOV lane and the adjacent GP lane, a phenomenon called the smoothing effect of HOV lane, which was validated using real-world data by Cassidy et al. (2010). Also based on real-world data, Wu et al. (2011) found that the ingress/egress areas of limited access HOV facilities could trigger the formation of bottlenecks in the HOV lanes. A study by Jang et al. (2012) revealed that the continuous access control offers slightly higher utilization of HOV lanes, compared with the limited access control.

However, the continuous access control could suffer from the frictional effect where HOVs in the HOV lane would slow down as the speed differential with the adjacent GP lane increases (Jang and Cassidy, 2012). Wu et al. (2015) found that a freeway segment with limited access control would have higher capacity than that with continuous access control, given that everything else is held equal. Based on high-resolution lane change data collected in the field, it was shown that, compared to continuous access HOV facilities, limited access HOV facilities have higher lane change intensity (over ingress/egress areas), and the HOVs on these facilities have shorter time gaps when they move out of the HOV lane (Du et al., 2013; Qi et al., 2016). According to Boriboonsomsin et al. (2013), limited access HOV facilities are better at regulating traffic flow resulting in higher freeway throughput, while continuous access HOV facilities are more likely to spread out lane changes, which allows traffic to maintain higher travel speed.

These findings imply that an alternative design in geometric configuration of HOV facilities, where the continuous access is generally provided along a freeway to achieve higher travel speed while buffers are strategically placed on selected freeway segments (e.g., recurrent bottlenecks, ramp areas) to accommodate higher throughput on those segments, may result in better overall operational performance than either the limited access or continuous access designs. Therefore, this research investigates the so called *partially limited access* design (see Fig. 1(c)) and evaluate its operational performance compared with the other two access controls.

A major consideration in the design of partially limited access HOV facilities is determining the location and length of buffers that prohibit or discourage lane changes from the HOV lane to the adjacent GP lane, and vice versa. These buffers are designed primarily for reducing the impact of HOV cross-weave flow on the capacity of GP lanes. Liu et al. (2012) analyzed the HOV cross-weave effect downstream of on-ramps to a freeway with a limited access HOV facility using simulation method. The results reveal that the capacity of GP lanes decreases as the HOV cross-weave flow or the number of GP lanes increases. The length of buffer from the gore point of the on-ramp to the starting point of the ingress/egress area has significant influence on the capacity drop. In the design of partially limited access HOV facilities, it is also important to understand the HOV cross-weave effect upstream of off-ramps where mandatory lane changes occur frequently. However, to the best of our knowledge such effect has not been analyzed.

2. Research objectives

The objectives of this research are to: (1) analyze the impact of HOV cross-weave flow on the capacity of GP lanes upstream of off-ramps; (2) develop a methodology for designing partially limited access HOV facilities that also conforms with the existing general guidelines for designing HOV facilities, e.g., (California Department of Transportation, 2003; California Department of Transportation, 2011); and (3) evaluate the operational performance of freeways with partially limited access HOV facilities in comparison with freeways with limited access or continuous access facilities.