Intellimotion

Keeping up with California PATH Research in Intelligent Transportation Systems

Volume 14, No. 2 2008

Safety Evaluation of High-Occupancy Vehicle (HOV) Facilities in California

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High Occupancy Vehicle (HOV) lanes have been implemented on urban freeways to mitigate continuously growing traffic congestion and improve overall mobility within metropolitan freeway systems. HOV lanes allow vehicles carrying more passengers to bypass the congested General Purpose (GP) lanes thereby encouraging the use of carpools and public transportation to move more passengers per lane with a fewer number of vehicles. In California, HOV lanes were first introduced in 1970's and increasingly implemented in congested freeway segments in Southern and Northern California metropolitan regions. As of 2005, HOV lanes comprised 1,305 (directional) lane-miles of freeway, with 895 lane-miles located in Southern California, 410 lane-miles in Northern California, and 950 additional lane-miles of HOV lanes have been proposed for construction.

Since their inception, two configurations for HOV lanes—continuous and limited—have emerged in California (figure 1, pg 2). Continuous access HOV lanes allow vehicles to enter or exit the HOV facility continuously along the freeway such that lane changing maneuvers are not concentrated at specified location; on the other hand, the traffic operation in the continuous HOV lane is more frequently interrupted by the lane changing vehicles. Limited access HOV lanes have specified ingress and egress locations that permit maneuvers to enter and exit, and are separated from other freeway lanes by buffer zones, demarcated by pavement markings or physical barriers. Such separation is intended to allow less interrupted traffic flows and offer protection to freely flowing traffic in the HOV lane independent of the traffic conditions in GP lanes. Predominant in Northern California, continuous access HOV lanes are in operation only during peak hours, while limited access HOV lanes, which are predominant in Southern California, are in operation 24 hours a day, seven days a week.

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The present study evaluated traffic collision patterns in continuous and limited access HOV lanes and investigated the attributes accounting for safety performance of HOV lanes.

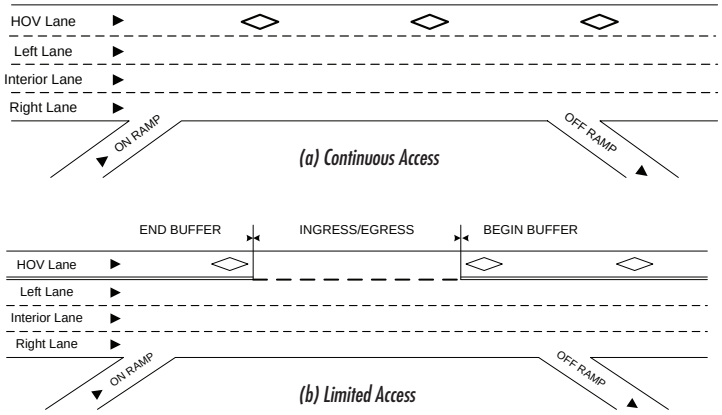
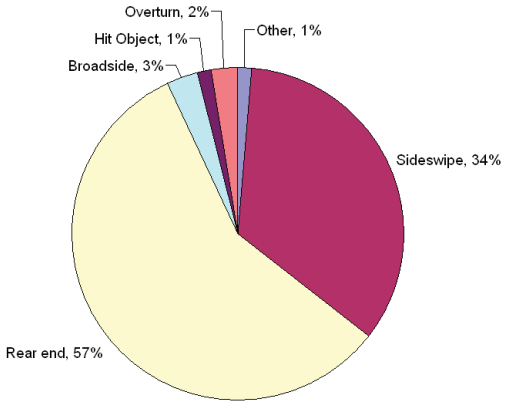


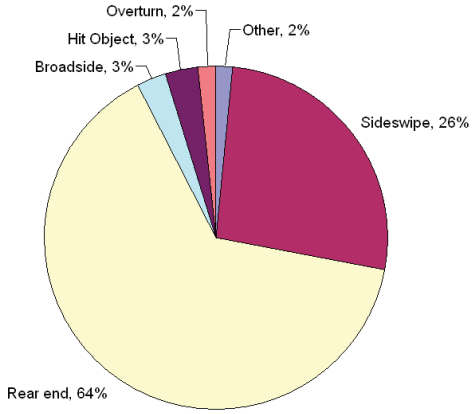
Figure 1 HOV facility types in California.

Comparison of Collision Distribution (Statewide)

A statewide comparison of limited and continuous access HOV facilities was conducted. Collision data from the Traffic Accident Surveillance and Analysis System (TASAS) between year 1999 and 2003 along 824 miles of freeways with HOV facilities were examined, including 279 miles of HOV lanes with continuous access and 545 miles with limited access. For the purpose of comparing the collision distributions in different HOV facilities, only the collision data during the peak hours were analyzed since the continuous access HOV lanes operate as regular lanes outside of the peak hour period.



(a) Continuous Access



(b) Limited Access

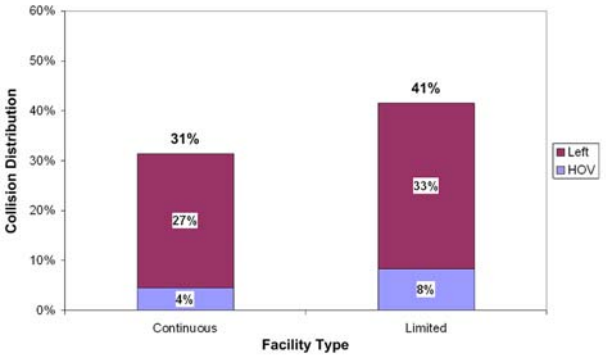
Figure 2 Type of collisions in HOV lanes.

Rear-end and sideswipe collisions together comprised over 90 percent of all collisions in both facilities. In continuous access HOV lanes, 57 percent of collisions were rear-end and 34 percent were sideswipe collisions. In limited access HOV lanes, 64 percent were rear-end, and 26 percent were sideswipe collisions (figure 2).

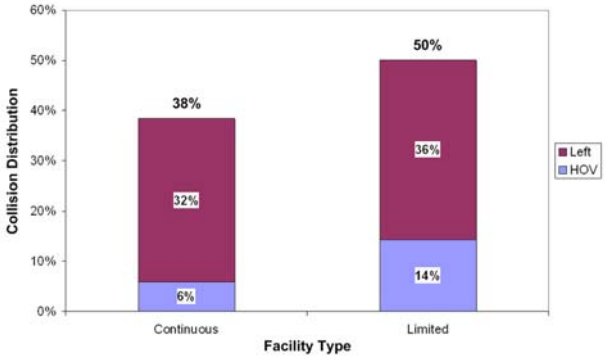
The difference in types of collisions observed in continuous versus limited access HOV lanes could be due to the difference in traffic movements inherent to continuous and limited access HOV facilities. Compared with the traffic in limited access HOV lanes, the traffic in continuous access HOV lanes are more likely to be exposed to continuous interaction with traffic in adjacent lanes, and thus there is a greater occurrence of sideswipe collisions. On the other hand, the traffic in limited access HOV lanes are prohibited from changing lanes except at ingress/egress areas and tend to have more interaction with vehicles in the back or front than those in adjacent lanes such that they experience a greater number of rear-end collisions.

The distribution of collisions in the HOV lane and its adjacent lane was examined to determine whether there is a consistent pattern of collisions between the two different types of HOV facilities. The lane adjacent to the HOV lane is called the left lane by its definition within TASAS.

A higher distribution of both Property Damage Only (PDO) and injury related collisions was observed in the HOV and left lanes of the HOV facilities with limited access. It can be seen that the limited access facilities have a considerably higher percentage of collisions, PDO or injury, concentrated in the HOV and left lanes (figure 3).



(a) PDO collision distribution across lanes.



(b) Fatal and injury collision distribution across lanes.

Figure 3 Collision distribution across lanes.

Comparison of Collision Rates (Selected Routes)

The differences observed in collision distribution could have been the result of the difference in lane utilization of traffic. To investigate this phenomenon further, a more detailed analysis was conducted for a selective list of routes, for which detailed geometric and traffic data were available. These freeway segments were suggested by regional transportation engineers from California Department of Transportation (Caltrans). The routes were included in the detailed analysis on the basis that these routes shared similar traffic patterns, according to local district engineers who were familiar with the configurations and operations of these freeway segments.

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Table 1: List of eight study sites.

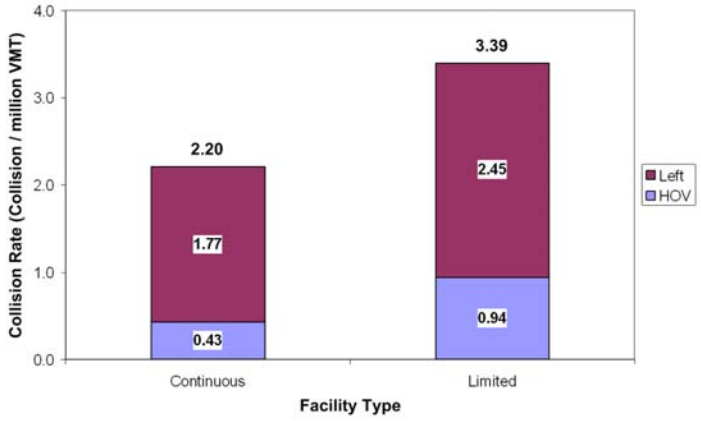
Facility Type	County	Freeway	Length (Mile)	Operation Hours
Continuous	Contra Costa	I-80E	10	Weekdays, 5~10AM & 3~7PM
	Contra Costa	I-80W	9.8	Weekdays, 5~10AM & 3~7PM
	Alameda	I-880N	7.4	Weekdays, 5~10AM & 3~7PM
	Santa Clara	SR-101S	13.5	Weekdays, 5~10AM & 3~7PM
Limited	Los Angeles	I-105E	15.7	24 Hour
	Los Angeles	I-105W	14.3	24 Hour
	Los Angeles	I-210E	11.6	24 Hour
	Los Angeles	I-405S	9.3	24 Hour

continued from page 2

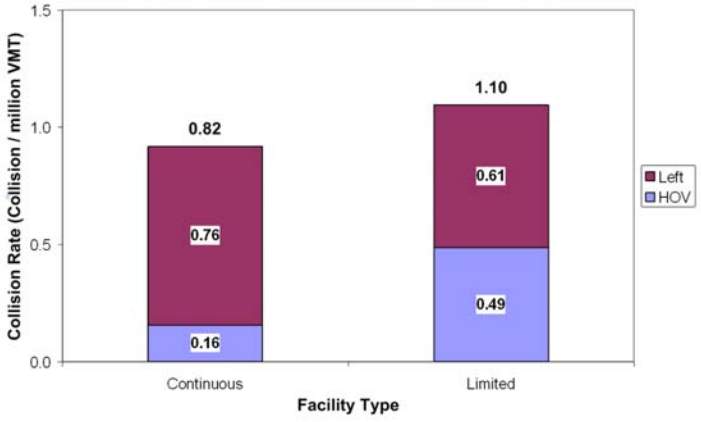
Using traffic volume data from the Freeway Performance Measurement System (PeMS), collision per million Vehicle Miles Traveled (VMT) was calculated by dividing the number of collisions by total operation hours, average hourly traffic volume and lane-mile for HOV and left lanes. Higher PDO collision rates were observed in both HOV and left lanes of the HOV facility with limited access. The combined injury related collision rates for the HOV and left lane was higher for the limited access. However, the injury related collision rate for the left lane alone was higher for the continuous access HOV facility. All the differences except for the difference of injury related collision rates in left lanes were statistically significant at the 95 percent level of confidence (figure 4).

Geometric Factors

Results from detailed analysis of HOV segments were conducted to explain the relationship between collision rates in HOV facility and geometric attributes, including shoulder width, length of the access, and the proximity of the access to its neighboring ramps. The same collision data set from the eight routes was used for this part of the analysis.



(a) PDO collision rate.



(b) Fatal and injury collision rate.

Figure 4 Collision rates.

1. Shoulder width

Effects of shoulder width on safety performance are illustrated (figure 5) with the observed collision rates for the eight freeway segments plotted versus the corresponding shoulder width. The plot indicates that collision rates diminish with an increase in shoulder width, regardless of the type of access associated with the HOV lane. The group of limited access does exhibit a higher collision rates when compared to the group of continuous access with comparable shoulder width.

2. Total (Shoulder + HOV Lane + Buffer) width

The total width is defined as the lateral space including the shoulder, the HOV lane and buffer. A scatter plot (figure 6) of collision rate versus total width was constructed and a trend line for each type of HOV facility was estimated based on the scatter plot. Narrower total width was associated with a higher collision rate in both types of HOV lanes. Notably, the trend line for the limited access, shown as a black line, exhibits remarkable resemblance to the trend line of the continuous access, a grey line, but with a vertical shift upward. The pattern implies that given the same amount of total width, employing continuous access HOV lanes can result in fewer numbers of collisions; more shoulder width can be allocated to the HOV lane with continuous access since it does not require a buffer.

3. Spatial collision patterns

Continuous Risk Profile (CRP) method, which can generate a variation of risk measurement interpretable as the number of collisions per unit distance along a freeway, was applied to investigate the spatial distribution of collisions along the freeway. The CRP plots (figure 7) for HOV and left lanes of the eight routes were constructed to examine the spatial distribution of collision concentration locations along the freeways. Using CRP analysis, the followings were observed.

- In the continuous access facility:
  - Each of the peaks accompanies a peak in adjacent left lanes.
  - This implies that the factors causing the concentration of collisions appear to have equal influence on both HOV and left lanes.
- In the limited access facility:
  - Some of the peaks are observed only in either HOV or left lane.
  - These peaks were often found at locations where HOV lane is separated by buffers from the adjacent GP lanes where lane change is prohibited.
  - This indicates that lane change maneuvers are not necessarily a collision causative factor at this location of collision concentration.

4. Ingress/Egress analysis

To understand the potential impacts of traffic movements near ingress/egress areas and nearby freeways, a detailed analysis is carried out for a number of sites. The site samples were obtained from 24 different ingress/egress sections along the four limited access HOV lanes, for which per lane traffic volumes were available. No apparent systematic relationship can be identified between the collision rates and the distance from ingress/egress to the nearby on- or off-ramps. However, three locations showed significantly higher collision rates than the average collision rate in limited access HOV lanes. It was found, after inspecting the configurations of these three locations, that these three ingress/egress segments were associated with the following common features:

(1) They were located within 0.3 mile of the nearest on- or off- ramp,
(2) They had short access lengths (0.25 mile), and
(3) They possessed high traffic volume in the HOV lane during peak hours (1000–1200 vehicles per hour versus 700–800 vehicles per hour on average).

Summary of Findings and Future Research

The findings from this research show that the HOV facility with limited access offers no safety advantages over the one with a continuous access. The combined collision rates of the HOV and its adjacent lane were higher for the HOV facility with limited access.

The relationship between collision rates in HOV lanes with respect to its shoulder width, length of the access, and the proximity of the access to its neighboring ramps were studied. HOV facilities with shoulder width greater than 8ft displayed significantly lower collision rates regardless of access type. Based on the analysis of total width and crash rates, it can also be inferred that facilitating HOV lane with continuous access may result in lower collision rate, given the same total width of right of way. Furthermore, it was found that limited-access HOV facilities with a combination of short ingress/egress length and a close proximity to the nearest on- or off-ramp tends to exhibit markedly higher collision rates than other limited access freeway segments.

For the evaluation of the relationship between the collision rate and the total width, the present study did not attempt to quantify the effect of individual width element if given the same total width. This is a critical question that needs to be further explored because it can be used as a guideline for allocating spaces where the right-of-way is limited. In addition, additional study sites should be included to evaluate the relationship between the length of ingress/egress and its proximity to the neighboring on or off ramps. These remain the topics of future research.

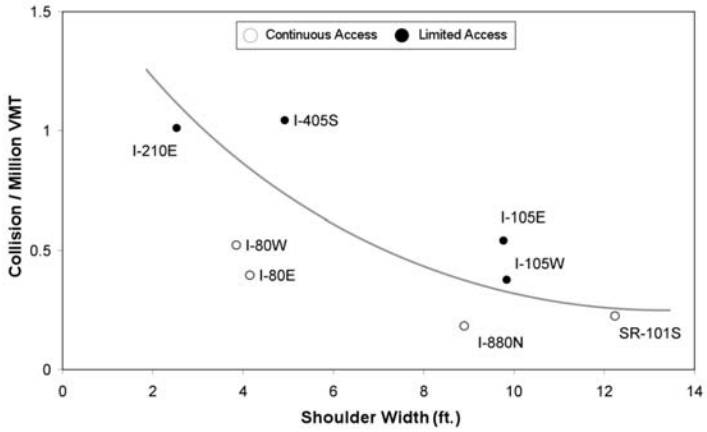


Figure 5 Relationship between shoulder width and collision rate.

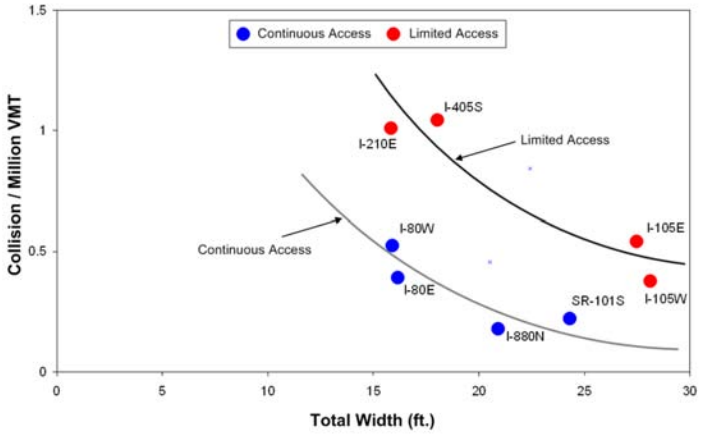


Figure 6 Relationship between total width and collision rate.

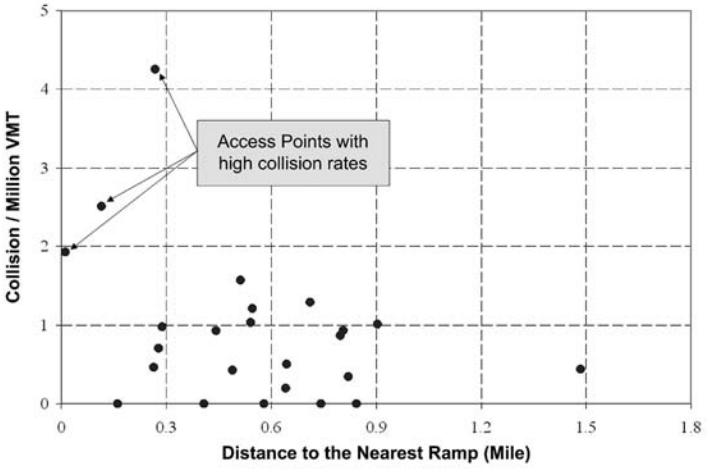


Figure 7 Relationship between collisions per mile per hour and distance to nearest entrance/exit ramp in limited access HOV facilities.

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Photos by Bill Stone, Jay Sullivan, Kitae Jang. Figures by authors.

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Primary funding provided by: Caltrans, Department of Transportation, United States of America

ITS America — Member — Intelligent Transportation Society of California (ITS-CA)

ISSN-1061-4311

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