

# Effects of Left Turn Treatments on Intersection Safety

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## **Abstract**

Road fatalities represent a major engineering and public health concern. In the United States of America, intersections are the locations with the highest number of motor vehicle crashes, with over 2.3 million intersection-related crashes occurring in 2008. These accidents resulted in more than 7,770 fatalities and around 733,000 injury crashes (NHTSA, 2008). Factors such as geometric design, sight distance, traffic control, vehicle speed, traffic volume and the percentage of turning vehicles influence intersection safety.

This paper presents an in-depth analysis of the type of left-turn control and its impact on safety at signalized intersections. The number of accidents is correlated with the type of left-turn control, speed, number of lanes, and other variables using data from selected intersections from a city in Southern California.

Left turning movements at signalized intersection may operate under protective, permissive, or protective plus permissive controls. Selection of the type of left-turn protection is normally based on the volumes of left-turning vehicles, cross product of left-turning movements and opposing flow, intersection geometry, speed, and accident history.

While protective control is deemed the safest and most desirable, the increasing traffic demand on roadways has seen an increase in the use of protective plus permissive control. Protective plus permissive control provides exclusive phase for left turn movement, and allows left turn movements when there is sufficient gaps between left turning vehicles and opposing through traffic. Protective plus permissive control may improve traffic flow, however, it has been documented that this type of control causes driver's confusion and compromises safety.

## **Introduction**

This paper studies the relationship between left-turn traffic signal control and intersection safety. The study is based upon an assessment of the characteristics of accidents that occurred at a signalized intersection.

Intersections are areas of concentrated conflicting crossing, merging, and diverging traffic flows that can impact travel delay and the number and severity of roadway crashes. A conventional four-leg intersection has a total of 32 points of conflict between the various through and turning movements as shown on Figure 1. A carefully designed intersection achieves a balance between safety and efficiency by reducing conflicting movements through some form of intersection control such as signalization.

According to the Federal Highway Administration (FHWA), over 2.8 million intersection-related crashes occur each year. These crashes resulted in the loss of about 8,500 lives and over one million injuries per year. As a result, road safety engineers are constantly searching for roadway and roadside improvements to reduce the probability and severity of crashes.

Left-turn operation significantly affects the safe and efficient operation of a signalized intersection. The appropriate type of left-turn phasing will result in reducing traffic delay, improving traffic flow, and decreasing accident rates. In 2008, Raghavan Srinivasan, et. al. evaluated the safety effectiveness of engineering improvements. The results indicated that changing to protected left-turn phasing from permissive or permissive-protected phasing could lead to a virtual elimination of left-turn crashes but other crashes, which were likely to be less severe rear-end variety, could increase.

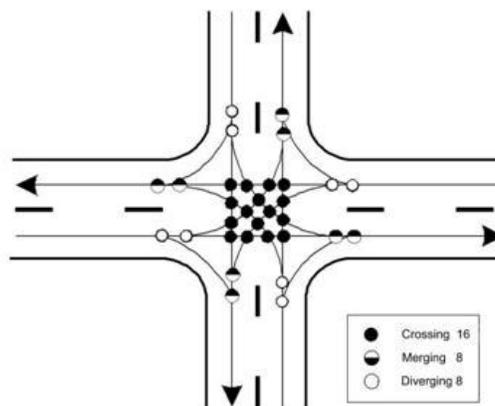


Figure 1. Conflict Points at Intersection (Source: FHWA)

The Manual on Uniform Traffic Control Devices (MUTCD) defines three types of left-turn controls:

- Permissive-Only left-turn control: Left turns do not have dedicated right-of-way and can be made when an acceptable gap exists in the opposing through movement;
- Protected-Only left-turn control: Left turns have dedicated right-of-way with a green arrow indication; and
- Protected/Permissive left-turn control: This is a combination of the above two left-turn controls. Left turns have a dedicated right-of-way during the protected interval. In another part of the cycle, left turns may be made when an acceptable gap exists in the opposing through movement.

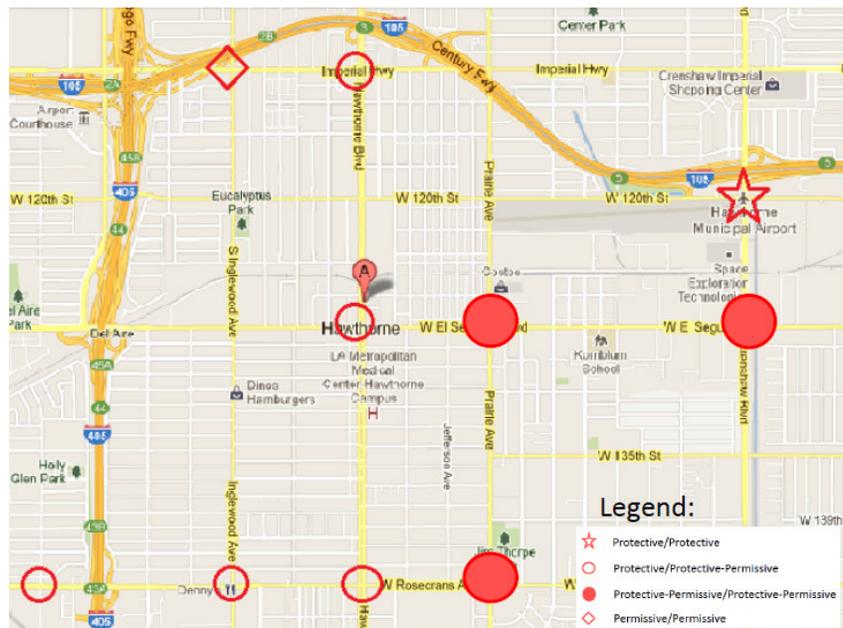
The frequency, type, and severity of collisions that occur at signalized intersections can vary between locations and may be influenced by the type of left-turn control. In 2011, Siamak A. Ardekani, and James C. Williams, evaluated the operational performance of left-turn phasing and indication sequences. Their study concluded that full protection is not called for unless it is required for improving safety. Permissive only phasing, gives the lowest through and approach delays. However, it should only be considered under very low left-turn and opposing traffic volumes.

## Methodology

Ten four-legged signalized intersections were selected for this study. One intersection has left turn permissive control on all approaches, one has left turn protection on all approaches, and eight intersections have a combination of protective-permissive control. Accident data were collected and analyzed for each type of left turn control. Information on intersection geometry design features, traffic control, speed limit, traffic flows, and crashes from 2007 to 2011 were obtained. The accident data were collected from California Highway Patrol Statewide Integrated Traffic Reporting System (SWITRS) report. The volume data were collected from the City Public Works Office. The original annual average daily traffic (AADT) for each intersection was available for 2010 only.

## Study Area

The ten intersections used in this study are shown in Figure 2. All intersections are four-legged intersections and have either two or three lanes on each approach. The width of each lane is 12 ft. The intersection information is summarized in Table 1.



## Accident Analysis

The five year accident data for all the ten intersections are summarized in Table 2 and the accident rates for the year 2010 are summarized in Figure 3. Most of the accidents that occurred at the intersection of Imperial Highway and Inglewood Avenue are rear-end, left-turn and broadside, which is predictable due to the permissive/permissive type of left turn signal control. This intersection has the highest accident rate.

Rear-end was the most recorded type of accident at the intersection of 120<sup>th</sup> Street and Crenshaw Boulevard which has protective/protective left turn signal control. It represents 38 percent of all the accidents recorded in five years. This intersection did not have a left turn accident in 2010. These intersections operate at 40 mph speed limit on both EB/WB and NB/SB directions.

The intersections of Imperial Highway and Hawthorne Boulevard, El Segundo Boulevard and Hawthorne Boulevard, Rosecrans Avenue and Hindry Avenue, Rosecrans Avenue and Inglewood Avenue, and Rosecrans Avenue and Hawthorne Boulevard have a combination of protective/protective-permissive left-turn controls. Rear-end and left turn accidents were the most common occurrences at these intersections where the speed limit on major road is 40 mph and 35 mph on minor road. Rear-end accidents ranged from 21 to 58 percent while left turn accidents ranged from 7.5 to 36 percent. The intersection of Rosecrans Avenue and Inglewood Avenue consistently showed high left turn accidents with a five-year average of 36 percent. This intersection has protective left turn signal on the minor road and protective/permissive left turn signal on the major road.

Table 1. Intersection Information

<b>INTERSECTION INFORMATION</b>														
<b>NO.</b>	<b>Intersection</b>	<b>Street Dir.</b>	<b>Speed Limit (mph)</b>	<b>No. of Lane (EB)</b>	<b>No. of Lane (WB)</b>	<b>Width of Lane (ft)</b>	<b>Intersection</b>	<b>Street Dir.</b>	<b>Speed Limit (mph)</b>	<b>No. of Lane (NE)</b>	<b>No. of Lane (SB)</b>	<b>Width of Lane (ft)</b>	<b>Type of Signal</b>	
													<b>NB/SB</b>	<b>EB/WB</b>
1	Imperial HWY	E/W	35	3	3	12	Inglewood Ave.	N/S	35	2	2	12	Permissive	Permissive
2	Imperial HWY	E/W	35	3	3	12	Hawthorne Blvd.	N/S	35	3	3	12	Protective	Prot / Perm
3	120 <sup>th</sup> St.	E/W	40	3	2	12	Crenshaw Blvd.	N/S	40	3	3	12	Protective	Protective
4	El Segundo Blvd.	E/W	40	3	3	12	Hawthorne Blvd.	N/S	35	3	3	12	Protective	Prot / Perm
5	El Segundo Blvd.	E/W	40	3	3	12	Prairie Ave.	N/S	40	3	3	12	Prot / Perm	Prot / Perm
6	El Segundo Blvd.	E/W	40	3	3	12	Crenshaw Blvd.	N/S	40	3	3	12	Prot / Perm	Prot / Perm
7	Rosecrans Ave.	E/W	40	3	3	12	Hindry Ave.	N/S	35	2	2	12	Protective	Prot / Perm
8	Rosecrans Ave.	E/W	40	3	3	12	Inglewood Ave.	N/S	35	2	2	12	Prot / Perm	Protective
9	Rosecrans Ave.	E/W	40	3	3	12	Hawthorne Blvd.	N/S	35	3	3	12	Protective	Prot / Perm
10	Rosecrans Ave.	E/W	40	3	3	12	Prairie Ave.	N/S	40	3	3	12	Prot / Perm	Prot / Perm

The intersections of El Segundo Boulevard and Prairie Avenue, El Segundo Boulevard and Crenshaw Boulevard, Rosecrans Avenue and Prairie Avenue have protective-permissive/protective-permissive left-turn controls. At these intersections, left-turn accidents were the most common type of accident representing 38 percent, 55 percent, and 30 percent, respectively of the total accidents.

## Effects of Left Turn Signal Control

The total and left turn accident rates in 2010 were plotted against the type of signal control as shown in Figures 4 and 5. The results show that the intersection with permissive/permissive controls show a higher rate of accident compared with the protective/protective left turn controls. Intersections with a combination of protective and permissive control seem to show no clear trend, although the total accident rates at intersections with protective-permissive left turn control on all approaches seem to have higher accidents compared to intersections with protective control one road and protective-permissive control on another. However, when only the left turn accident rates are considered, the intersection with protective control on one road and protective-permissive control on another seem to cause higher average accident rate compared to the intersection with protective-permissive controls on all approaches.

Average accident rates are calculated for intersections with the same type of control and presented in Figure 6. The trend for left turn accidents is consistent with the results shown in Figure 5 for individual intersections. However, the average total accidents on intersections with protective/protective-permissive control show the lowest average, which is contrary to what one would expect at intersections with this type of control.

Table 2. Accident Data for the Years 2007-2011

No.	Intersection	Type of Accident								Total
		Rear-End	Left Turn	Broad-side	Side-swipe	Head-On	Bicycle	Pedestrian	Fixed-Object	
1	Imperial Hwy. - Inglewood Ave.	12	17	11	3	0	0	1	3	47
2	Imperial Hwy. - Hawthorne Blvd.	13	3	6	4	1	2	4	7	40
3	120 <sup>th</sup> St. - Crenshaw Blvd.	21	6	7	6	1	2	4	8	55
4	El Segundo Blvd. - Hawthorne Blvd.	9	8	4	5	1	3	3	3	36
5	El Segundo Blvd. - Prairie Ave.	5	14	5	4	0	4	3	2	37
6	El Segundo Blvd. - Crenshaw Blvd.	14	36	5	5	0	0	2	3	65
7	Rosecrans Ave. - Hindry Ave.	21	5	4	2	0	3	0	1	36
8	Rosecrans Ave. - Inglewood Ave.	10	17	7	2	1	1	5	4	47
9	Rosecrans Ave. - Hawthorne Blvd.	9	10	5	2	1	2	1	3	33
10	Rosecrans Ave. - Prairie Ave.	10	14	10	6	1	1	2	3	47

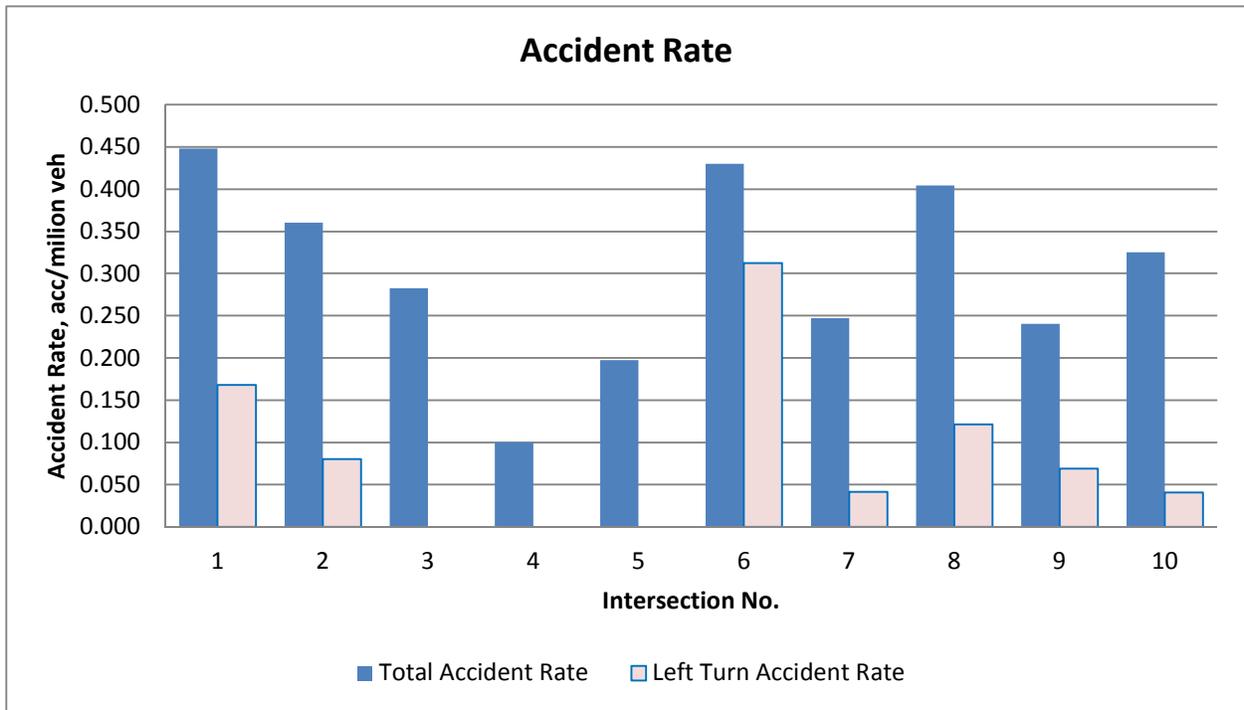


Figure 3. Total and Left Turn Accident Rates vs. Intersection

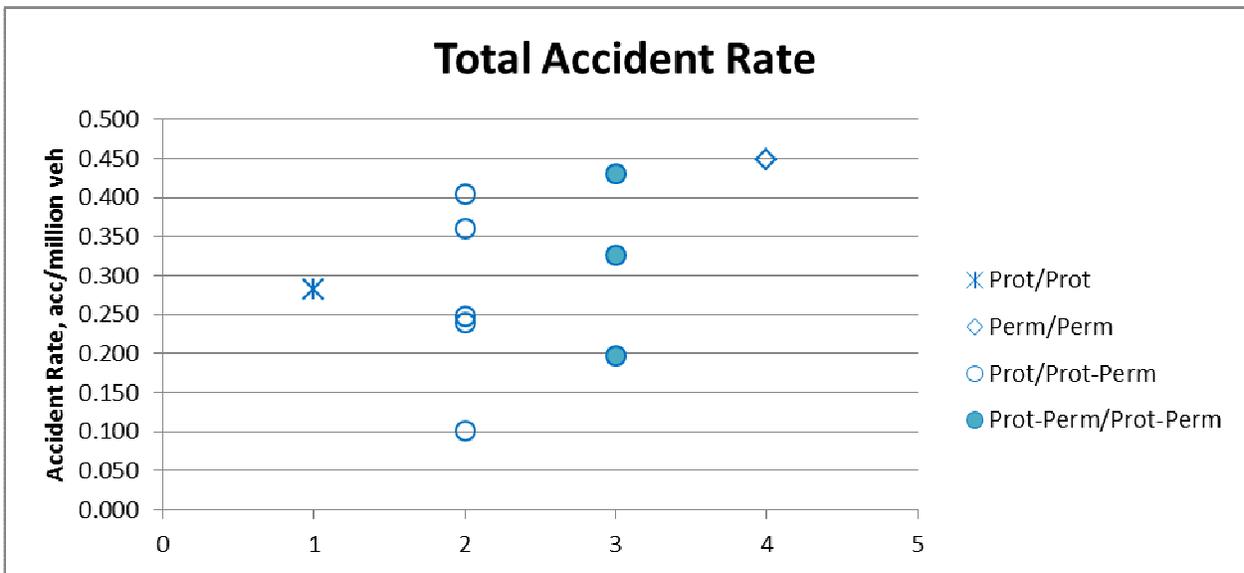


Figure 4. Total Accident Rate vs. Type of Signal Control

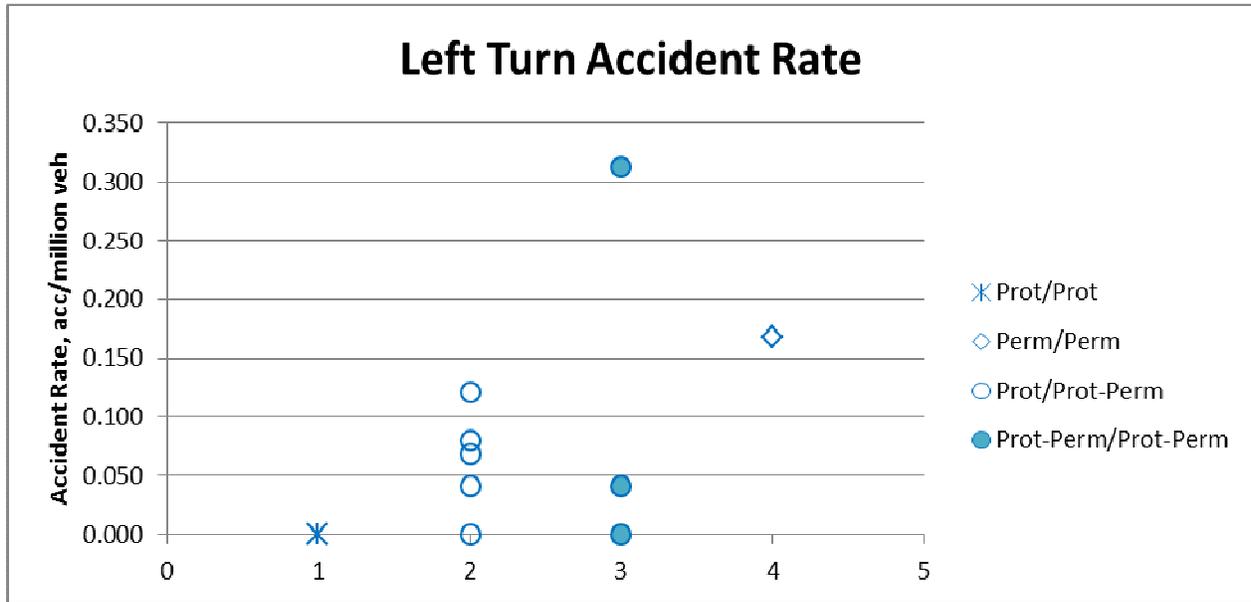


Figure 5. Left Turn Accident Rate vs. Type of Signal Control

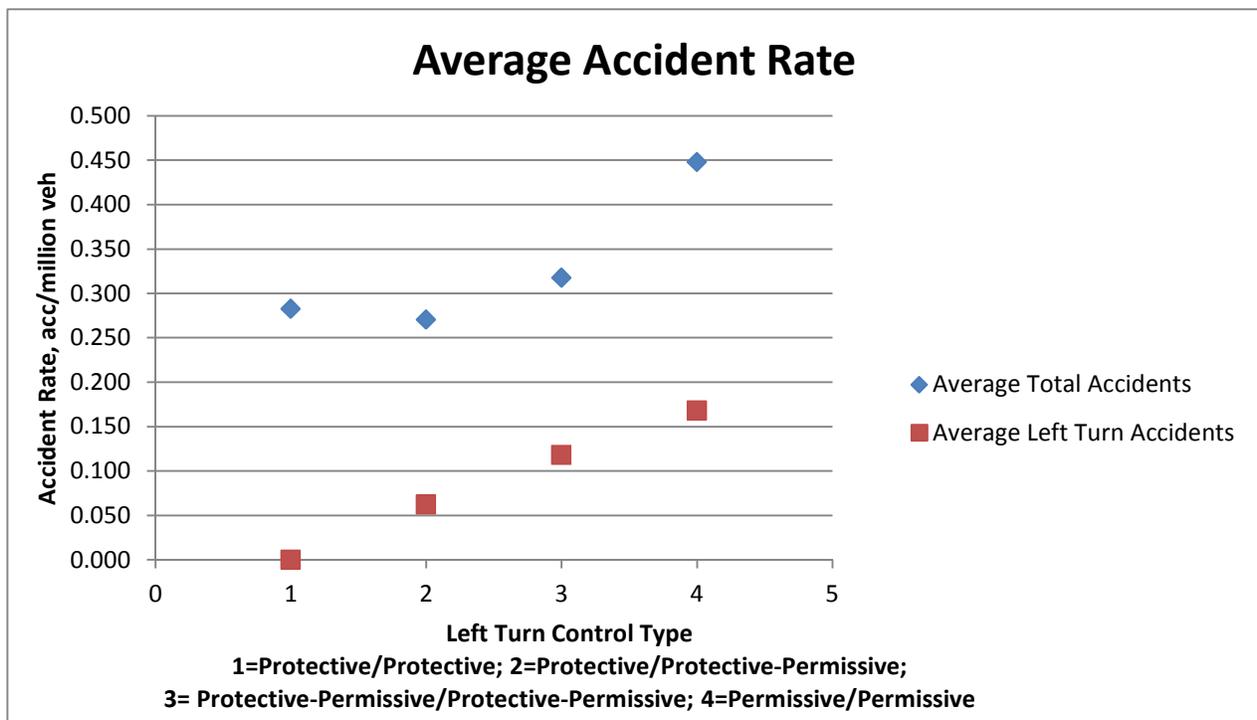


Figure 6. Left Turn Accident Rate vs. Type of Signal Control

### Conclusion

This study evaluates the effects of different types of left-turn signal control on intersection safety. In this study, ten intersections with different type of traffic signals were studied. All intersections were four-leg signalized intersections.

The results show the intersection with permissive/permissive left turns had the highest number of left-turn accidents while the intersection that has protective/protective left turn traffic signal control showed the lowest left turn accidents. The use of a combination of protective-permissive left turn controls show mixed-results.

### **Acknowledgements**

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### **References**

- 1) Federal Highway Administration, Manual on Uniform Traffic Control Devices, 2009.
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- 3) Raghavan Srinivasan, Forrest Council, Craig Lyon, and Frank Gross, “Safety Effectiveness of Selected treatments at Urban Signalized Intersections”, *Transportation Research Record*, 2008.
- 4) Siamak A. Ardekani, and James C. Williams, “A Simulation Study of the Operational Performance of Left-Turn Phasing and Indication Sequences”, System and Program Planning Bureau, New York State Department of Transportation, Albany, New York 12232-0411, 2011.

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