# Head-On, Left-Turn Accidents at Intersections with Newly Installed Traffic Signals

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Installations of traffic signals at intersections are often associated with changes in the accident characteristics at those sites. Past studies have indicated a reduction in the severity of accidents, but in some instances accident frequencies have increased. Traffic signals also influence changes in the distribution of accident types. Head-on, left-turn accidents at signalized intersections are of great importance to traffic engineers. A study of newly installed traffic signals was performed in Michigan to evaluate the changes in the distribution of accident types, including head-on, left-turn accidents. This study involved statistical testing of before and after accident rates at groups of similar intersections. The results of this study indicated an increase in head-on, left-turn accidents at the group of signalized intersections with and without separate left-turn lanes. However, the rate of increase in such accidents at locations without a separate left-turn lane was not significant at the 95 percent confidence level. The group of locations in which a separate left-turn lane was installed along with the traffic signals also did not indicate a statistically significant change in the head-on, left-turn accident rate.

Traffic signals at intersections are often installed to alleviate traffic operational problems. However, such installations are often associated with changes in accident characteristics. Past studies at newly signalized intersections have concluded that the following:

- Accident frequency increases, as well as decreases, have been reported after traffic signal installation (*1*).
- Accident severity is generally reduced (*1*).
- Right-angle accident frequency decreases (*2–4*).
- Rear-end accidents generally increase (*2,4,5*).
- Head-on, left-turn accidents generally increase (*2*).
- Use of multiphase signals results in a reduction in head-on, left-turn accidents (*6*).

These generalized conclusions have been used by engineers to predict the impact on accident characteristics caused by the installation of traffic signals.

In October 1986 the Michigan Department of Transportation (*7*) sponsored a study of traffic signals at intersections scattered throughout the state. The signals were installed between 1978 and 1983. The objective of this study was to evaluate the change in accident characteristics at these newly signalized locations.

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The project included collection of all available data on the candidate traffic signal locations from existing files, plans, and diagrams. The data consisted of

- Intersection names, locations, and milepoints;
- Intersection geometry;
- Traffic volumes;
- Signal equipment;
- Signal timing and phasing; and
- Traffic accidents.

The study investigated the impact of traffic signal installations on accident characteristics. The results of the analysis on groups of intersections with and without left-turn lanes are presented, with particular emphasis on the head-on, left-turn accident rate.

## DATA COLLECTION

A list of 235 candidate locations was initially selected as a part of this study. This time period was selected to provide 2 to 3 years of accident data for both the before and after conditions of the proposed study sites.

During the study a number of locations were eliminated from the candidate site list, either because they were of temporary nature due to construction activities or because they were not judged to be of interest (such as a traffic signal at a shopping center entrance). Also, several sites were eliminated because of a lack of traffic volume information. A total of 102 intersection locations were studied.

## DATA ANALYSIS

The before and after accident rates were studied to evaluate the impact of signal installation. In this analysis the accident rate is defined as the number of accidents per million entering vehicles (accidents/MV).

The effect of signal installations was determined on the following accident types:

| *Accident Type* | *Measure of Effectiveness* |
|---|---|
| Total accidents | Total accidents/MV |
| Right-angle accidents | Right-angle accidents/MV |
| Rear-end accidents | Rear-end accidents/MV |
| Injury accidents | Injury accidents/MV |
| Head-on, left-turn accidents | Head-on, left-turn accidents/MV |
| Other type accidents | Other type accidents/MV |

### Accident Rate Calculation Procedures

The procedure for calculating the accident rate consisted of three distinct efforts:

- Determination of before and after accident frequency from the statewide accident data base,
- Determination of before and after average daily traffic (ADT),
- Determination of accident rate.

#### *Before and After Accident Frequency*

The total number of accidents for the 3-year period before installation of the signal and the 3-year period after installation was identified. For signals installed after 1982 or before 1979, a 2- or 1-year study period was selected depending on the date of signal installation and availability of data.

#### *Before and After ADT*

The average traffic volume (total ADT of all approaches) for a 3-year period before and after the installation of the traffic signal at each location was calculated as follows:

Total ADT of all approaches = approach ADT on trunkline + approach ADT on minor streets

If only after or only before minor street ADT was available, the missing information was calculated using a growth factor (GF) as follows:

$$GF = \frac{\text{average ADT on trunkline after signal}}{\text{average ADT on trunkline before signal}}$$

Minor (before) street ADT = minor (after) street ADT/GF

#### *Accident Rate*

The accident rate for each location before and after signal installation was calculated using the following formula:

$$\text{Accident rate} = [A(10^6)]/(365TV)$$

where

$A$ = accident frequency (total for the study period),
$T$ = time period of the study (in years),
$V$ = average daily traffic.

### Test of Significance

The before and after accident rates for the groups of intersections were compared using paired $t$-tests to determine if there were statistically significant differences. The three groups of intersections tested were

- Groups with separate (exclusive) left-turn lanes,
- Groups without separate left-turn lanes, and
- Groups of intersections where the left-turn lane was added coincident to the signal installation.

The comparison of the $t$ statistic with $t$ critical was performed within each of these three groups for the before and after accident rates. The tests were two-tailed tests at a level of significance of .05.

## EVALUATION OF HEAD-ON, LEFT-TURN ACCIDENT RATES

Head-on, left-turn accidents at intersections are of great concern to traffic engineers. Past studies have generally concluded that this type of accident increases after the installation of traffic signals. Intersections at which left-turn lanes existed and locations at which separate left-turn lanes did not exist were analyzed by comparing mean accident rates both before and after the installation. Locations at which a left-turn lane was installed coincident to signal installation were also analyzed. The results of this mean accident rate analysis are presented in Table 1 and shown graphically in Figure 1.

The statistical test of the mean rate of head-on, left-turn accidents showed significant differences at locations with left-turn lanes. In fact, the accident rate went up from 0.15 to 0.27. However, at locations without left-turn lanes and locations at which the left-turn lane was installed coincident to signal installation, the changes were not statistically significant.

## ANALYSIS OF INTERSECTIONS WITH AND WITHOUT A LEFT-TURN LANE

As part of this analysis, comparisons of the before and after mean accident rates by total, rear-end, injury, head-on, left-

TABLE 1 RESULTS OF PAIRED $t$-TESTS FOR HEAD-ON, LEFT-TURN ACCIDENT RATE

| Intersection Type | No. of Sites | Mean Accident Rate (Accidents/MV) | | Percent (%) Increase (+) Decrease (-) | "t" Statistics | Two Tail $t_c$ $\alpha = 0.05$ |
|---|---|---|---|---|---|---|
| | | Mean Before Accident Rate | Mean After Accident Rate | | | |
| Locations With Left-turn Lane | 29 | 0.15 | 0.27 | +80.0 | -2.25* | 2.048 |
| Locations Without Left-turn Lane | 35 | 0.12 | 0.19 | +58.3 | -1.58 | 2.030 |
| Locations Where Left-turn Lane Was Installed Coincident to Signal Installation | 14 | 0.27 | 0.29 | +7.4 | -0.22 | 2.160 |

* Means Significantly Different

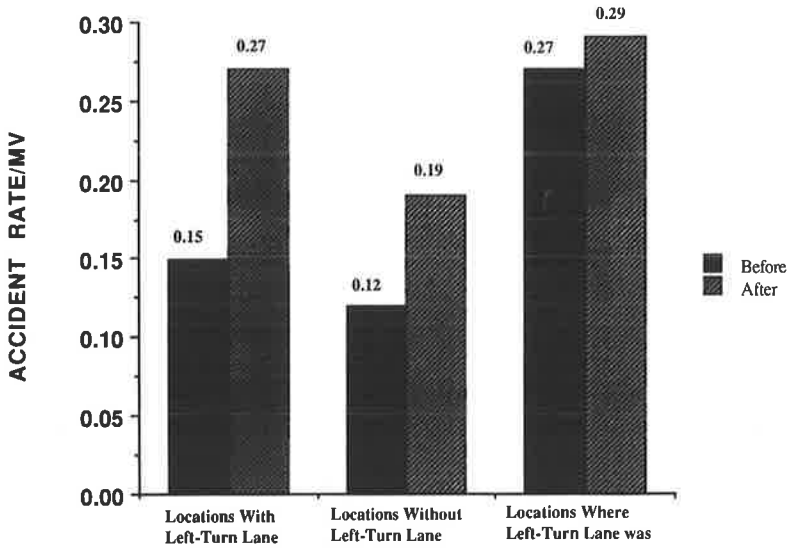


**FIGURE 1 Before and after head-on, left-turn accident rates for locations with and without left-turn lane.**

TABLE 2 RESULTS OF PAIRED *t*-TESTS FOR LOCATIONS WITH LEFT-TURN LANE

| Accident Type | Mean Accident Rate (Accidents/MV) | | Percent (%) Increase (+) Decrease (-) | "t" Statistics | Two Tail $t_c$ $\alpha = 0.05$ d.f. 28 |
|---|---|---|---|---|---|
| | Mean Before Accident Rate | Mean After Accident Rate | | | |
| Total | 1.98 | 1.78 | -10.1 | 0.87 | 2.048 |
| Right-angle | 0.60 | 0.24 | -60.0 | 4.06* | 2.048 |
| Injury | 0.66 | 0.54 | -18.2 | 1.34 | 2.048 |
| Rear-end | 0.32 | 0.57 | +78.1 | -2.46* | 2.048 |
| Head-on left-turn | 0.15 | 0.27 | +80.0 | -2.25* | 2.048 |
| Other | 0.91 | 0.70 | -23.1 | +2.08* | 2.048 |

* Means Significantly Different

turn, and other types of accidents were performed. The results are presented in Tables 2–4 and shown graphically in Figures 2–4.

Table 2 presents the results of the paired *t*-tests for locations with left-turn lanes. For this group of 29 intersections, the following were observed:

- The total accident rate was reduced 10.1 percent, but the difference between before and after was not statistically significant.
- The right-angle accident rate was reduced by 60 percent, and the change was statistically significant.
- The injury accident rate was reduced by 18.2 percent, but the change was not statistically significant.
- The rear-end accident rate increased by 78.1 percent, which was statistically significant.
- The head-on, left-turn accident rate increased by 80 percent, which was statistically significant.
- The rate for other types of accidents was reduced by 23 percent, which was statistically significant.

Table 3 presents the results of the paired *t*-tests for locations without left-turn lanes. For this group of 35 intersections, the following were observed:

- The total accident rate was reduced by 23.6 percent, and this change was statistically significant.
- The right-angle accident rate was reduced by 51.7 percent, which was statistically significant.
- The injury accident rate was reduced by 11.8 percent, which was not statistically significant.
- The rear-end accident rate was reduced by 48.3 percent, which was statistically significant.
- The head-on, left-turn accident rate increased by 58.3 percent, but this change was not statistically significant.

TABLE 3 RESULTS OF PAIRED *t*-TESTS FOR LOCATIONS WITHOUT LEFT-TURN LANE

| Accident Type | Mean Accident Rate (Accidents/MV) | | Percent (%) Increase (+) Decrease (-) | "t" Statistics | Two Tail $t_c$ $\alpha = 0.05$ d.f. 34 |
|---|---|---|---|---|---|
| | Mean Before Accident Rate | Mean After Accident Rate | | | |
| Total | 1.74 | 1.33 | -23.6 | 2.35* | 2.03 |
| Right-angle | 0.58 | 0.28 | -51.7 | 2.53* | 2.03 |
| Injury | 0.51 | 0.45 | -11.8 | 0.78 | 2.03 |
| Rear-end | 0.31 | 0.46 | +48.3 | -3.09* | 2.03 |
| Head-on left-turn | 0.12 | 0.19 | +58.3 | -1.58 | 2.03 |
| Other | 0.74 | 0.41 | -44.6 | +4.58* | 2.03 |

* Means Significantly Different

TABLE 4 RESULTS OF PAIRED *t*-TESTS FOR LOCATIONS WHERE LEFT-TURN LANE WAS ADDED COINCIDENT TO SIGNAL INSTALLATION

| Accident Type | Mean Accident Rate (Accidents/MV) | | Percent (%) Increase (+) Decrease (-) | "t" Statistics | Two Tail $t_c$ $\alpha = 0.05$ |
|---|---|---|---|---|---|
| | Mean Before Accident Rate | Mean After Accident Rate | | | |
| Total | 2.08 | 1.42 | -31.7 | 3.98* | 2.16 |
| Right-angle | 0.74 | 0.27 | -63.5 | 3.23* | 2.16 |
| Injury | 0.77 | 0.43 | -44.2 | 4.07* | 2.16 |
| Rear-end | 0.31 | 0.39 | +25.8 | -1.59 | 2.16 |
| Head-on left-turn | 0.27 | 0.29 | +7.4 | -0.22 | 2.16 |
| Other | 0.76 | 0.47 | -38.2 | 3.31* | 2.16 |

* Means Significantly Different

- The rate for other types of accidents was reduced by 44.6 percent, which was statistically significant.

Table 4 presents the results of the paired *t*-tests for 14 locations at which the left-turn lane was constructed during the installation of the traffic signals. The following were observed from the analysis of this group of locations:

- The total accident rate was reduced by 31.7 percent, which was statistically significant.
- The right-angle and injury accident rates were reduced by 63.5 and 44.2 percent, respectively. Both of these changes were statistically significant.
- The rear-end and head-on, left-turn accident rates were increased by 25.8 and 7.4 percent, respectively. However, neither of these changes was statistically significant.
- The rate for other types of accidents was reduced by 38.2 percent, which was statistically significant.

## FINDINGS

For intersections with and without a left-turn lane, the following were concluded:

- The mean head-on, left-turn accident rate was significantly different only for intersections with left-turn lanes in the before period.
- The mean head-on, left-turn accident rate at intersections with left-turn lanes increased 80 percent, compared with 58.3 percent for locations without left-turn lanes.

For intersections at which a left-turn lane was added coincident to signal installation, the following were concluded:

- The head-on, left-turn, accident rate increased by 7 percent.
- The total accident rate was reduced by 31.7 percent, which was statistically significant.
- Right-angle and injury accident rates were reduced by 63.5 and 44.2 percent, respectively, and the differences between the before and after accident rates were statistically significant.
- The rate for other types of accidents was reduced significantly (by 33.1 percent), as it was for locations with and without a left-turn lane.

The criteria for installation of traffic signals were assumed to be consistent with the warrants for traffic signals. No effort was made to determine if there were inconsistencies in signal installation criteria.

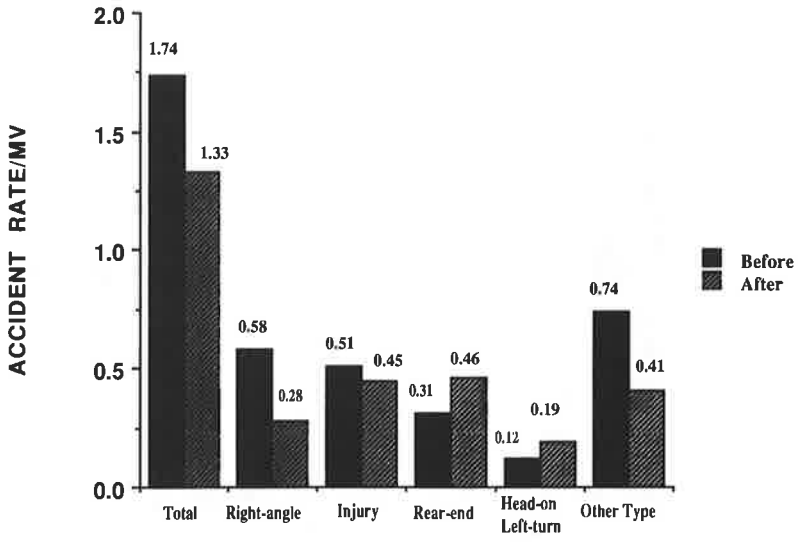


**FIGURE 2 Before and after accident rates for locations without left-turn lane.**

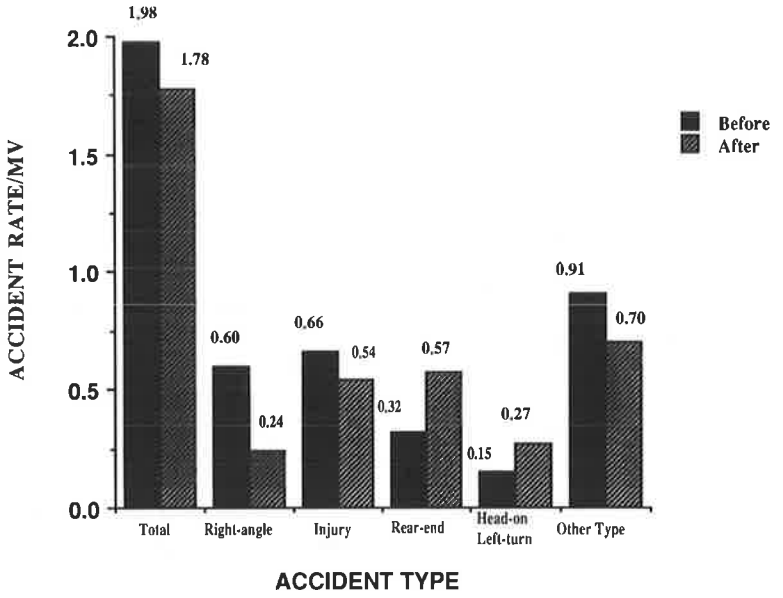


**FIGURE 3 Before and after accident rates for locations with left-turn lane.**

## SUMMARY

The results of this study require additional commentary to make the findings usable for traffic and safety engineers. These comments are as follows:

- Locations with an exclusive left-turn indicated a statistically significant difference in head-on, left-turn accident rates before and after the signal installations. In fact, the study showed an 80 percent increase. This observation might be due to the following:
  - —Locations with an exclusive left-turn lane provide a better opportunity for left turns, thus attracting more left-turning traffic and creating increased accident potential.
  - —Intersections with exclusive left-turn lanes may often require a left-turn phase. In the state of Michigan, the left-turn phase is rarely included when a traffic signal is initially installed. Many of the intersections might have been safer with a separate left-turn phase.
  - —The absence of specific warrants for installation of a left-turn phase may have contributed to the absence of this phase in many locations where it could have reduced head-on, left-turn accidents.
- The significant decrease in right-angle accidents in all cases verifies past research results.
- In most categories, the increase in rear-end accident rates also verifies historical observations.
- The decrease in total accident rates at locations without left-turn lanes and at locations at which a left-turn lane was

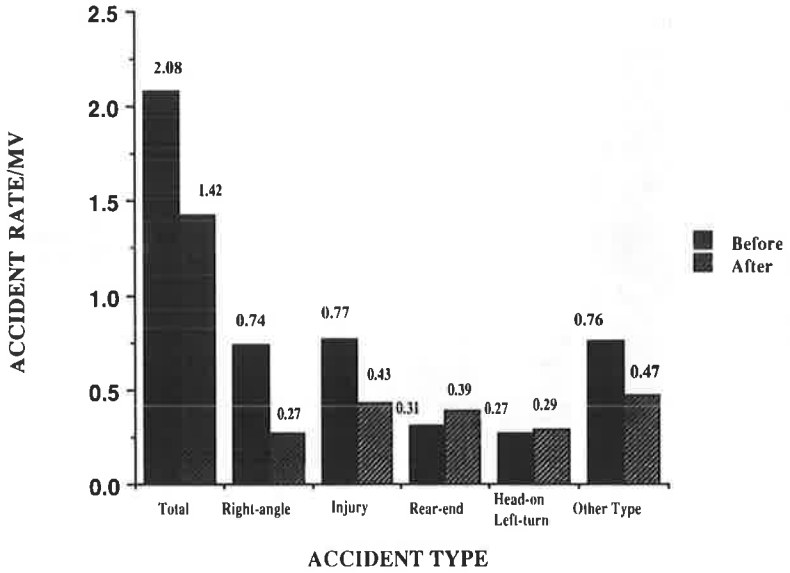


**FIGURE 4 Before and after accident rates for locations where left-turn lane was added coincident to signal installation.**

added coincident to signalization was somewhat unique and should be studied with a larger sample of intersection sites.

## REFERENCES


1. D. Solomon. Traffic Signals and Accidents in Michigan. *Public Roads*, Vol. 30, Oct. 1959, pp. 234–237.
2. M. N. Clyde. Michigan Study Indicates Signals Increase Accidents. *Traffic Engineering*, Vol. 35, Nov. 1964, p. 32.
3. A. F. Malo. Signal Modernization. In *Special Report 93: Improved Street Utilization Through Traffic Engineering*, HRB, National Research Council, Washington, D.C., 1967, pp. 96–126.
4. G. F. King and R. B. Goldblatt. Relationships of Accident Patterns to Type of Intersection Control. In *Transportation Research Record 540*, TRB, National Research Council, Washington, D.C., 1976.
5. J. T. Hanna, T. E. Flynn, and W. K. Tyler. Characteristics of Intersection Accidents in Rural Municipalities. In *Transportation Research Record 601*, TRB, National Research Council, Washington, D.C., 1976.
6. K. R. Agent and R. C. Deen. Warrants for Left-Turn Signal Phasing. In *Transportation Research Record 737*, TRB, National Research Council, Washington, D.C., 1979.
7. T. K. Datta and U. Dutta. *Traffic Signal Installation and Safety*. Report FHWA-MI-RD-88-04. Michigan Department of Transportation; FHWA, U.S. Department of Transportation, Feb. 1989.


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