# Should Direct Left Turns from Driveways Be Avoided? A Safety Perspective

THE FINDINGS OF THIS STUDY PROVIDE SOME USEFUL INSIGHTS ON THE CONTINUATION OF THE USE OF DIRECT LEFT TURNS INTO HIGH-VOLUME ARTERIALS.

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## INTRODUCTION

Access management has been defined as the process of managing access to land development while simultaneously preserving the safety and efficiency of the surrounding roadway system.[1] It helps achieve the necessary balance between traffic movement and property access by careful control of the location, type and design of driveways and street intersections. Various research efforts have evaluated the impacts of access management on roadway safety. *Access Management, Location and Design, Participant Notebook* suggests that effective access management can reduce crashes by as much as 50 percent, increase capacity by 23 percent to 45 percent, and reduce travel time and delay as much as 40 percent to 60 percent.[2] While there are some studies providing important information on various access management methods and techniques, questions still remain surrounding the effects of specific access management treatments on roadway safety and operations. Some of these concerns relate to the safety impacts of left-turn movements at median openings. Direct left turns from the driveways onto busy high-volume arterials are normally perceived as dangerous. Traffic engineers have often looked at other alternatives of facilitating left turns such as median U-turns known as Michigan U-turns, Bowtie, Superstreet, Paired Intersections, Jughandle and, recently, right turns followed by U-turns.[3–5]

The right turn followed by U-turn alternative is attractive and becoming more popular since it does not require a major financial investment such as roadway reconstruction or right-of-way acquisition. Another advantage is that the effect of U-turn movements on left-turn lanes at signalized intersections could be avoided when proper intermediate turn lanes are provided. For example, direct left-turn exits onto major arterials are prohibited in many locations in Florida through the provision of nontraversable medians and midblock median openings in advance of signalized intersections to accommodate U-turn movements. However, some road users have expressed safety concerns related to right turns followed by U-turn movements since it requires drivers to weave on a certain stretch of the roadway and then evaluate the available gaps for making the U-turn. According to a driver survey conducted by TEI Engineers and Planners on this subject, the most common complaint was regarding the safety of U-turn movements.[6] According to the findings of this study, 43 percent of the surveyed people did feel inconvenienced by U-turns.

Therefore, this study looked at the safety of two alternative left-turn treatments from driveways, direct left turns and right turns followed by U-turns, with the intention of identifying whether it is appropriate to avoid direct left turns from a safety perspective.

## METHODOLOGY

Traffic conflict data were gathered at several locations where driveways met with high-volume major arterials. Each of the locations facilitated either one or both of the left-turn alternatives selected for evaluation. Two considered left-turn treatments are graphically illustrated in Figure 1. All the major arterials had three or more lanes in each direction and speed limit was greater than or equal to 45 miles per hour (mph). In the case of right turn followed by U-turn, U-turn was facilitated at a median opening located at a reasonable distance [300 feet (ft) to 1,000 ft] downstream of the driveway. Video cameras were used as the data-collection methodology. To achieve enough viewing heights, the cameras were mounted on scaffoldings as shown in Figure 2, in the absence of other appropriate facilities such as buildings. Videotapes that recorded all the traffic movements at the selected sites were later

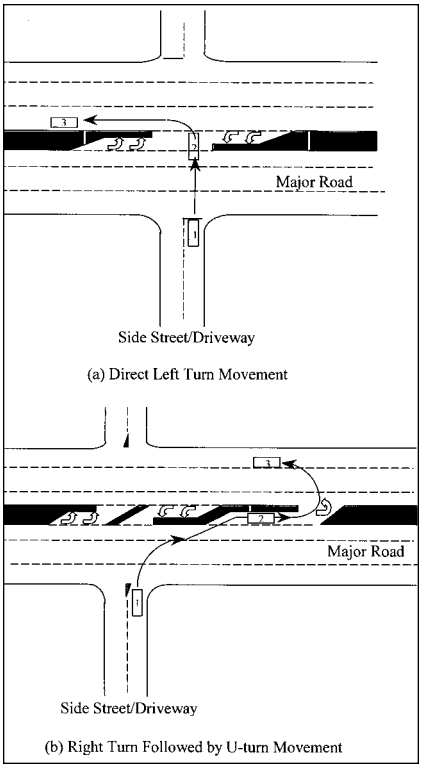


**Figure 1. Two left-turn treatments considered.**

**Figure 2. Video cameras are placed on scaffoldings.**

reviewed, and the information on the type, severity and numbers of conflicts were gathered together with the volumes. The types of conflicts that were considered in this study included right-turn out conflicts, slow-vehicle same-direction conflicts, lane-change conflicts, U-turn conflicts, slow U-turn vehicle same-direction conflicts, left-turn out of driveway conflict from right, direct-left turn and left-turn in from-right conflicts, direct-left-turn and left-turn in from-left conflicts, and left-turn out of driveway conflict from left. The two directional traffic volumes on the major streets varied from about 2,600 to 6,700 vehicles/hour (veh/hr) with an approximate average of 4,500 veh/hr.

Two conflict rates were considered in this study—one based on the time and the other based on the volumes as follows:

$$R_1 = \frac{Number\ of\ conflicts}{Number\ of\ hours}$$

$$R_2 = \frac{Number\ of\ conflicts}{\sqrt{(V_1) \times (V_2)}} \times 1{,}000$$

where

$R_1$ = Conflicts per hour;

$R_2$ = Conflicts per thousand involved vehicles; and

$V_1$ and $V_2$ = Traffic volumes of the two conflicting traffic maneuvers corresponding to the conflict type being considered.

Severity of traffic conflicts were assessed in categorical form by using two indices commonly used in the past studies, Risk of Collision (ROC) and Time to Collision (TTC). ROC is somewhat subjective in nature where it was assigned based on the judgment of the observer who was properly trained with that regard.[7–9] TTC is based on a quantitative measure defined as the time required for two vehicles to collide if they continue at their present speeds on the same paths.[10] If the TTC was greater than 1.51 seconds (sec), it received score 1, which referred to a low-risk conflict. TTC values from 1.00 to 1.50 sec were score 2, medium-risk conflict, and TTC values from 0 to 0.99 sec were score 3, the highest-risk category. Each conflict received both ROC and TTC scores to evaluate the severity of conflicts for both direct left turn (DLT) and right turn followed by U-turn (RTUT) maneuvers.

## ANALYSIS RESULTS

### *Number of Conflicts and Conflict Rates*

More than 300 hours of daytime traffic data collected at seven sites in the Tampa Bay Area included a total of 1,654 conflicts. When these conflicts were separated into the two left-turn treatments considered, direct left turn and right turn followed by U-turn, the average number of conflict values given in Figure 3 were obtained for peak, off-peak and total time periods. More DLT conflicts occurred during peak periods than that during off peak. However, for RTUT, more conflicts occurred during off-peak periods than during peak periods even though the numbers are smaller than those for DLT. For each time period, the difference in number of conflicts was estimated as:

$$Difference\ \% = \frac{Number\ of\ DLT\ Conflicts - Number\ of\ RTUT\ Conflicts}{Number\ of\ DLT\ Conflicts} \times 100$$

Accordingly, the differences in the average number of conflicts were 50.4 percent, 22.2 percent and 34.0 percent, during peak, off-peak and total time periods, respectively. This indicated that replacing DLT with RTUT could significantly reduce the average hourly number of conflicts.

Consideration of the number of conflicts per hour did not take the effect of the associated volumes into account. Therefore, the conflict rate $R_2$ was then estimated. Details on the number of conflicts per thousand involved vehicles are given in Table 1 for each of the sites. On average, direct left-turn movements experienced 30.2 conflicts per thousand involved vehicles. As for right turn followed by U-turn, the corresponding value was only 18.7. Accordingly, RTUT movement appeared to be much safer than DLT.

Study site 3, US 19 and 116th Avenue, was of particular interest as it underwent median changes during the data-collection time period providing an opportunity for the research team to conduct a "Before-and-After" study. During the before period, drivers coming from 116th Avenue could either make a direct left turn or right turn followed by U-turn, if they wanted to make

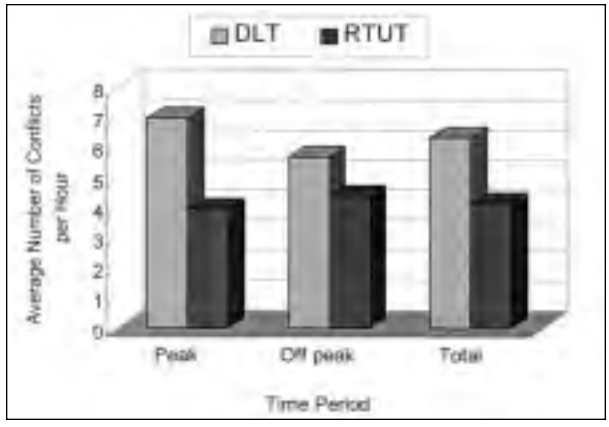


**Figure 3. Average number of conflicts for DLT and RTUT movements.**

a left turn onto US 19. The full median opening was later changed to a directional median opening allowing only left-turn in vehicles to enter the driveway. In other words, drivers from the driveway intending to make left turns were forced to make right turns followed by U-turns. Summary of the total average number of conflicts per hour during before-and-after time periods and the percentage reduction is given in Table 2. It could be seen that the total number of conflicts could be reduced by almost 50 percent by prohibiting the DLT and forcing such drivers to make RTUT instead.

**Table 1. Number of conflicts per thousand involved vehicles.**

| Site | | DLT | RTUT |
|---|---|---|---|
| 1 | Fowler Avenue and 46th Street | N/A | 19.61 |
| 2 | Fowler Avenue and 19th Street | 39.36 | 10.12 |
| 3 (a) | US 19 and 116th Avenue (Before) | 49.11 | 19.02 |
| 3 (b) | US 19 and 116th Avenue (After) | N/A | 36.80 |
| 4 | Bruce B. Downs Medical Center | 28.46 | 11.69 |
| 5 | Hillsborough Avenue and Golden Street | 26.90 | 12.10 |
| 6 | US 19 and Enterprise Center | 11.33 | 17.74 |
| 7 | US 19 and Innisbrook | 26.12 | 12.41 |
| 8 | Fowler Avenue and 52nd Street | N/A | 28.90 |
| | Average | 30.21 | 18.71 |

**Table 2. Total number of conflicts per hour during before-and-after time periods.**

| | Number of conflicts / hour during the before period | | | Number of conflicts / hour during the after period | | | Reduction % |
|---|---|---|---|---|---|---|---|
| | Due to DLT | Due to RTUT | Total | Due to DLT | Due to RTUT | Total | (Before-After) x 100 / Before |
| Peak period | 23.92 | 3.20 | 27.12 | 0 | 13.14 | 13.14 | 51.5 % |
| Nonpeak period | 19.00 | 4.25 | 23.25 | 0 | 12.06 | 12.06 | 48.1 % |
| Total average | 21.46 | 3.72 | 25.18 | 0 | 12.60 | 12.60 | 49.9 % |

**Table 3. ANOVA test results to compare the severities of DLT and RTUT conflicts.**

| Index | Movement | Number of conflicts | Mean severity | F statistic | $F_{Critical}$ |
|---|---|---|---|---|---|
| ROC | DLT | 902 | 1.45 | 6.79 | 3.85 |
| | RTUT | 738 | 1.38 | | |
| ROC + TTC | DLT | 529 | 3.07 | 35.59 | 3.85 |
| | RTUT | 738 | 2.72 | | |

*Severity Analysis*

The average severity indices for direct left turn and right turn followed by U-turn conflicts were obtained by using the ROC score and the sum of ROC and TTC scores. ROC and TTC values varied from 1 to 3 where a higher rating indicated a more severe conflict. Accordingly, the analyses done using ROC had a range from 1 to 3 and sum of ROC and TTC had a range from 2 to 6. Average ROC score for DLT and RTUT movements were 1.45 and 1.38, respectively, and the corresponding average sum of ROC and TTC scores was 3.07 and 2.72. Analysis of Variance (ANOVA) tests were also conducted to see whether the severity levels of the two movements were significantly different at 5 percent level of significance. The results of the tests that considered a null hypothesis of equal severities are given in Table 3. Estimated F statistic for both cases, which considered ROC and sum of ROC and TTC, were greater than the critical F statistic, 3.85. Therefore, the null hypotheses were rejected, and average severity of DLT conflicts was found to be more severe than that of RTUT conflicts.

## CRASH-DATA ANALYSIS

Crash data were also used to supplement the findings obtained through conflict analysis. Since the conflict data were collected at only seven sites, examining the crash history at those sites did not provide a sufficiently large sample size. Therefore, a large number of sites, which provided either DLT or RTUT, were selected for crash-data analysis. The sample consisted of 133 DLT sites that experienced a total of

**Table 4. Comparison of crash experiences of the two left-turn movements.**

| Crash characteristic | | Average number of crashes | | | | Average crash rate (crashes per MVM) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | DLT | RTUT | Difference[a] % | Significantly different[b] | DLT | RTUT | Difference[a] % | Significantly different[b] |
| All crashes | | 16.35 | 13.9 | 14.98 | No | 3.20 | 2.63 | 17.8 | Yes |
| By severity | Property damage only | 11.08 | 10.52 | 5.05 | No | 2.18 | 2.04 | 6.4 | No |
| | Injury/fatality | 6.31 | 4.92 | 22.02 | Yes | 1.21 | 0.88 | 27.3 | Yes |
| By type | Rear-end | 6.80 | 6.49 | 4.56 | No | 1.28 | 1.12 | 13.3 | No |
| | Sideswipe | 1.75 | 2.31 | –32.0 | Yes | 0.36 | 0.44 | –19.5 | No |
| | Angle | 5.35 | 4.20 | 21.5 | Yes | 1.06 | 0.81 | 24.5 | Yes |

[a]*Difference = 100 (DLT – RTUT)/DLT.* [b]*Tests the null hypothesis of equal number of crashes or crash rates.*

2,175 crashes and 125 RTUT sites with a total of 1,738 crashes over the most recently available three-year period. The average number of crashes and the average crash rates for both left-turn movements are given in Table 4 together with the statistical test results to see whether the differences are significant at 5 percent level of significance. Results indicated that for all of the categories except sideswipe crashes, DLT safety experience as indicated by average number of crashes and average crash rate were much worse than RTUT. However, as for RTUT, more sideswipe crashes occurred than DLT, which could be explained by the fact that RTUT needs excessive weaving. When number of crashes was considered, the difference was statistically significant at 5 percent level of significance for injury/fatality crashes, sideswipe crashes and angle-crashes only. As for crash rates, total crashes, injury/fatality crashes and angle crashes indicated statistical significance but not the other categories.

## CONCLUSIONS

Direct left turns from driveways onto busy, high-volume arterials are more frequently being considered for alternative left-turn measures such as right turns followed by U-turns. This study looked at the performance of direct left turns as compared to right turns followed by U-turns from safety perspectives. Conflict data collected at several appropriate sites were first analyzed by considering number of conflicts per hour and also conflict rates as conflicts per thousand involved vehicles. Both parameters indicated that direct left turns experienced more conflicts than right turn followed by U-turns. In addition to the consideration of average frequencies and rates, severities of the conflicts related to the two movements were also compared. Conflicts associated with direct left turns were found to be more severe in nature according to both indices used in this study. Results of a before-and-after study conducted at a site where a direct left turn from a driveway was later converted to a right turn followed by U-turn illustrated highly significant safety improvements in terms of traffic conflicts. Crash-data analysis was also conducted by using two large sets of sites, which facilitated either of the two left-turn alternatives. Comparison of average number of crashes and crash rates also confirmed the fact that the right turn followed by U-turn movement is much safer than direct left turns in the case of high-volume, multilane major arterials.


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*References*


1. Koepke, F., and H. Levinson. *NCHRP Report 348: Access Management Guidelines for Activity Centers.* Washington, DC, USA: Transportation Research Board, National Research Council, 1992.

2. National Highway Institute. NHI Course No. 133078 2000. *Access Management, Location and Design, Participant Notebook*, 2000.

3. Hummer, J.E., and J.L. Boone. "Travel Efficiency of Unconventional Suburban Arterial Intersection Designs." *Transportation Research Record 1500* (1995): 153–161.

4. Hummer, J.E. "Unconventional Left-turn Alternatives for Urban and Suburban Arterials Part One." *ITE Journal*. Vol. 68, No. 9 (September 1998): 26–29.

5. Hummer, J.E. "Unconventional Left-turn Alternatives for Urban and Suburban Arterials Part Two." *ITE Journal*. Vol. 68, No. 9 (September 1998): 101–106.

6. Gwynn, D.W. "Public Information Meetings for Access Management Projects." www.fhwa.dot.gov/realestate/am_d5pub.pdf, accessed Sept. 29, 2001.

7. Salman, N.K., and K.J. Al-Maita. "Safety Evaluation at the Three-leg, Unsignalized Intersections by Traffic Conflict Technique." *Transportation Research Record 1485* (1995): 177–185.

8. Katamine, N.M. "Nature and Frequency of Secondary Conflicts at Unsignalized Intersections." *Journal of Transportation Engineering*. Vol. 126, No. 2 (2000): 129–132.

9. Glauz, W.D., B.M. Bauer and D.J. Migletz. "Expected Traffic Conflict Rates and Their Use in Predicting Accidents." *Transportation Research Record 1026* (1985): 1–12.

10. Hayward, J.C. "Near-Miss Determination Through Use of a Scale of Danger." *Highway Research Board Record No. 384* (1972): 24–33.



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