

Guidelines for Median Treatment at Urban Roadways to Solve Left-Turn Movement

Author: Mohammed Mallah, Assistant Prof.
Engineering Faculty, Al-Baha University, Al-Baha, Saudi Arabia

Introduction

Traffic safety problems have continued over the past century, causing enormous economic and social cost. Traffic accidents have been a serious concern for transportation planners and engineers. Traffic conflicts which cause accidents often happen at road intersections where drivers are required to perform more driving maneuvers within a shorter time period than are necessary on roadway segments between intersections. Unsignalized intersections are complex to analyze because their capacity and delay depend on driver, vehicle, roadway characteristics and environmental conditions. Improving the design and operation of unsignalized intersections can reduce user cost in delays and accidents. Improvement in design and operation largely depend on applying the suitable access management techniques. The majority of access-related crashes have been attributed to left-turn movements. The safety benefits of access management techniques have been attributed to reduction in traffic conflict points, improved access design, and higher driver response time to potential conflicts. At unsignalized intersections, left turn movements from a driveway to a major road pose many problems and a large number of conflict points. According to the roadway safety and operations problem, specific access management treatments are applied according to many variables such as location, volume, speed, geometric design and land use. Median treatments are the most important techniques that can improve safety at unsignalized intersections. The main goal of this study was to design a guideline for the full opening median treatment at unsignalized intersection using the predicted conflict rate as the safety measure. As a conclusion three guideline charts was performed for three different major road volumes. Those guidelines can be easily used, and then transportation planners and engineers can make the right decision when and what kind of median treatment can be applied.

Problem Statement

The fact that the medians treatments can reduce conflict points and improve safety make the guideline for the median treatment needed. The prohibition of direct left-turns from existing driveways may transfer the displaced left-turns to the nearest traffic-signal-controlled intersection unless intermediate U-turn lanes are provided. Recently, many States and local transportation agencies are considering installing non-traversable median openings on multilane highways.

Research Objective

The main goal of this study is to design a guideline for median treatment at unsignalized intersections in urban roadways. Transportation planners and engineers to reduce conflicts and improve safety at full opening medians can use this guideline charts.

Literature Review

Traffic conflict is one of the main traffic safety problems that researchers are trying to understand. Traffic conflict studies are a new issue in comparison to other traffic related issues; however, it is a very important topic according to safety improvement. To design a guideline for a median treatment we need to quantify and estimate the safety effects of median treatments to direct left-turns from driveways. One of the top issues that need to be reviewed carefully is traffic conflict and access management. To predict conflict rate at any segment of the road network, understanding operational effects at that segment and the impact of access management techniques is the key factor. Modeling design and applied regression analysis are the most important parts to develop a model for a conflict rate.

Traffic conflicts are traffic events involving the interaction of two or more drivers where one or both drivers take evasive action to avoid a collision (Parker and Zeeger, 1988). Conflict can be considered to be vehicle interaction, which may lead to crashes. Traffic conflict is a potential accident situation. Traffic conflict studies can provide measures of traffic safety. Most of the traffic conflicts occurred due to conflicting maneuvers at unsignalized intersections where design and operation is comprised of a complex set of parameters including number of traffic lanes, traffic volumes, spacing between intersections, medians, and speed and turning movements. They are a major source of vehicular conflict resulting in delay, congestion, and accidents (Katamine and Hamarneh, 1998). The higher the number of conflicts, the greater the potential for accidents and a related goal is to reduce these accidents by reducing the number of conflicts. Because a driver can only handle one conflict at a time, access management is used to separate the remaining conflict points that cannot be eliminated (Amundsen and Hyden, 1977).

Salman and Al-Maita (1995) worked on determining the relationship between conflicts and volumes, although this study concentrated on three-leg unsignalized intersections. In this study, the number of conflicts per hour was compared to two types of volumes. One volume was defined as the summation of all the volumes entering the intersection, and the other one was defined as the square root of the product of the volumes that generated conflicts. Linear regression models were used for correlating same direction, left turn, and same direction conflicts with volumes.

Left Turn Movement from Driveway

To understand the safety problems related to left-turning movements from a driveway, according to the driver's behavior, there are three scenarios that might occur. First of all, the driver will wait for a suitable gap for crossing the arterial, which in most cases will be selected once the platoon of the upstream signals clears the path. The second scenario occurs when a non-aggressive driver exposed to a long delay while waiting for an acceptable gap decides to turn to the right and make a U-turn at the next median opening. The final scenario occurs when a driver suffers a long delay for turning to the left, so that the driver's behavior becomes impatient and aggressive. At that moment, the driver is willing to take the risk of crossing the street when there is a short gap, which could create a conflict or even a collision. This is because too short gaps can cause high speed differentials and turbulence in the through traffic since vehicles are required to decelerate or attempt to change lanes (Stover, et al. 1994). Once the driver proceeds with the left turn movement, he/she must be aware of other vehicles interacting at the same time. Full median openings allow several movements at the same time, therefore traffic conflicts can be created not only because of through traffic vehicles but also because of vehicles turning into and out from the same driveway. If other vehicles do not interfere with the egress of the vehicle, then the driver crosses the arterial and gets to the median's storage area. Here again, the driver must find a suitable gap in order to merge into the opposite direction and to accelerate to the mean speed of the oncoming through traffic. The last scenario is risky and unsafe. Furthermore, full median opening makes it more complicated and dangerous. More than two-thirds of all driveway related accidents involve left turning vehicles (Levinson, 1998).

Medians

Medians are elements of the roads that separate traffic traveling in opposite directions and can be divided into three categories: non-traversable, traversable and Two-Way Left Turn Lane. The usefulness of medians is that they are very effective in reducing the number of conflict points. Medians should be as wide as feasible but of a dimension that is in balance with other design components of the roadway cross section. The minimum spacing if median opening is a function of the pattern of the movements permitted as well as the functional limit of the maneuvers (Williams, 2000).

If an intersection has only right-in and right-out movements allowed, only two conflict points will exist. Obviously, the safety on the through movement will be greatly improved.

However, the left-turn in and left-turn out traffic will have to be transferred to the downstream median or intersection when left-turn in and left-turn out movements were prohibited.

A conflict point is defined as the point at which two traffic movements intersect each other. For example, Figure 1 illustrates that there are 32 conflict points on a four-leg intersection with full-median opening, while showing that another four-leg intersection with a directional-median opening would only have 10 conflict points.

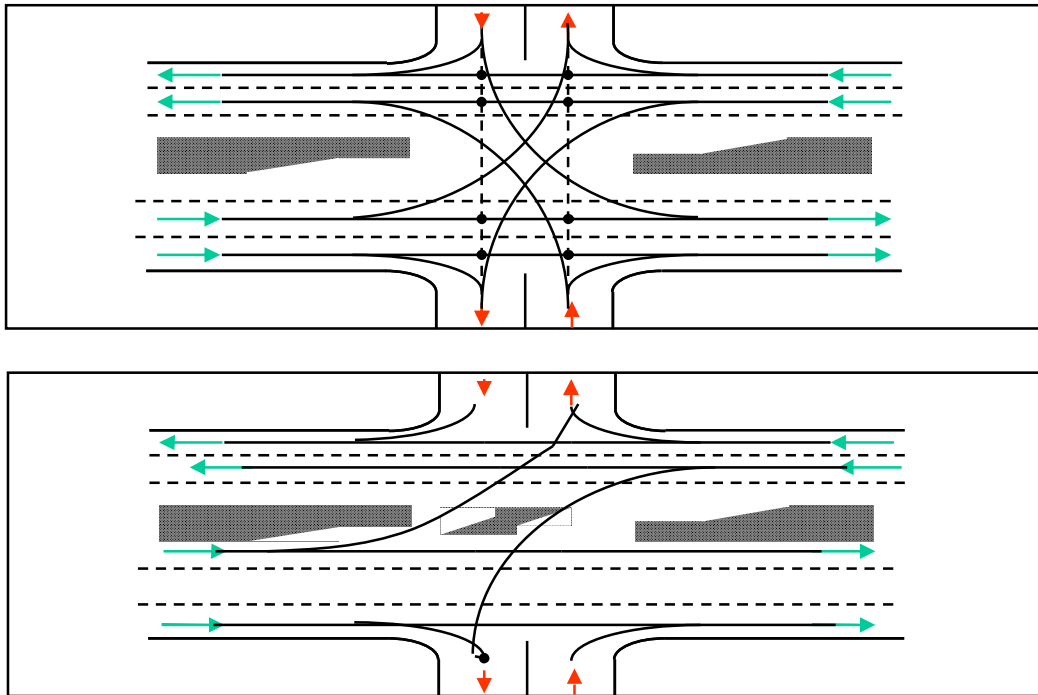


FIGURE 1: Effect of Median on Conflict Points at Four-Leg Intersections.

It is clear that left-turning movements either from a cross street or left-turn bay generate most of the conflict points. Thus, left-turn maneuvers are of special consideration when evaluating either signalized or unsignalized intersections. Little research has been performed on the effect of left-turn maneuvers from driveways.

To overcome the safety problems generated by left turn vehicles, different treatments have been proposed, such as Median U-turns, Jug Handles, and recently by NCHRP Report 420 (1999), the right turn followed by U-turn, as alternatives for direct left turns from a driveway

Access management

Access management is a new element of roadway geometric design. Traditional roadway design addresses roadway location, horizontal and vertical design and other general geometric design features such as number of lanes, treatment of medians, and provisions of curbs and shoulders. Access design and location recognizes that access control elements, such as signal spacing, driveway spacing, median opening and other traditional geometric elements, must progress in a logical or optimal manner that results in improved roadway capacity, safety and maintenance of through-traffic speeds.

Access Management Techniques

A variety of access management, location and design practices and policies can be used to improve safety and operations of the roadway (William, 2000), including;

1. Limiting the Number of Conflict Points
2. Separating Conflict Areas
3. Remove Turning Vehicles from the Through Lanes
4. Reduce the Number of Turning Movements
5. Improve Traffic Operations on the Access Drive or Intersection Local Street
6. Improve Traffic Operations on the Roadway

There are several methods by which the number of conflict points can be reduced, including the following: (William and Marshall, 2000)

1. Install a non-traversable median.
2. Close the median opening.
3. Construct a directional median opening.
4. Install a division island to prevent entry into left-turn bay where weaving length is inadequate.
5. Install a physical barrier to eliminate uncontrolled access along property frontage.
6. Locate access opposite signalized 3-way intersection.
7. Install a channelizing island to discourage turn maneuver.
8. Install a non-traversable median with indirect left-turns.
9. Midblock pedestrian/ bicycle crossing.
10. Grade separation access.

Install a Directional Median Opening

At 4-way intersections, total conflicts are reduced from 32 to 10 conflicts when a full median opening was replaced by a directional median opening that only allow left-turn ingress to abutting developments as in figure 2-a. However, turning right onto the arterial road and then making U-turns would make the left-turn egress movements. The median in this case was replaced by a directional median opening that only allows left turn egress from two approaches as shown in figure 2-b. U-turns are often used as alternatives to direct left-turns because U-turns can reduce conflict points and improve safety. The prohibition of direct left-turns from existing driveways may transfer the displaced left-turns to the nearest traffic-signal-controlled intersection unless intermediate U-turn lanes are provided.

Install a Nontraversable Median

The characteristic of this treatment is using U-turns as alternative to both left-turns, left-turn in from major roads and left turn out from driveways. Installing a non-traversable median reduced the number of conflicts to 4 at a 4-way intersection and to only 2 at a 3-way intersection as shown in figure 2-c. This technique provides positive access control on major roadways through closure of median opening so as to allow only right-turn in and right-turn out into driveways. If an intersection has only right-in and right-out movements allowed, only two conflict points will exist. Obviously, the safety on the through movement will be greatly improved. However, the left-turn in and left-turn out traffic will have to be transferred to the downstream median or intersection when left-turn in and left-turn out movements were prohibited.

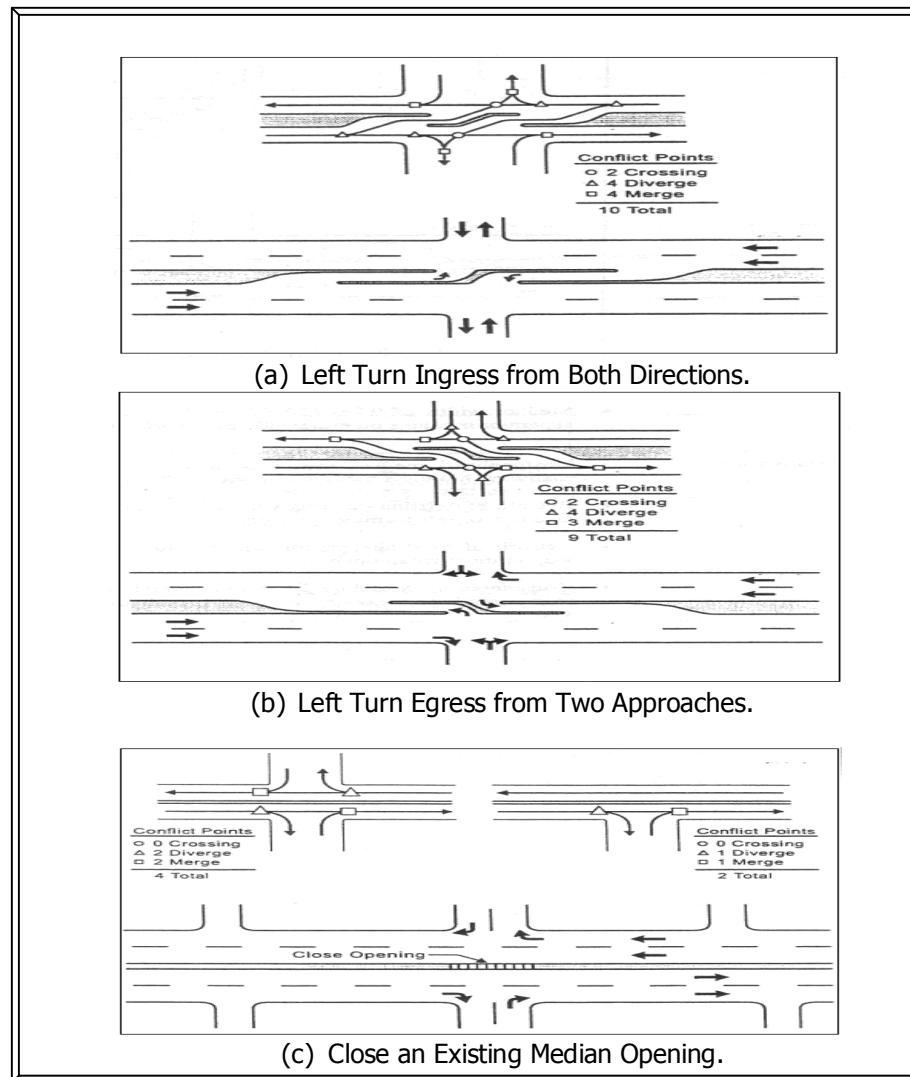


FIGURE 2: Effect of Full Median Opening Treatments.

Finally, using conflict rate as a measure tool for safety could be a better method for transportation engineers on the future. In addition, after analyzing all access management techniques, Installing U-turns, as alternative to direct left-turn treatment could be a better solution to reduce the conflict points and improve the safety at unsignalized intersection. Median treatment is the key factor for all those alternatives and the guideline for the median treatment is needed.

Methodology

Unsignalized intersections are junctions where a driver could cross through or make one of the three known maneuvers: right turn, left turn or u-turn. These intersections are usually controlled by stop signs. The right of way is known at these locations but sometimes due to lengthy queue and delay, those rules are ignored. Median opening is the most important factor in the unsignalized intersections.

In order to develop a guideline for media treatments, first we need to find the predicted conflict rate for the left turn maneuver and then compare that rates with the conflicting volumes. Three types of data were needed: segment geometric data, traffic volumes, and traffic conflict data.

From these data, the observed conflict rates will be calculated for direct left turn then the predicted conflict rate will be defined using the prediction model that has been developed separately in this study.

Data Collection

Eight sites for this study were selected carefully. They were defined as an urban or suburban arterial street segment that has two or more unsignalized access points along its length. Each segment has a constant cross section and raised curb median. Sites were selected with a full median opening where a vehicle can do either a Direct Left-Turn maneuver from the driveway and Left turn in the driveway from the major road.

Sites were selected for data collection based on some specific geometric criteria. These criteria include:

1. The major road should have three or more lanes in each direction.
2. The driveway traffic volume should be relatively high or moderate, so that the time necessary to collect conflicts would not take many hours.
3. Posted speed on the major road is equal to or greater than 45 MPH.
4. Median width should be wide enough to store the left-turn vehicles.
5. The distance between the driveway and an upstream signal should not be less than 200 feet.
6. The entire site is located in commercial and residential areas.

Automatic traffic counters were used to measure volumes and speed. Also, four video cameras were used to monitor all traffic operations. Using video cameras allowed the observer to review all the conflicts vehicle by vehicle. This methodology requires spending several hours reducing the data from the videotapes to calculate the observed traffic conflicts. Then the data plugged into the prediction model to calculate the prediction conflict rate.

Data was collected during weekdays, peak periods, normal traffic conditions, good weather conditions and dry pavement. Data were collected for two weeks at each site for about four hours a day. About three hundred hours of traffic data were recorded by video cameras at all sites, only the peak hours were selected for the study. Reviewing and analysis of one hour of videotape consumed from three to four hours.

Conflict Rate Calculation

Once traffic conflicts are recorded and counted, conflict data must be reviewed so that any noticeable error or missing record could be corrected promptly. Also conflict data must be collected at the same time in all the approaches and must disregard those periods of time in which there are missing values. Once the number of conflicts is obtained, conflict rates could be calculated as:

$$CR = \frac{\text{Number of conflicts}}{\sqrt{(V1 * V2)}} \times 1000$$

Where: CR = Conflict Rate (Conflicts per Thousand Involved Vehicles) calculated from observed data.

V1, V2 = Traffic conflicting volumes according to maneuver and conflict type.

The conflict rate is the ratio between the number of conflicts and traffic conflicting volumes, which is used in the development of the prediction models. This rate is defined as the number of conflicts per thousand involved vehicles by maneuver type.

Modeling for Conflict Rate Prediction

The correlation coefficient is the standard measure of association between two variables. It is used to measure the strength of linear association between two variables. One example of

its use is the study of the relationship between the conflict rates as dependent variables and the conflicting volumes as independent variables. Reduction and validation procedure, using many methods such as stepwise, backward and forward reduces the number of independent variables that can be in the final model. After testing the normality, the distribution and the linearity of the data, linear regressions were found to be the best form of regression that can explain and draw inferences about the relationship of the conflict data. As a result of this study this model to predict conflict rate for direct left turn movement become as the final output:

$$CR_{(DLT)} = 50.44 - (0.021) MR1 + (0.009) MR2 + (0.507) DLT + (0.034) LTin + (3.85) LTops$$

Where:

$CR_{(DLT)}$ is the predicted conflict rate for direct left turn maneuver.

MR1 is the major road traffic volume in one direction.

MR2 is the major road traffic volume in the opposite direction.

DLT is the direct lefts turn volume,

LTin is the left turn in the driveway volume.

LTops is the left turn in the opposite driveway volume.

For model validation, PRESS statistic procedures were used, which is The Predicted Residual Sum of Squares. This is an out-of-sample validation statistic where you hold out just one point at a time.

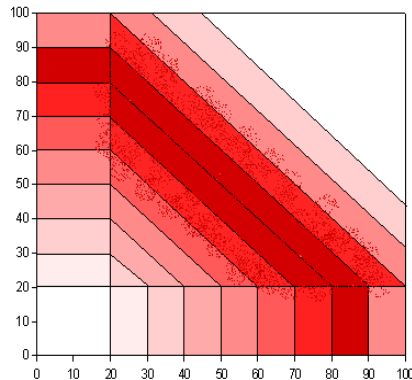
$$PRESS = \sum_{i=1}^n (y_i - \hat{y}_i)^2$$

Hold out the i^{th} point and find the regression equation using the remaining $n-1$ points, then predict the held out value to get $\hat{y}_i$. Compare to the value of y_i and do this for all points to obtain the PRESS statistic. Finally, calculate this statistic for the entire candidate model; the one with the smallest PRESS is considered the best, which were the two models above.

Full Opening Median Treatment

The major road volume and the volume of direct left turn in driveway from right mainly affect conflict rate. After finding suitable gap on the major road, vehicles making direct left turn need to give the right of way to vehicles making left turn in driveway from right. Usually, most of those gaps taken by vehicles making left turn in which means more time (delay) and another gap search. For that reason, more left turns in volume means less chance to make direct left turns and more chance for conflicts. Figure 3 shows a photograph for some drivers surfed searching for a gap then they ignored the right-of-way. Concentration on this point will lead to good results. This is the starting point of designing a guideline chart for median treatment. This chart as shown in figure 5.12, built according to the predicted conflict rates and conflicting volumes. Understanding that chart is very simple, when the major road volume is between 1500 and 3000, only the Direct left turn volume and left turn in driveway-volume is entered in the chart as x and y point. The chart designed in a way that the predicted conflict rate is founded for each (x, y) from low to high. According to those measurements, the location of high conflict rates is shown as dark areas on the figure and the location with low conflict rates is shown as light areas. It was very clear that the most conflicts accorded on the medial of the graph, where the direct left turn volume and the left turn in volume are close to each other and higher than 50 vehicles per hour.

D. Left turn v/h



Left turn in
v/h

FIGURE 3 Illustrations for the Concentrated Locations of the Predicted Conflict Rates.

As a conclusion of developing that idea, figure 4 is the final outcome. In that figure, three deferent major road volume ranges can be used to enter the chart as shown in table 1. The first range is when the major road volume is between 1500 and 2000 vehicle per hour. The second range is when the major road volume is between 2000 and 2500 vehicle per hour. The third range is when the major road is between 2500 and 3000 vehicle per hour. In the same table, the actions need to be taken for deferent kind of treatment is very clear where the limit of direct left turn volume and the limit of right turn plus u-turn volume is shown. Median treatment may take place after certain level of predicted conflict rates in this study it was about 90 conflicts per 1000 vehicles involved per hour for direct left turn and about 60 conflicts per 1000 vehicles involved per hour for right turn plus u-turn.

TABLE 1 Median Treatment Guideline Table at Unsignalized Intersections.

Major Road Volume Bi-direction, vph	Left Turn Into Driveway	Direct Left Turn Out From Driveway	Median Treatment	
			Directional	Close
1500-2000	> 90	> 70 ^{*1}	NO	YES
	> 90	< 20	YES (Ingress)	NO
	< 20	> 70	YES (Egress)	NO
2000-2500	> 80	> 60 ^{*2}	NO	YES
	> 80	< 20	YES (Ingress)	NO
	< 20	> 60	YES (Egress)	NO
2500-3000	> 70	> 50 ^{*3}	NO	YES
	> 70	< 20	YES (Ingress)	NO
	< 20	> 50	YES (Egress)	NO

^{*1} Plus the area above the line between the points (90, 20) and (20, 70) in the figure.

^{*2} Plus the area above the line between the points (80, 20) and (20, 60) in the figure.

^{*3} Plus the area above the line between the points (70, 20) and (20, 50) in the figure.

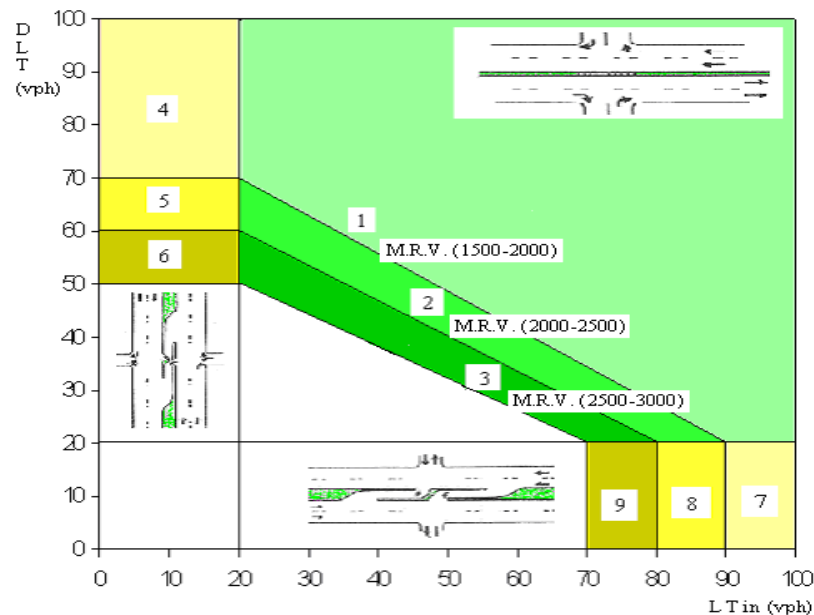


FIGURE 5.13 Guideline Chart for Full Median Opening Treatments at Unsignalized Intersections.

1. In figure 4 there are deferent areas for each kind of median treatment. Areas 1, 2, and 3 are the location of high and dangerous conflicts and the area where the conflict reduce due to limitation of aggressive movements. So if the direct left turn volume and the left turn in volume intersect at any point within those areas, then the median treatment is to close that median. Areas 4, 5 and 6 shows the areas where the most of the conflicts comes from direct left turn maneuvers where the left turn in volume is low. The medina treatment within those areas is to convert the full opining median to directional median allowing only direct left turns and prohibit the left turn in. Finally, areas 7, 8, and 9 shows the areas where the most of the conflicts comes from left turn in maneuvers where the direct left turn volume is low. The medina treatment within those areas is to convert the full opining median to directional median allowing only left turn in and prohibit the direct left turns.

Finally, transportation engineers and planers to take a right decision when they try to upgrade safety or solve a traffic problem in similar layout locations as in this study can use those charts. Using these charts needs attention to important factors such as location and geometric design for the upstream and the downstream medians and also the distance from the upstream and the downstream signals.

Conclusion

Conflict rate prediction will make conflict data more applicable and helpful to design a median treatment. In order to construct a guideline for full opining median treatment, both the direct left turn volume and the left turn in volume are needed. The location of the signals before and after the driveway is critical and that will affect the arrivals of the incoming vehicles on the major road both directions. For that reason more consideration of upstream and downstream distance and signal timing is recommended. Finally, the results of this study can be applied with caution to similar sites having both geometric and traffic characteristics.

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