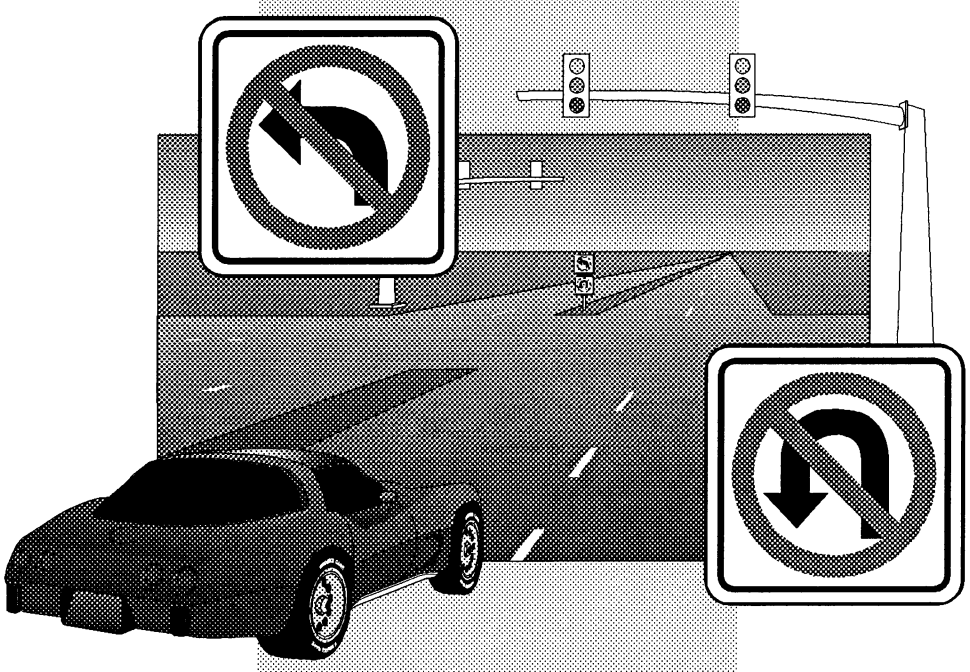
FINAL REPORT

GUIDELINES FOR THE USE OF NO U-TURN AND NO-LEFT TURN SIGNS



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Supplementary Notes

Abstract

The objective of this study was to establish a set of written guidelines identifying traffic and road conditions where No U-Turn and No Left Turn signs should be installed. The effect of these signs on traffic safety was also investigated.

A questionnaire was sent to all Virginia Department of Transportation District Traffic Engineers, selected city and county traffic engineers in Virginia, and selected state, city and county traffic engineers outside of Virginia, asking about their current procedures for installing No U-Turn and No Left Turn signs.

Eight signalized intersections where these signs had been installed were studied to determine the effect of the signs on left-turn and U-turn related accidents. The signs reduced left-turn and U-turn related accident rates an average of 63 percent for the restricted movement, and 66 percent for the intersection. The decrease in accident numbers paralleled the decrease in accident rates, a 59 percent reduction for the restricted movement and a 62 percent reduction for the intersection.

Based on the results from the questionnaire and a literature review, guidelines were established to aid traffic engineers in determining where to install these signs.

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ABSTRACT

The objective of this study was to establish a set of written guidelines identifying traffic and road conditions where No U-Turn and No Left Turn signs should be installed. The effect of these signs on traffic safety was also investigated.

A questionnaire was sent to all Virginia Department of Transportation District Traffic Engineers, selected city and county traffic engineers in Virginia, and selected state, city and county traffic engineers outside of Virginia, asking about their current procedures for installing No U-Turn and No Left Turn signs.

Eight signalized intersections where these signs had been installed were studied to determine the effect of the signs on left-turn and U-turn related accidents. The signs reduced left-turn and U-turn related accident rates an average of 63 percent for the restricted movement, and 66 percent for the intersection. The decrease in accident numbers paralleled the decrease in accident rates, a 59 percent reduction for the restricted movement and a 62 percent reduction for the intersection.

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INTRODUCTION AND PROBLEM STATEMENT

No U-Turn and No Left Turn signs reduce conflicts and accidents by limiting the number of movements motorists can make at an intersection or entrance. These signs also help improve access management techniques and the overall capacity of the intersection or roadway. For instance, on a heavily traveled four-lane highway, a substantial number of left turns at an intersection without an exclusive left-turn lane can adversely affect traffic flow and cause delays and accidents, especially for vehicles in the inside lane. Prohibiting left turns is one counter-measure to improve traffic flow and reduce delay and accidents.

Although the *Manual on Uniform Traffic Control Devices* (MUTCD) provides information on the symbol, size, and placement for these signs, it has no guidelines for identifying the traffic and road conditions under which installation is warranted.[1] Engineering judgment is currently the only basis for determining where these signs should be installed. The Virginia Department of Transportation (VDOT) currently uses these signs sparingly on a case-by-case basis, primarily to reduce accidents. Guidelines are needed to identify the traffic and road conditions appropriate for these signs.

Guidelines based on road geometrics and traffic conditions should enable engineers to use these signs effectively and uniformly. The guidelines should include precautions against relocating or creating traffic problems upstream or downstream of the newly signed intersection.

PURPOSE AND SCOPE

The primary purpose of this study was to develop guidelines identifying the road geometrics and traffic conditions where No U-Turn and No Left Turn signs should be installed. The effect these signs had on traffic safety was also investigated. Research was limited to three- and four-legged intersections and median crossovers. Corridors, or sections of roadway containing several intersections, were not considered.

METHODOLOGY

Literature Review

The literature on guidelines for prohibiting U-turns and left turns was reviewed. A computerized literature search was conducted and the Federal Highway Administration (FHWA) and the Institute of Transportation Engineers (ITE) were solicited for information on this subject.

To aid in determining where to install these signs, a correlation between the conditions that warrant the prohibition of left turns and those warranting the installation of exclusive left-turn bays was hypothesized. The reasoning was that at locations without an exclusive left-turn bay and where accidents and delays are high, one method to improve safety and reduce delay would be to install an exclusive left-turn bay, provided there is sufficient right-of-way (R/W). Locations with similar traffic conditions that lack R/W usually have the left turn restricted to improve safety and reduce delay. Literature from VDOT's Location and Design Division and the American Association of State Highway and Transportation Officials (AASHTO) on guidelines for exclusive left-turn bays was therefore reviewed.

Questionnaire Survey

A questionnaire ascertaining the practices and procedures currently used by traffic engineers for prohibiting U-turns and left turns was distributed to traffic engineers in VDOT, Virginia, and other states representing a wide range of traffic settings (Appendix A).

The survey was distributed to the nine District Traffic Engineers (DTEs) and the Traffic Engineering Division (TED) of VDOT; to 22 city and county traffic engineers in Virginia, chosen from large cities and counties experienced in using these signs; and to 70 state, city, and county traffic engineers in other states, arbitrarily chosen from the ITE Membership Directory.[2] The survey contained12 questions regarding the prohibition of U-turns and left turns, dealing with traffic conditions, roadway geometrics, accident history, and whether commercial developments are considered when installing these signs. Space was provided for Virginia respondents to suggest sites for study.

Site Selection and Data Collection

The study sites were individual intersections or median crossovers. Sites were chosen based on the availability of before-and-after accident data. Before-and-after turning movement volumes were considered to be supplementary information.

Data collection primarily consisted of gathering existing data to analyze the safety and operational aspects of the study sites. Three types of data were collected: 1) traffic characteristics, 2) intersection geometrics, and 3) accidents. Data for the study sites were obtained from VDOT district traffic engineering offices, TED, VDOT's Highway Traffic Records Information System

(HTRIS), and local traffic engineering offices. A field survey/inventory was conducted to supplement existing data by observing and documenting conditions at each site. A list of the types of data collected is shown in Table 1.

Data Analysis

The criteria used for data analysis are shown in Table 2. The before-and-after accident data were analyzed by developing collision diagrams for each site illustrating left-turn and U-turn related accidents. A spreadsheet was then developed using Quattro–Pro to determine the intersec-

Table 1
TYPES OF DATA COLLECTED

1. TRAFFIC DATA
   - ADT volumes
   - peak hour turning movement counts
2. INTERSECTION GEOMETRY DATA
   - intersection diagram
   - turn bay lengths
   - lane widths
   - timing and phasing plans (if applicable)
   - types of traffic control
3. ACCIDENT DATA (angle and rear-end accidents involving left or U-turning vehicles)
   - before and after accident data when available (before data corresponds to accidents occurring prior to installation of the prohibition sign)

Table 2
CRITERIA FOR DATA ANALYSIS

1. Road geometric features that affect U-turn and left-turn movements.
2. Number and percentage changes in accidents reduced by implementing the turn prohibition signs.
3. Number and percentage changes in volume/capacity (V/C), level-of-service (LOS), and delay from implementing the prohibitions.

tion's before-and-after accident rates, the average number of accidents per year, and the reductions, if any, in accident numbers and rates. Accident rates for each site were calculated using Equation 1, and the average number of accidents per year for each site was calculated using Equation 2. From these values, the *t-Test* was used to determine whether or not installation of the turn prohibition sign resulted in a statistically significant reduction in left-turn and U-turn related accident.

The *Highway Capacity Software* was used to calculate the Volume to Capacity ratio (V/C), level-of-service (LOS), and average delay for sites using before-and-after turning movement counts (TMCs) as input.

$$\text{Accidents per Million Vehicles Entering} = \frac{(\text{Number of Accidents} \times 1,000,000)}{(\text{ADT} \times \text{Number of Days within Study Period})} \quad 1$$

$$\text{Average Annual Number of Accidents} = \frac{(\text{Number of Accidents} \times 365)}{\text{Number of Days within Study Period}} \quad (2)$$

RESULTS AND DISCUSSION

Literature Review

A computerized literature search did not produce any relevant significant publications on the subject. Several organizations, including AASHTO, FHWA, ITE, and VDOT, were solicited for information. A summary follows.

The *Traffic Control Devices Handbook* published by FHWA said, "uniformity in the use of traffic control devices is a nationwide objective and is becoming increasingly important with increasing demand on existing roadways."[3] It stated that No U-Turn and No Left Turn signs are sometimes installed because of public or political pressure. Installing unnecessary signs may tempt motorists to ignore signs at locations where they are needed. Uniform guidelines will help reduce motorist confusion, apathy, and disrespect for these signs, especially on unfamiliar routes.

Guidelines for Signalized Left-Turn Treatments, also published by FHWA, advised traffic engineers to consider other consequences of installing these signs, such as the new route drivers will take to get to their destination and the resulting impact on traffic flow and the environment. The prohibition of a left turn or a U-turn usually only relocates the problem upstream or downstream of the intersection. In some cases, the relocated problem proves to be more troublesome than at the original site.[4]

Whan a left turn problem exists at an intersection it may be corrected in two ways. The movement that is causing the problem can be prohibited, which forces motorists who would normally execute this maneuver to find an alternative route. Conversely, the opposing left-turn movement could be prohibited, if the visibility of on-coming traffic is the cause of the problem. The prohibition of left turns has both advantages and disadvantages. The potential advantages include:

- Prohibiting left turns for selected time periods (Peak Hour)
- Reducing left-turn-related congestion
- Reducing the number of left-turn-related accidents.[4]

The potential disadvantages include:

- Relocating the problem upstream or downstream of the installation
- Rerouting traffic onto residential streets
- Increased travel distances, travel times, gasoline consumption, and emissions.[4]

The *Traffic Control Devices Handbook* also suggested other factors for consideration when prohibiting left-turns:

- Volume and classification (type) of vehicle diverted
- Adequacy of alternate route
- Transit routes
- Additional travel time and distance
- Enforcement needs (particularly during the initial week or two)
- Whether the problem will simply move somewhere else.[5]

The handbook also stated that traffic engineers need to determine whether the turn prohibition is required for the entire day or only part of the day. A study could show when a congestion or accident problem exists and when a suitable alternate route is available, providing the time frame within which to prohibit the maneuver.[6]

A paper published in 1967 by the Highway Research Board (HRB) corroborated the effectiveness of No Left Turn signs in reducing the number of left-turn related accidents while increasing the overall capacity at intersections. The paper investigated four locations in California where No Left Turn signs were installed. The results indicated that these signs reduced the number of left-turn-related accidents by 47 to 63 percent, while increasing the capacity of the intersections by a minimum of 10 percent.[7]

In February 1981, the ITE Technical Committee 4N-M published its findings.[8] This committee mailed questionnaires to all fifty states and to counties and cities with urban areas having a population over 50,000. Their survey had a response rate of 67 percent. When asked what criteria or warrants were used to determine where left turns should be restricted, only 10 percent of the responding jurisdictions said that they used warrants for determining when to prohibit left turns. When asked to rank the most important factors for considering the prohibition of a left turn, the top five responses were accidents, left-turn volumes, vehicle delay, opposing volumes, and alternate turning locations, in that order.

The City of Hartford, Connecticut, considered prohibiting a left turn when an accident analysis revealed five or more left-turn accidents at a site within one year. St. Louis, Missouri, used the criteria of three or more left-turning accidents at a site within one year. Victoria, British Columbia, examined an accident trend over a three-year period. When rear-end and head-on collisions accounted for 60 percent of the total reported accidents at that site, the left turn was prohibited.

Wichita, Kansas, considered a left-turn prohibition on roadways when the through traffic speed was greater than 45 mph, left-turn volumes exceeded 50 vehicles per hour (vph), and there

was no channelized left-turn bay. The City of Wichita stated, "an alternate left turn location must be provided either prior to or after the intersection where the turn is prohibited."[8]

Even though the jurisdictions responding to the ITE survey listed vehicle delay and opposing volumes as two of the most important factors in the prohibition of left turns, none of them provided any quantifiable data. The majority of the jurisdictions relied mostly on engineering judgment.

A number of respondents to the ITE survey said they prohibited left turns only when an alternate turning location was available. The City of Phoenix, Arizona, for example, prohibited left turns at signalized intersections along a six-mile corridor. The left-turn movement was permitted at mid-blocks and at unsignalized local streets. Phoenix's goal was to increase the capacity of the signalized intersections.[8]

The ITE survey also found that many jurisdictions restrict left-turn movements at intersections with no exclusive left-turn lane.[8] In the past, signalized intersections were designed with no provision for left-turn lanes. These intersections are now experiencing increased levels of delay caused by left-turning vehicles, and elevated left-turn accident rates caused by restricted visibility from the opposing left-turn traffic stream.[4] According to a study conducted by Ohio State University in 1983, when signalized or unsignalized intersections had exclusive left-turn lanes, the left-turn accident rate was significantly lower than at intersections without exclusive left-turn lanes.[9] That study recommended a set of warrants to be considered when deliberating an exclusive left-turn lane.[9,10] These warrants may be relevant to restricting left turns, since one way to reduce left-turn accidents and delay at intersections with no exclusive left-turn lane is to restrict the left-turn movement. The warrants were:

> *Accident Experience*: Install a separate left-turn lane if a critical number of left-turn-related accidents occurred. Four left-turn accidents at an unsignalized intersection and five at a signalized intersection in one year for one approach are considered critical.
>
> *Volume*: Install a separate left-turn lane when volumes meet the criteria given in the critical-volume warrant graph for signalized intersections (Figure 1). It is recommended that the curve representing a critical delay of 20 seconds be used for unsignalized intersections (Figure 2).
>
> *Traffic Conflicts*: Consider adding a separate left-turn lane when a conflict study shows an hourly average of 30 or more total left-turn related conflicts or 6 or more opposing left-turn conflicts in a 3-hour study period during the peak-volume conditions. Also, consider adding a lane if 45 or more total left-turn related conflicts or 9 or more opposing left-turn related conflicts occur in any 1-hour period.

Figure 1 is a critical-volume warrant graph based on delay to determine the need for an exclusive left-turn bay. For example, if a signalized four-lane roadway intersection has a total main-street volume of 1,400 vph and a 90 second cycle length with a 60/40 cycle split, 30 percent left turns would be the point at which delay becomes excessive, therefore requiring a left-turn lane. Figure 2

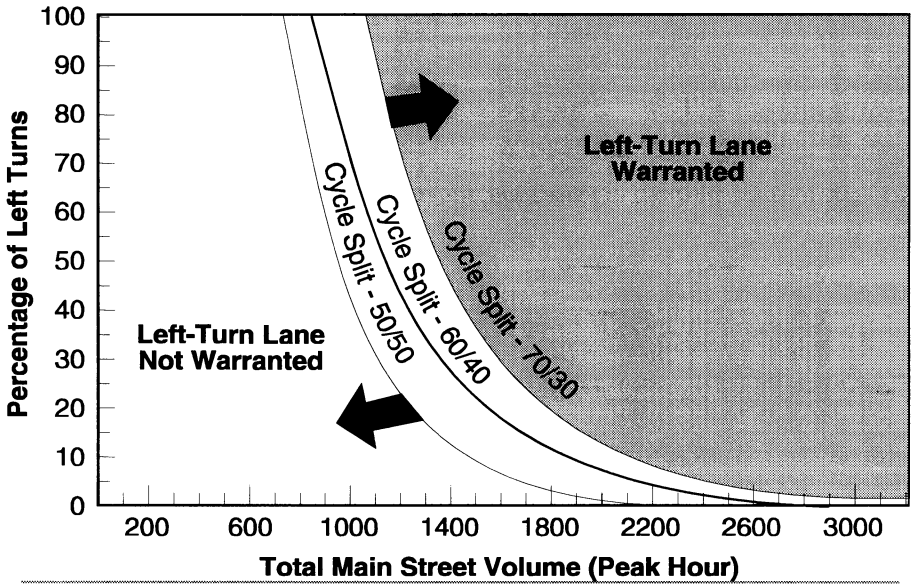


Figure 1. Critical-Volume Warrant Graph[10] (90 second cycle, four-lane highway).

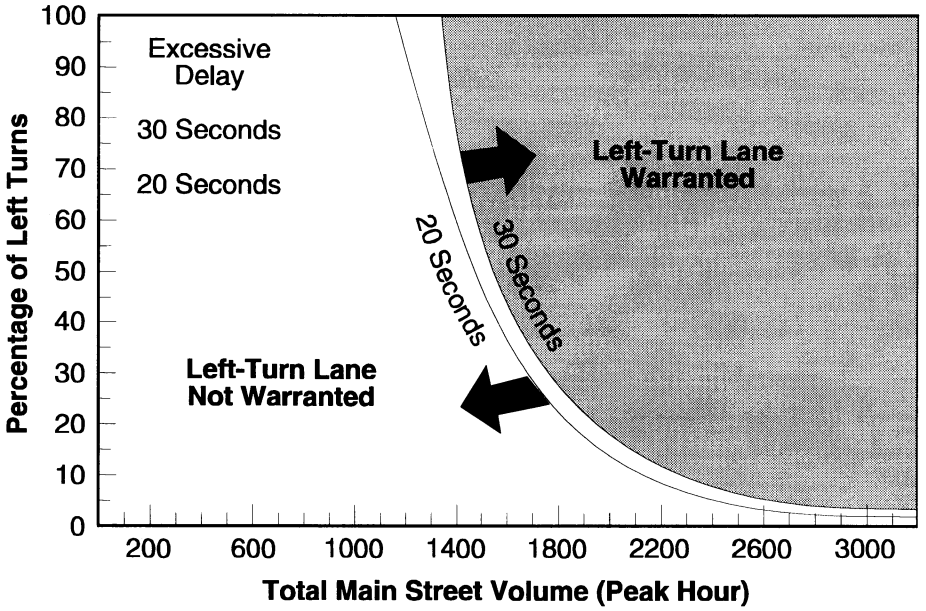


Figure 2. Critical-Volume Warrant Graph[10] (Four-lane highway, unsignalized).

is similar to Figure 1, also being based on excessive delays. In this example, an unsignalized four-lane roadway that has a total main-street volume of 1,700 vph would require a left-turn lane when the left-turn percentage reached 30.

VDOT currently uses AASHTO guidelines to determine the need for left-turn lanes on two-lane highways. Table 3 summarizes these guidelines. The table compares the opposing volume to the percentage of the advancing volume making a left turn at given operating speeds, to provide the critical advancing volume that would warrant a left-turn lane based on the traffic volumes.

Table 3
GUIDE FOR LEFT-TURN LANES ON TWO LANE HIGHWAYS[11,12]

Opposing Volume	Advancing Volume (Left Turns)			
	5%	10%	20%	30%
	40-mph Operating Speed			
800	330	240	180	160
600	410	305	225	200
400	510	380	275	245
200	640	470	350	305
100	720	515	390	340
	50-mph Operating Speed			
800	280	210	165	135
600	350	260	195	170
400	430	320	240	210
200	550	400	300	270
100	615	445	335	295
	60-mph Operating Speed			
800	230	170	125	115
600	290	210	160	140
400	365	270	200	175
200	450	330	250	215
100	505	370	275	240

Minimum designs for U-turns based upon the type of maneuver (for instance, inner lane to inner lane) are provided in the AASHTO "Green Book". These design standards are valid for a range of design vehicles. Figure 3 (see below) depicts these standards.

There is little information regarding the prohibition of left turns, and even less about prohibiting U-turns. However, based on the perception that a U-turn is a series of left turns, one could assume that the information related to prohibiting left turns is also valid for U-turns. The prohibition of a left turn would also mean the prohibition of a U-turn

Questionnaire Survey Results

Since the literature on this topic was minimal, a questionnaire was developed to ascertain the current procedures used by traffic engineers for prohibiting U-turns and left turns. Three sets of surveys were distributed. The VDOT survey had a response rate of 9 out of 10. The Virginia City/County survey had a response rate of 10 out of 22. The "out-of-state" survey had a response

rate of 21 percent (15 out of 70). The survey response was 33 percent (34 out of 102). Responses are summarized below. Appendix A summarizes each of the three sets of surveys separately.

The first question asked about present policies or practices for determining the conditions for using No U-Turn and No Left Turn signs. Eighty-six percent of the respondents did not have a written policy, and installed these signs case-by-case using "engineering judgment." The remaining 16 percent had written policies. San Antonio, Texas, prohibited U-turns at all signalized intersections except where otherwise signed, in accordance with their City Charter. Two respondents from Virginia referred to section 46.2-845 of the Code of Virginia, entitled "Limitations on U-turns":

> The driver of a vehicle within cities, towns or business districts of counties shall not turn his vehicle so as to proceed in the opposite direction except at an intersection.
>
> No vehicle shall be turned so as to proceed in the opposite direction on any curve, or on the approach to or near the crest of a grade, where the vehicle cannot be seen by the driver of any other vehicle approaching from any direction within 500 feet. [14]

Cincinnati, Ohio cited section 506-87 of their city ordinance, entitled "Turns in the Business District":

> No person, within a business district, shall turn any vehicle so as to proceed in the opposite direction except where the left turn from the same direction is permitted and where a continuous centerdivider exists 100 feet or more in length.
>
> No vehicle shall be turned so as to proceed in the opposite direction upon any curve, or upon the approach to, or near the crest of a grade, where such vehicle cannot be seen by the driver of any other vehicle approaching from either direction 500 feet, or at any other location unless such movement can be made in safety without backing or otherwise interfering with traffic. [15]

The second survey question asked under what type of traffic conditions No Left Turn signs were used. Seventy-four percent of the respondents did not have any numeric thresholds, but considered the following factors:

- Capacity constraints and delay caused by left-turn movement
- Left-turn volumes
- Opposing volumes
- Left-turn related accidents
- Availability of alternate turn locations.
- Feasibility of alternate solutions.

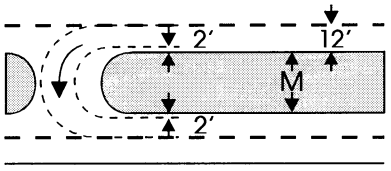
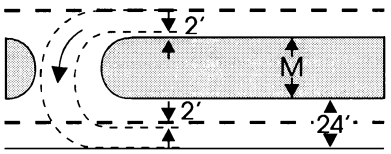
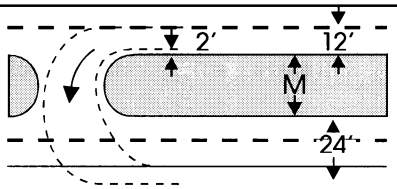
Type of Maneuver		M - Min. width of median - feet for design vehicle						
		P	WB-40	SU	BUS	WB-50	WB-60	TDT
		Length of design vehicle						
		19′	50′	30′	40′	55′	65′	118′
Inner Lane to Inner Lane		30	61	63	63	71	71	101
Inner Lane to Outer Lane		18	49	51	51	59	59	89
Inner Lane to Shoulder		8	39	41	41	49	49	79

Figure 3. Minimum designs for U-turns.[13]

The remaining 26 percent of the respondents did have established criteria, represented below.

Pennsylvania Department of Transportation

Penn-DOT evaluates each location on a case-by-case basis using the criteria in their Engineering and Traffic Studies guide. A straight-through or turning movement may be restricted if the restricted movement can be made at an alternate location, and if one or more of the following conditions exist:

- A 3-year accident review indicates that ten accidents have occurred which can be attributed to vehicles making or attempting to make the movement.
- A capacity analysis or field review of the intersection indicates that turning or crossing vehicles are causing unreasonable delays or accident potential for through vehicles.
- A field review of traffic flow through the intersection indicates significant conflict between vehicles making or attempting to make a particular movement and other vehicular or pedestrian movements.

- Turning or straight-through movements delay the platoon movement of vehicles through a progressive signal system.
- The geometric design or the available sight distance does not adequately provide for the movement or the movement frequently cannot be safely executed. [16]

City of Richmond

Richmond, Virginia, does not have specific numeric thresholds for prohibiting left-turns, but does use the following criteria as a "rule-of-thumb":

- Opposing volume: 1500+ vehicles per hour per lane.
- Left-turn volume: 150+ vehicles per hour (vph).
- Accident rate: 5 or more left-turn related accidents per 12 month period.
- Capacity: Loss of through lane utilization due to left-turners.

City of Hampton

Hampton, Virginia, considers a No Left Turn sign warranted when the following criteria are satisfied:

- Five or more accidents per year at an unsignalized intersection.
- Three or more accidents at a driveway just beyond a signalized intersection out to a distance of 300 feet.

VDOT Suffolk District

Left-turn movements are restricted at unsignalized intersections when an exclusive left-turn bay does not exist and when:

- Opposing volume: 700+ vph.
- Accident rate: two or more accidents per 12 month period.

In addition, this district installs No Left Turn signs when one-way conditions prohibit left-turns.

Cobb County

Cobb County, Georgia, uses these signs in residential traffic management to discourage cut-through traffic.

The third survey question addressed the traffic conditions under which No U-Turn signs were used. Thirty-five percent of the respondents did not have numeric thresholds for No U-Turn signs, but reviewed the intersection's capacity and accident history. Penn-DOT used the same guidelines for No U-Turn and No Left Turn signs. Sixty-five percent of the respondents restricted U-turn movements where the traffic signal phasing had a right turn overlap phase from a side street approach on the left during the protected left-turn phase on the mainline. This practice is consistent with the MUTCD, which states, "No movement that may involve an unexpected crossing of pathways of moving traffic should be indicated during any green or yellow interval."[1]

The fourth survey question asked under what geometric conditions No Left Turn signs were installed. Eighteen percent of the respondents installed these signs on a case-by-case basis only, while 74 percent installed these signs at intersections where a left-turn bay did not exist or when sight distance was limited. A number of these respondents defined *limited sight distance* as any sight distance not meeting the AASHTO criteria. Other geometric conditions included the ends of exit ramps and at entrance points to one-way streets.

The fifth question asked under what geometric conditions No U-Turn signs were installed. Twenty-six percent of the respondents installed No U-Turn signs on a case-by-case basis only. Forty-seven percent installed these signs at intersections with no exclusive left-turn lanes or when sight distance is limited. Another 26 percent installed No U-Turn signs on narrow median thoroughfares if the receiving pavement width was 24 feet or less, reasoning that an average automobile could not complete the turn in a single continuous maneuver, thereby increasing the potential for delays or accidents. The Minnesota DOT said that they use No U-Turn signs at all freeway median crossovers that are intended for use only by emergency vehicles.

The next question asked about the role of accident history in installing either of these signs, and whether any thresholds were used. Seventy-nine percent of the respondents said that accident history was integral to their agency's determination, but did not have any threshold values established. The other 21 percent used the following accident threshold values:

- 2+ accidents / 12-month period
- 5+ accidents / 12-month period
- 10 accidents / 36-month period

Seventy-one percent of the respondents who have accident thresholds used the 5+ accidents/12-month period criterion. The values above represent the number of accidents that can be attributed to vehicles making or attempting to make a left turn or U-turn.

The seventh question of the survey asked whether any turn accommodations were provided downstream of the intersection if it was signed to restrict left turns and/or U-turns. Thirty-eight percent responded that they did not provide any type of accommodations downstream, while 62 percent of the respondents did. Many of the organizations that provided these accommodations said that they would only restrict turns **if** the restricted movement could be made at an alternate location, usually within a one-block radius.

The next question asked whether the effect of the signs on commercial businesses was considered. This question was intended to determine whether potential economic impact was a key consideration in the installation of these signs. Forty-four percent responded that they did not consider impacts on commercial businesses. Considerations of safety and traffic flow were their primary concerns. Fifty-six percent did consider the potential impact on businesses, sometimes by providing downstream turn accommodations within a one-block area or restricting the left or U-turn movement only during the weekday peak period.

Results from questions nine and ten were combined to help the researchers determine approximately what percentage of signalized intersections in the respondents' jurisdictions were signed to prohibit U-turns and left-turns. Responses regarding the restriction of U-turns at signalized locations ranged from 0 percent to 99 percent. San Antonio, Texas prohibited U-turns at 99 percent of their signalized locations as a result of their City Charter. The prohibition of left turns at signalized intersections was lower, ranging from 0 percent to 29 percent.

The responses from questions eleven and twelve were combined to help the researchers determine approximately what percentage of unsignalized intersections in the respondents' jurisdictions were signed to prohibit U-turns and left turns. Responses regarding the restriction of U-turns at unsignalized locations ranged from 0 percent to 13 percent. VDOT's Salem District prohibited U-turns at 13 percent of their unsignalized locations to reduce cut-through traffic and increase safety at median crossovers. The responses for the prohibition of left-turns at unsignalized intersections ranged from 0 percent to 5 percent.

Data Analysis Results

A list of 41 candidate study sites was compiled from the in-state survey. Eight sites for which before-and-after accident data were available were chosen for study. The other 33 sites were rejected for one or more of the following reasons: 1) the date of sign installation was not known, 2) accident data was not available, 3) the intersection was geometrically reconfigured. Only three of the eight sites selected for study had before-and-after peak period TMCs. One of the three had both A.M. and P.M. peak period TMCs. The geometric characteristics and traffic conditions of the sites varied greatly. One site was a three-legged intersection, one was the entrance to a "7-Eleven" store from a two-lane roadway, two sites were entrances to shopping centers, and the other four were four-legged intersections. Table 4 displays the characteristics of each site. As a result of these varying characteristics and the smallness of the sample of study sites, the road geometric features and traffic conditions that affect U-turn and left-turn movements could not be identified.

The duration of the "before" and "after" study periods also differed from site to site. Because of these varying study periods, the data needed to be placed in uniform terms before it could be statistically tested. This was achieved by normalizing differences in the accident rates and the average number of accidents per year between the before and after periods for each site. The process used to normalize the data is contained in Appendix B of this report.[17] Once the data were normalized, the accident rates and numbers were tested using the one tail *t-Test* at a 95 percent confidence interval. (CI).

Table 4
SITE CHARACTERISTICS

Site	City/County	Type of Sign	Before Intersection Entering ADT	After Intersection Entering ADT	Duration of Before Study Period (days)	Duration of After Study Period (days)
Hermitage Rd. @ Westbrook Ave.	City of Richmond	No U-Turn	19,435	21,715	810	1,015
Route 250 @ Morningside Rd.	Henrico County	No U-Turn	42,000	41,000	487	608
Route 360 @ Glen Lea Shopping Cntr.	Henrico County	No U-Turn & No Left-Turn	29,245	34,000	1,215	1,340
Broad Street @ Westmore-land St.	City of Richmond	No Left-Turn	39,203	40,682	1,083	1,106
Midlothian Trnpike @ Roanoke St.	City of Richmond	No Left-Turn	24,258	30,201	465	1,031
Orange Ave. @ 10th Street, N.W.	City of Roanoke	No Left-Turn	26,168	26,440	516	183
Route 1 - 0.5 Miles South of Route 10	Chesterfield County	No Left-Turn	23,715	32,000	1,053	192
Route 360 @ Ent. to 360W Shopping Cntr.	Chesterfield County	No Left-Turn	38,650	41,000	488	791

Accident Analysis

Of the eight study sites, twenty-five percent had an approach controlled with a No U-Turn sign, while 63 percent had an approach controlled with a No Left Turn sign. Only one of the eight sites had an approach controlled with both signs. A collision diagram representing all of the left-turn and U-turn-related accidents that occurred during the study period was developed for each site. The type of sign installed and the movement the sign restricted were also placed on each of the collision diagrams. From these collision diagrams, it was possible to differentiate between the accidents that occurred prior to the sign being installed and those which occurred after the sign was installed.

For each site the left turn and U-turn-related accidents associated with the restricted movement were analyzed separately from the "total intersection" (restricted movement and its opposing left-turn movement). This was to determine whether or not the prohibition sign was significant in reducing accidents for that particular movement.

The total number of left-turn and U-turn related accidents, for the "total intersection," was then analyzed to determine whether or not the prohibition sign was significant in reducing accidents for the restricted movement as well as for the opposing movement.

The results of the restricted movement accident analysis revealed that the use of these signs reduced the restricted movement's accident rate on the average of 63 percent, from an average of 0.87 accidents per million vehicles entering the intersection to an average of 0.32 accidents per million vehicles entering the intersection (Table 5). Although the analysis revealed that these

Table 5
RESTRICTED MOVEMENT ACCIDENT RATE

Site	Sign	Before Accident Rate	After Accident Rate	Percent Change in Accident Rate
Hermitage Rd. @ Westbrook Ave.	No U-Turn	0.44	0.23	-48%
Route 250 @ Morningside Rd.	No U-Turn	0.78	0.32	-59%
Route 360 @ Glen Lea Shopping Cntr.	No U-Turn & No Left-Turn	0.96	0.22	-77%
Broad Street @ Westmoreland St.	No Left-Turn	0.68	0.18	-74%
Midlothian Trnpike @ Roanoke St.	No Left-Turn	0.98	0.32	-67%
Orange Ave. @ 10th Street, N.W.	No Left-Turn	0.52	0.21	-60%
Route 1 - 0.5 Miles South of Route 10	No Left-Turn	0.84	0.33	-61%
Route 360 @ Ent. to 360W Shopping Cntr.	No Left-Turn	1.75	0.71	-59%
AVERAGE		0.87	0.32	-63%

signs were not significant in reducing the accident rate at the 95 percent CI, they were significant at the 90 percent CI. As expected, the number of accidents for the restricted movement decreased from an average of 10.08 accidents per year to an average of 3.99 accidents per year. This corresponds to an average accident reduction of 59 percent for the restricted movement (Table 6). As with the accident rates, the use of these signs to reduce the average number of accidents for the restricted movement was not significant at the 95 percent CI, but were significant at the 90 percent CI. A reason why these tests failed the *t-Test* at the 95 percent CI could be due to the small sample size and the large variation in study periods.

Table 6
RESTRICTED MOVEMENT ACCIDENT NUMBER

Site	Sign	Before Accident Rate	After Accident Rate	Percent Change in Accident Rate
Hermitage Rd. @ Westbrook Ave.	No U-Turn	3.15	1.80	-43%
Route 250 @ Morningside Rd.	No U-Turn	11.99	4.80	-60%
Route 360 @ Glen Lea Shopping Cntr.	No U-Turn & No Left-Turn	10.21	2.72	-73%
Broad Street @ Westmoreland St.	No Left-Turn	9.77	2.64	-73%
Midlothian Trnpike @ Roanoke St.	No Left-Turn	8.63	3.54	-59%
Orange Ave. @ 10th Street, N.W.	No Left-Turn	4.95	1.99	-60%
Route 1 - 0.5 Miles South of Route 10	No Left-Turn	7.28	3.80	-48%
Route 360 @ Ent. to 360W Shopping Cntr.	No Left-Turn	24.68	10.61	-57%
AVERAGE		10.08	3.99	-59%

The results of the "total intersection" accident analysis paralleled the restricted movement accident analysis. The use of these signs reduced the total intersection's accident rate on the average of 66 percent, from an average of 1.05 accidents per million vehicles entering the intersection to an average of 0.36 accidents per million vehicles entering the intersection (Table 7). In this accident analysis, these signs were determined to be significant in reducing the intersection's accident rate when tested at the 95 percent CI. The number of accidents for the total intersection also decreased, from an average of 12.07 accidents per year to an average of 4.41 accidents per year. This corresponds to an average accident reduction of 62 percent for the intersection (Table 8). The use of these signs to reduce the average number of accidents for the intersection was not significant at the 95 percent CI, but was significant at the 90 percent CI. The researchers suspect that the accident rate passed the 95 percent test and the number of accidents failed the 95 percent test is attributable to the fact that the normalized accident rates had smaller standard deviations than the normalized accident numbers. This was caused by the small sample size and the large variations in study periods.

Table 7
TOTAL INTERSECTION ACCIDENT RATE

Site	Sign	Before Accident Rate	After Accident Rate	Percent Change in Accident Rate
Hermitage Rd. @ Westbrook Ave.	No U-Turn	0.83	0.41	-51%
Route 250 @ Morningside Rd.	No U-Turn	0.83	0.32	-61%
Route 360 @ Glen Lea Shopping Cntr.	No U-Turn & No Left-Turn	1.01	0.29	-71%
Broad Street @ Westmoreland St.	No Left-Turn	1.11	0.22	-80%
Midlothian Trnpike @ Roanoke St.	No Left-Turn	0.98	0.32	-67%
Orange Ave. @ 10th Street, N.W.	No Left-Turn	0.96	0.21	-78%
Route 1 - 0.5 Miles South of Route 10	No Left-Turn	0.84	0.33	-61%
Route 360 @ Ent. to 360W Shopping Cntr.	No Left-Turn	1.86	0.74	-60%
AVERAGE		1.05	0.36	-66%

Capacity Analysis

Only three of the study sites had adequate before and after TMCs, phasing diagrams, and geometric information to conduct a before and after capacity analysis. One of these three sites had both the A.M. and P.M. peak data. The *Highway Capacity Software* was used to calculate the V/C and average delay for each site. All of the sites that had their capacity analyzed were signal controlled and had a left-turn approach restricted. Table 9 summarizes the results of the capacity analysis, which indicate that the capacity of the intersections, calculated by the volume to capacity ratio (V/C), decreased in the range of 9 percent to 53 percent, and on an average of 29 percent. This means that after the left-turn restriction was implemented, the intersection's calculated V/C decreased, thereby increasing the reserve capacity of the intersection. The results for one site indicated that the average intersection delay, in seconds/vehicle, was increased by 43 percent.

The results of the capacity analysis should be used with extreme caution due to the exceptionally small sample size. The calculated increase in reserve capacity is not very realistic, since the current capacity methods become unreliable for V/C > 1.20 and half of the study sites had abefore V/C greater than 1.20. It should also be noted, however, that when a left-turn movement is restricted or removed from the traffic stream, the number of potential vehicle conflicts is reduced, thereby increasing the intersection's capacity, provided all other variables remained constant. The increase in the reserve capacity value may be used as a general indication of what will happen to an intersection's capacity after a No Left Turn sign is installed. The increase in vehicle delay value is also limited since only one site had the before delay calculated. By restricting the left-turn movement, the average intersection delay should have decreased since the left-turn volume now became part of the through volume. The increase in intersection delay for this site can be attributed to the municipality which has control of the signal, changing the signal phasing after the pro-

hibition sign was installed in an attempt to provide additional green time to the opposing left-turn movement.

Table 8
TOTAL INTERSECTION ACCIDENT NUMBER

Site	Sign	Before Accident Rate	After Accident Rate	Percent Change in Accident Rate
Hermitage Rd. @ Westbrook Ave.	No U-Turn	5.86	3.24	-45%
Route 250 @ Morningside Rd.	No U-Turn	12.74	4.80	-62%
Route 360 @ Glen Lea Shopping Cntr.	No U-Turn & No Left-Turn	10.81	3.54	-67%
Broad Street @ Westmoreland St.	No Left-Turn	15.84	3.30	-79%
Midlothian Trnpike @ Roanoke St.	No Left-Turn	8.63	3.54	-59%
Orange Ave. @ 10th Street, N.W.	No Left-Turn	9.20	1.99	-78%
Route 1 - 0.5 Miles South of Route 10	No Left-Turn	7.28	3.80	-48%
Route 360 @ Ent. to 360W Shopping Cntr.	No Left-Turn	26.18	11.07	-58%
AVERAGE		12.07	4.41	-62%

Table 9
CAPACITY ANALYSIS RESULTS

Site	Before Delay (sec/veh)	After Delay (sec/veh)	Before V/C	After V/C	Change in Delay	Change in V/C
Broad St @ Westmoreland	*	23.9	1.324	0.858	*	-35%
Midlothian @ Roanoke	*	37.5	1.928	0.901	*	-53%
Orange @ 10th St. (AM)	11	15.6	0.601	0.486	42%	-19%
Orange @ 10th St. (PM)	12	17.4	0.675	0.615	45%	-9%
AVERAGE INCREASE					43%	-29%

*Unable to be calculated

Development of Guidelines

The guidelines in the Recommendations section of this report were based on the literature review and the questionnaire survey. Due to insufficient data, no recommendations could be developed from the accident and capacity analyses. The reasoning behind each element of the recommended guidelines was as follows:

1. Some respondents to the questionnaire survey installed No U-Turn signs at locations that have a right-turn overlap phase from a side street approach on the left during the protected left-turn phase on the mainline. This is consistent with MUTCD's statement, "No movement that may involve an unexpected crossing of pathways of moving traffic should be indicated during any green or yellow interval."[1]

2. The Code of Virginia has a section that places limitations on U-turns. This recommendation is simply a restatement of that portion of the Code. Since the Code refers to sight distance, the minimum sight distance criteria of AASHTO were also included. AASHTO's minimum sight distance criteria were reflected in the responses to the questionnaire, and adopting them would be conductive to uniformity.

3. AASHTO's minimum design standards for U-turns would also be a good basis for the uniform installation of No U-Turn signs. Sites not meeting the design standards should have the maneuver restricted.

4. On the questionnaire, engineers indicated that they regularly restricted U-turns at intersections with a receiving pavement of 24 feet or less because the turn cannot be completed in a single continuous maneuver by an average automobile.

5. The literature and questionnaire revealed that left-turn bays alleviate left-turn accident or delay problems. If the R/W is not available, the least costly solution would be to restrict the left turn. There needs to be an alternate turn location within a one block radius of the turn restriction to avoid driver disregard for the sign.

6. Based on the literature and the questionnaire, an accident review is integral to determining whether or not to implement a turn prohibition. To avoid driver apathy toward unwarranted traffic control devices, ITE's Toolbox for Alleviating Congestion and some respondents to the questionnaire state that they conduct an accident analysis to determine if the restriction is required only at certain times or for certain days.

7. The majority of the respondents to the questionnaire use an accident history threshold of five or more left-turn or U-turn-related accidents per year, consistent with the MUTCD requirement.

CONCLUSIONS

1. There is a lack of uniformity between states, cities and counties in and outside of Virginia, and even within VDOT for determining when to prohibit U- turns and left-turns.

2. The majority of traffic engineers surveyed install these signs on a case-by-case basis using "engineering judgment" and not numeric thresholds.

3. The majority of traffic engineers surveyed restrict left-turn and/or U-turn movements based on three criteria: 1) an intersection's accident history; 2) the availability of an alternate turn location and; 3) whether or not the approach has an exclusive left-turn bay.

4. Since a U-turn is defined as a series of left-turns, the restriction of a left-turn also means that the U-turn movement is restricted.

5. The use of No U-Turn and No Left Turn signs is more prevalent at signalized intersections than at unsignalized intersections.

6. At the limited number of study sites, No U-Turn and No Left Turn signs were effective in reducing U-turn and left-turn-related accidents, thereby increasing the safety of the intersection. This finding was consistent with previous studies.

RECOMMENDATIONS

VDOT traffic engineers should use the following guidelines to ensure that No U- Turn and No Left Turn signs are installed uniformly throughout the Commonwealth:

- No U-Turn signs should be installed at all signalized intersections that have a right-turn overlap phase from a side street approach on the left during the protected left-turn phase on the mainline.

- U-turns should be prohibited at any curve or on the approach to or near the crest of a grade where the vehicle cannot be seen by the driver of any other vehicle approaching from any direction within 500 ft. In addition, any left turn or U-turn at an intersection that does not meet the minimum sight distance criteria established by AASHTO should be restricted.

- Sites that do not meet the minimum design standards for U-turns as established by AASHTO (Figure 3) should have the U-turn movement restricted.

- U-turn movements at intersections with a receiving pavement width of 24 feet or less and where the average vehicle cannot execute this maneuver in a single continuous movement should be restricted.

- At locations without an exclusive left-turn bay, it should first be determined whether or not a left-turn lane is required. If one is required but the right-of-way (R/W) is inadequate to install a left-turn bay, then the left-turn movement should be restricted, only if the maneuver can be made safely at an alternate location within a one block radius of the proposed turn restriction.

- When considering a left-turn or U-turn restriction, the location's accident history should be reviewed to determine whether the restriction should be implemented for certain times or certain days only.

- As an interim measure, an accident history threshold of 5 or more left- turn or U-turn related accidents per 12 month period should be used. Future accident threshold criteria should be developed by using the expected value analysis to determine whether or not a location is experiencing higher accident levels than other locations with similar geometric and traffic characteristics.

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APPENDIX A

SUMMARY

QUESTION 1

What is the present policy and/or practice of your agency on determining when and where to use No U-Turn and No Left-Turn signs?

VDOT RESPONSES

No written policy exists. Engineering judgement is used. (We use them where roadway geometrics prohibit safe left-turn and U-Turn maneuvers. e.g. An intersection with high speed approaches and no left-turn lane which also has a high accident rate or an intersection where the receiving approach is not wide enough to make a U-Turn. {Suffolk})

MUTCD & Va. Code 46.2-845

IN-STATE RESPONSES

No firm written policy or standard exists. Some reasons for prohibiting turns include: a) lack of a channelized left-turn lane, b) heavy opposing traffic to left-turn or U-turn maneuver, c) anti- vehicle cruising regulations (No U-Turn 9pm to 5am), d) high accident locations. {City of Richmond}

No written documentation. Restrictions imposed if accident problems (or potential for) or vehicle maneuvering problems are caused by these maneuvers. U-Turn restrictions are imposed where double left-turn lanes are provided.

{County of Henrico}

MUTCD 2b-15 Turn Prohibition Signs (R3-1 to 3) are used as guidelines. Also, Accident data for left-turn movements/conflicts considered in determining need for "No U-Turn" sign.

{City of Newport News}

Signs of this nature are installed based on engineering judgement and on a case-by-case basis. (No written policy)

OUT-OF-STATE RESPONSES

There is no specific written policy or practice. We address conditions on a "case by case" basis and determine through engineering judgement, when and where No U-Turn and/or No Left-Turn signs are to be installed. {This is generally the case for No Left- Turn signs.}

Guidance is provided by the Manual on Uniform traffic Control Devices (MUTCD). No specific policy is documented other than the MUTCD.

QUESTION 1 (CONTINUED)

U-Turns are prohibited at all signalized intersections by city charter (except where otherwise signed).

Documented safety or operational problem.

PENN-DOT {Engineering and Traffic Studies}

(67 PA Code, Chapter 201)

U-Turns are prohibited in the CBD by general ordinance.

"No person, within a business district, shall turn any vehicle so as to proceed in the opposite direction except where the left turn from the same direction is permitted and where a continuous center divider exists 100 feet or more in length.

No vehicle shall be turned so as to proceed in the opposite direction upon any curve, or upon the approach to, or near the crest of a grade, where such vehicle cannot be seen by the driver of any other vehicle approaching from either direction within 500 feet, or at any location unless such movement can be made in safety and without backing or otherwise interfering with traffic." {506-87, Cincinnati, Ohio}

"The traffic engineer may determine the locations at which drivers of vehicles shall not make a right, left, or U-turn and shall place proper signs at such locations. Right, left, and U-turns may be prohibited between certain hours of the day and permitted at other times. At such locations, the different times shall be plainly shown on the signs or the signs may be removed when turn are permitted." Sec. T2.46 Jackson, Michigan.

QUESTION 2

Under what type of traffic conditions do you use No-Left Turn signs? (example of traffic conditions might be opposing volumes, left turn volumes, opposing speed, accident rate, etc...) Please explain.

VDOT RESPONSES

1) Amount of congestion and delay caused by turning movements
2) Left-turn volumes and/or accidents
3) Availability of alternate locations if turns are restricted
4) Feasibility of alternate solutions

*Note: NOVA mentioned accident rate exceeding the expected rate.

QUESTION 2 (CONTINUED)

1) Unsignalized intersection, no left-turn lane:

- Opposing volume = 700+ (vph)
- Accident rate approximately 2+/year

2) Where one-way conditions prohibit left-turns.

{Suffolk District}

IN-STATE RESPONSES

All the items listed above, as well as capacity constraints, are evaluated in determining the need for a "No Left-Turn" sign.

No thresholds at this time. Locations evaluated on a case-by-case basis. (Usually due to high accident rate). {Opposing traffic volumes vs number of left-turns (Chesapeake)}

No specific values for left-turn prohibitions are utilized. Some general guidelines are as follows:

- *Opposing volumes:* 1500+ vehicles per hour per lane.
- *Left-turn volumes:* 150+ vehicles.
- *Opposing speed:* Not utilized, all our streets are 45 mph or less.
- *Accident Rate:* No specific thresholds values are employed. However, if a specific left turn movement had 5 or more accidents in 12 months, I would consider prohibiting or adopting other measures.
- Loss of thru lane utilization due to the number of left-turners.{City of Richmond}

City warrant for "No Left-Turn" sign are as follows:

1. Five (5) accidents per year at non-signalized intersections.
2. Three (3) accidents at driveways just beyond a signalized intersection out to a distance of 300 feet.

{City of Hampton}

OUT-OF-STATE RESPONSES

No set guidelines or thresholds; however, No Left-Turn signs are used as a tool to treat accident or capacity problems.

No specific volume or accident level.

QUESTION 2 (CONTINUED)

Usual reasons for installing are:

- Reverse lanes (where we convert TWLTL to peak direction flow)
- More attractive turning location exists nearby
- Accident problem addressable no other way*

{City of Phoenix} *{City of Raleigh, N.C.}

Few, if any, left turn restrictions have been based on actual accidents. In the planning phase of new development or redevelopment where a left turn safety problem is anticipated, we prefer and recommend geometrics to restrict movements rather than signs. We try to accommodate left turns wherever possible with left turn lanes. {City of Overland Park, Kansas}

Opposing volumes on four-lane streets.

{City of Jackson, Michigan}

A straight through or turning movement may be restricted if the restricted movement can be made at an alternate location, and one or more of the following conditions exist:

1. A 3-year accident review indicates that TEN accidents have occurred which can be attributed to vehicles making or attempting to make that maneuver.

2. Where a capacity analysis or field review of the intersection indicates that turning or crossing vehicles are causing delays or accident potential for through vehicles.

3. Where a field review of traffic flow through the intersection indicates that a significant conflict exists between vehicles making or attempting to make a particular movement and other vehicular or pedestrian movements.

4. Where turning or straight through movements delay the platoon movement of vehicles through a progressive signal system.
   PENN-DOT {Engineering and Traffic Studies}
   (67 PA Code, Chapter 201) (2)

Neighborhood traffic management plan for discouraging cut-through traffic.
{Cobb County, Georgia}

QUESTION 3

Under what type of traffic conditions do you use No U-Turn signs? Please explain.

QUESTION 3 (CONTINUED)

VDOT RESPONSES

Where conflicts and accidents occur due to the U-turning movement. Traffic signal phasing (right turn overlap phase)

IN-STATE RESPONSES

Opposing traffic volumes, high accident rates, truck traffic, signalized intersections with conflicting movements.

We consider U-Turns to be one of the more hazardous maneuvers which can be made due to speed in which they must be made and the fact that most roads are not designed to accommodate them. {County of Henrico}

We use No U-Turn signs at the following:

1. Protected signalized left-turn phases where geometrics do not allow a single continuous U-turn movement.

2. Where a U-turn will conflict with a right turn overlap phase.

{City of Hampton}

OUT-OF-STATE RESPONSES

No set guidelines; however, No U-Turn signs are used where an accident problem or capacity problem exists.

Documented accident history.

"Most No U-Turn signs are in response to nuisance complaints (e.g. High school students u-turning in a subdivision to get to school easier by avoiding brief backups in a left-turn lane into the school) and NOT documented accidents."

{City of Overland Park, Kansas}

Conflicting movements. For example the side street right has a green arrow and the major street has a green left turn arrow. (MUTCD provides guidelines for this.)
PENN-DOT {Engineering and Traffic Studies}
(67 PA Code, Chapter 201)

QUESTION 4

Under what type of roadway geometric conditions do you routinely install No Left- Turn signs? Please be specific. (i.e. Absence of a left-turn bay, sight distance constraints, number of opposing lanes of traffic, etc...)

VDOT RESPONSES

Absence of left-turn bays, limited sight distance, and high volume of opposing traffic.

End of exit ramps.

IN-STATE RESPONSES

All of these items are considered using the guidelines of MUTCD.

{City of Newport News}

One-way roads or drives, absence of left-turn bays, and limited sight distance.

Lack of left-turn storage bay.

End of exit ramps.

Lack of channelized left-turn lanes, sight distance restrictions, vertical curve or horizontal curve.
{City of Richmond}

1. One-way roads or drives
2. Absence of a left-turn bay.

{Henrico County}

OUT-OF-STATE RESPONSES

Turn restrictions are unusual and therefore not routinely installed. (Case-by-case basis)

"No Left-Turn" signs are optional to reinforce the standard signing at one-way ramps (freeway entrance) and one-way streets.
{Minnesota}

Almost always installed opposing a lagging left turn phase.
{Cincinnati, Ohio}

QUESTION 4 (CONTINUED)

Left turns are prohibited during hours of reversible lane operations, absence of a left turn bay, if sight distance does not meet AASHTO criteria.

Under sight distance constraints and number of opposing lanes without signal control or on entrances to one-way heavy volume streets. {City of Jackson, Michigan}

Any turn or straight through movement may be restricted if the geometric design or the available sight distance does not adequately provide for the movement or the movement frequently cannot be safely executed.
PENN-DOT {Engineering and Traffic Studies}
(67 PA Code, Chapter 201)

QUESTION 5

Under what type of roadway geometric conditions do you routinely install No U- Turn signs? Please be specific.

VDOT RESPONSES

End of exit ramps.

At "T" intersections when we reconstruct a four (4) lane roadway to accommodate a 16 foot median with curb and gutter, "No U-Turn" signs are considered. This is due to the fact that an average vehicle will not be able to complete the turn in a single maneuver.
{NOVA}

Sight distance constraints.

No left-turn bay and/or where the receiving pavement is less than 24 feet wide which may prohibit vehicles from making the U-Turn in one continuous maneuver.
{Suffolk}

IN-STATE RESPONSES

Limited width of roadway, no channelized turn lane, U-turn conflict with minor street signal phasing, limited sight distance.
{City of Richmond}

Narrow width of roadway.

Signalized intersections; crossovers near interchange areas.

QUESTION 5 (CONTINUED)

Dual left-turn lanes and insufficient roadway widths for the vehicle to complete the turn in one continuous maneuver.

Median cuts where truck do not have sufficient room to complete the turn in one continuous maneuver.

Absence of left-turn bay, where double left-turn lanes exist, and where the U-turn conflicts with a right turn overlap.
{County of Henrico}

OUT-OF-STATE RESPONSES

U-Turn restrictions are unusual and therefore not routinely installed. (Case-by-case basis)

On wider median thoroughfares we are apt to permit U-turns whereas on narrow median thoroughfares where U-turns cannot be easily made in a continuous movement (for average size vehicle), signs may be posted if U-turns are observed. {City of Overland Park, Kansas}

If the roadway is too narrow and vehicles cannot remain on the pavement while making the maneuver. Conflicting movements. For example the side street right has a green arrow and the major street has a green left turn arrow. The absence of a left turn bay, and sight distance constraints.

We use the "No U-Turn" sign at ALL freeway median crossovers, which are intended for use only by emergency vehicles.
{Minnesota DOT}

Any turn or straight through movement may be restricted if the geometric design or the available sight distance does not adequately provide for the movement or the movement frequently cannot be safely executed.

PENN-DOT {Engineering and Traffic Studies}
(67 PA Code, Chapter 201)

QUESTION 6

What part does accident experience play in determining the installation of either of these signs? Please specify any accident thresholds used to determine the need for U-turn and left-turn prohibitions.

QUESTION 6 (CONTINUED)

VDOT RESPONSES

5 accidents/year
{Salem district}

Accident history plays an important part, expected value analysis usually determines whether I use these prohibitions. Many are decided on a case-by-case basis. There is NO magic number of accidents.
{Richmond district}

2-3 accidents/year
{Suffolk}

No threshold values established.

IN-STATE RESPONSES

Major part, but other aspects are also investigated.

No threshold values established.

No firm standards are utilized. However, guidelines might be:

- 5 of more left-turn accidents per 12 month period.
- 5 or more U-turn accidents per 12 month period.
- Overall public safety concerns and issues related to vehicle cruising and the need to regulate this activity.

{City of Richmond}

OUT-OF-STATE RESPONSES

There are no set accident thresholds established since they are reviewed on a case-by-case basis.

Accident history over a 3 year period plays a large role in determining installation. No set thresholds.
{City of Raleigh, N.C.}

For us, the driving force is litigation. One accident may be enough if it documents a legitimate hazard. The accident site is field checked before a recommendation is made.
{City of Knoxville, TN}

QUESTION 6 (CONTINUED)

No thresholds for U-Turns. 5-6 per year (12 month period) left-turn accidents.
{City of Jackson, Michigan}

A 3-year accident review indicates that TEN (10) accidents have occurred which can be attributed to vehicles making or attempting to make that maneuver.
PENN-DOT {Engineering and Traffic Studies}
(67 PA Code, Chapter 201)

QUESTION 7

If you prohibit left-turns or U-turns at an intersection, do you provide other accommodations downstream of the intersection. __ Yes __ No. If yes, please list, or provide documentation.

VDOT RESPONSES

No = 2

Yes:

The distance to the next turn location is considered when establishing No U-Turn restrictions.

IN-STATE RESPONSES

No = 5

The impact of the restriction is reviewed on nearby roads and intersections to ensure the restriction does not create another problem.

Yes:

Median crossovers provided prior to and after such intersections enabling turns.

Restriction of turns is usually based on the availability of turns within a one block area.

"Jug Handle" rights turns are provided, and very infrequently do we use downstream regulations to provide relief for prohibited turns. {City of Richmond}

OUT-OF-STATE RESPONSES

No = 4

QUESTION 7 (CONTINUED)

Yes:

A straight through or turning movement may be restricted if the restricted movement can be made at an alternate location.
PENN-DOT {Engineering and Traffic Studies}
(67 PA Code, Chapter 201)

We will try and squeeze in a left-turn lane at the next available turn spot if land-use, road width, and geometrics permit.
{City of Phoenix}

The availability of near-by alternate routes is a major factor in considering prohibiting any turns.
{City of Cincinnati, N.C. DOT}

QUESTION 8

What types of considerations are made for commercial businesses that might be affected by installing these signs?

VDOT RESPONSES

Accommodations for turning vehicles downstream.

None- Traffic flow and safety come first.

IN-STATE RESPONSES

No consideration is given.

1. Look for other alternatives such as jug handle right and left movements.

2. Peak period rather than 24 hour a day regulation or day of the week regulations (Monday-Friday).

{City of Richmond}

Businesses are informed of the proposed changes in advance and their suggestions are taken into consideration.
{City of Danville and Roanoke}

Restriction of turns is usually based on the availability of turns within a one block area.
{Cities of Lynchburg, Chesapeake, and Richmond}

QUESTION 8 (CONTINUED)

OUT-OF-STATE RESPONSES

None at this time.

We look for alternate routes- and stipulate common access agreements where we can.
{City of Overland Park, Kansas}

U-turns are allowed at downstream median openings and intersections.

We consider distance to alternate routes prior to implementing any of these restrictions.

We look for alternate routes; however, safety and capacity are the primary concerns.
PENN-DOT

QUESTION 9

Approximately how many signalized intersections in your jurisdiction are signed to prohibit __ U-turns? ___ Left-turns?

VDOT RESPONSES

No U-Turns	No Left-Turns	
21%	0%	{Lynchburg District}
3%	0%	
0%	<1%	
0%	0%	
20%	0%	{Richmond District}
13%	0%	{Salem District}
<1%	0%	

IN-STATE RESPONSES

No U-Turns	No Left-Turns	
8%	1%	
48%	0%	(Henrico County)
4%	1%	
7%	3%	
10%	2%	
7%	4%	
5%	0%	
2%	10%	(City of Richmond)

QUESTION 9 (CONTINUED)

OUT-OF-STATE RESPONSES

No U-Turn Signs	No Left-turn Signs	
1%	4%	
3%	1%	
0%	8%	
0%	1%	
Both Small percentage.		
99%	3%	{City of San Antonio, Texas}
5%	5%	
1%	0%	
2%	2%	
7%	0%	
> 1%	29%	{City of Cincinnati}
1%	0%	

QUESTION 10

Approximately how many unsignalized intersections in your jurisdiction are signed to prohibit ___ U-turns? ___ Left-turns?

VDOT RESPONSES

No U-Turns	No Left-Turns	
<1%	1%	
<1%	<1%	
<1%	<1%	
<1%	<1%	
0%	0%	
10%	0%	{Salem District}

IN-STATE RESPONSES

No U-Turns	No Left-Turns
<1%	2%
3%	3%
1%	<1%
<1%	<1%
<1%	<1%
Very small percentages for both.	

QUESTION 10 (CONTINUED)

OUT-OF-STATE RESPONSES

No U-turn	No Left-turn
2%	2%
5%	5%
Less than 1% for both (2 responses)	
Very small percentages.	
0%	2%
3%	2%

Please list other sources of information (i.e. individuals or reports) for any guidelines in dealing with the use of these signs.

PENN-DOT
(a) General Rule.- The driver of any vehicle shall not turn the vehicle so as to proceed in the opposite direction unless the movement can be made in safety and without interfering with other traffic.
(b) Turns on curves or grades.- No vehicle shall be turned so as to proceed in the opposite direction upon any curve, or upon the approach to or near the crest of a grade, where the vehicle cannot be seen by the driver of any other vehicle approaching from either direction within 500 feet.

Cincinnati, Ohio; 506-87

"No person, within a business district, shall turn any vehicle so as to proceed in the opposite direction except where the left turn from the same direction is permitted and where a continuous center divider exists 100 feet or more in length.

No vehicle shall be turned so as to proceed in the opposite direction upon any curve, or upon the approach to, or near the crest of a grade, where such vehicle cannot be seen by the driver of any other vehicle approaching from either direction within 500 feet, or at any location unless such movement can be made in safety and without backing or otherwise interfering with traffic."

APPENDIX B

PROCESS USED TO NORMALIZE ACCIDENT DATA[17]
(Example using accident rates)

Step 1. Calculate the difference in before and after accident rates.

Before Accident Rates ($a_n{}^b$)	After Accident Rates ($a_n{}^a$)	Difference in Accident Rates (a_n)
$a_1{}^b$	$a_1{}^a$	$a_1{}^b - a_1{}^a = a_1$
$a_2{}^b$	$a_2{}^a$	$a_2{}^b - a_2{}^a = a_2$
$a_3{}^b$	$a_3{}^a$	$a_3{}^b - a_3{}^a = a_3$
$a_4{}^b$	$a_4{}^a$	$a_4{}^b - a_4{}^a = a_4$
$a_5{}^b$	$a_5{}^a$	$a_5{}^b - a_5{}^a = a_5$
$a_6{}^b$	$a_6{}^a$	$a_6{}^b - a_6{}^a = a_6$
$a_7{}^b$	$a_7{}^a$	$a_7{}^b - a_7{}^a = a_7$
$a_8{}^b$	$a_8{}^a$	$a_8{}^b - a_8{}^a = a_8$

Step 2. Next, normalize the accident rates.

The following equation was used for each site:

$$a'_n = \frac{a_n}{\sqrt{\left(\left(\frac{1}{I_n^b}\right) + \left(\frac{1}{I_n^a}\right)\right)}}$$

where:

a'_n = normalized accident rate for site n

a_n = before/after accident difference for site n

$I_n{}^b$ = number of days in before study period for site n

$I_n{}^a$ = number of days in after study period for site n

From Step 2, one should obtain the following:

Normalized Before/After Accident Data (a'_n)
a'_1
a'_2
a'_3
a'_4
a'_5
a'_6
a'_7
a'_8

Step 3. Next, calculate the mean and the standard deviation from the normalized data and compare against the 95 percent confidence level.