Assessment of Current Practice in Selection and Design of Urban Medians To Benefit Pedestrians

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It is known that medians are an effective method of increasing vehicular safety and capacity on urban and suburban arterials. Medians can provide an additional lane for through traffic by removing left-turning vehicles from the traffic stream. Medians are also considered to be beneficial to pedestrian safety and operations, but their actual effects are unknown. The partial results of a study sponsored by FHWA are presented. A literature search and a state-of-the-practice survey regarding the effectiveness of alternative median designs and the availability of warrants, guidelines, and criteria for median installations in counties, cities, and states are summarized. The impact of median design on pedestrian safety is emphasized. The results are applicable to urban and suburban locations.

Medians and refuge islands are classifications of traffic control islands defined as areas between traffic lanes for control of vehicle movements or for pedestrian refuge. Medians can be designed to serve more than one purpose, including controlling or protecting vehicle crossover or other turning movements, providing a landscaped area, channelizing traffic, and providing pedestrian protection. Pedestrian refuge islands are specifically designed to provide a place of safety for pedestrians who cannot safely cross the entire roadway width at one time because of changing traffic signals or oncoming traffic.

Refuge islands are particularly useful at locations where heavy volumes of vehicular traffic make it difficult and dangerous for pedestrians to cross the roadway (*1*). The Manual on Uniform Traffic Control Devices (*2*) states that refuge islands are particularly useful (a) on multilane roadways, (b) in large or irregularly shaped intersections, and (c) at signalized intersections to provide a place of safety between different traffic streams.

It has long been recognized that medians are an effective method of increasing vehicular safety and capacity on urban and suburban arterials. Medians can provide an additional lane for through traffic by removing left-turning vehicles from the traffic stream. Medians are also generally considered to be beneficial to pedestrian safety and operations, but their actual effects are unknown.

This paper presents the results of an extensive literature search and state-of-the-practice survey that was conducted as part of a study sponsored by FHWA. The relevant objectives were (a) to conduct a literature review of the impacts of medians, emphasizing research of cases in which pedestrian safety was an issue and (b) to conduct a state-of-the-practice survey of state, county, and city agencies regarding current warrants, guidelines, and criteria for median installation.

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Nearly 70 articles were reviewed in the literature search, with about 50 percent of those published since 1982, reflecting renewed interest in this subject. The literature focus was on studies performed in urban and suburban locations, since rural locations do not have significant amounts of pedestrian traffic. The literature was used to identify existing guidelines that can be used to determine the appropriate median treatment to use.

MEDIAN TYPES

Raised medians promote safety and through traffic service by preventing left turns and U-turns across the medians except at designated crossover points. In addition to preventing left turns, raised medians reduce friction in the traffic stream by separating opposing traffic. The term *raised median* used herein implies the use of a curb. The effectiveness and utility of the median increase with increased width. If the raised median is at least 1.2 m (4 ft) wide it may be used by pedestrians as a rest area, enabling them to cross only one direction of traffic at a time. However, a 1.8-m (6-ft) median width is needed to accommodate multiple pedestrians in urban settings, persons with baby strollers, and wheelchairs propelled by attendants. If the median width is at least 3.0 m (10 ft) it can serve as a deceleration lane and storage area for left-turning vehicles at planned crossover points and as a pedestrian rest area.

Flush medians use delineation treatments that do not physically restrict the movement of traffic across the median. The typical type of delineation treatment is painted traffic lanes, but some jurisdictions also use raised pavement markers or mushroom buttons. The principal types of flush medians are narrow divider strips, continuous and alternating left-turn lanes, and two-way left-turn (TWLT) lanes. Flush medians are also described as "painted medians" or "painted left-turn channelization" if left-turn pocket lanes are involved.

The standard design for TWLT lanes is specified by the Manual on Uniform Traffic Control Devices (*2*). The major design requirement of this technique is the median width, which should be at least 3.7 m (12 ft). However it is recognized that 3.0-m (10-ft) widths are common in older urban areas. The intent of a TWLT lane is to remove left-turning vehicles from through lanes and to provide storage in the median area until an acceptable gap in opposing traffic occurs.

The continuous left-turn lane design is similar to the TWLT lane except that it provides individual left-turn lanes for each direction of traffic. This design is also referred to as *side-by-side* *left-turn pocket lanes.* This technique requires a 7.3-m (24-ft)-wide paved median and is not currently in frequent use.

The alternating left-turn lane design provides left-turn opportunity for only one direction of traffic at a time. Both directions of traffic therefore have left-turn capabilities over a limited section of roadway. This design is also described as *back-to-back left-turn pocket lanes.*

Previous research sponsored by NCHRP identified medians and refuge islands as techniques for increasing the safety of pedestrians crossing major arterial streets (*3*). The authors contend, however, that although the potential for increasing safety was present, the actual effect on pedestrian safety was unclear. To emphasize their concern they mention a previous study that claimed to reduce pedestrian accidents by the installation of refuge islands, which on close inspection exhibited problems of regression to the mean (*4*). The literature supports the conclusion of the NCHRP study that there is a substantial lack of definitive information on the effects of medians and refuge islands on pedestrian safety. Those articles that discussed or evaluated medians on roadways is urban and suburban locations were primarily concerned with their impacts on vehicular safety and operations.

The NCHRP study developed a general finding that it is substantially more convenient for pedestrians to cross multilane highways with medians than highways without medians. The authors concluded that medians should be divided as a standard feature of multilane suburban highways (*3*). They cited a study of an arterial street in suburban Virginia that found that almost 90 percent of pedestrian crossings occurred at midblock. It can be expected that when pedestrians are faced with long distances between intersections they will cross at midblock locations to reduce the total walking distance. The presence of medians at these locations can provide a significant benefit to both pedestrian convenience and potential safety on multilane roadways. This is particularly true at those midblock locations with relatively high volumes or unsignalized intersections, since medians greatly simplify the pedestrian's task of crossing the roadway.

The historic use of raised medians and the increased installation rate of TWLT median lanes have resulted in their selection as the predominant median types for the purposes of this paper.

RAISED VERSUS FLUSH MEDIANS

Raised medians were the predominant type of median first used on urban and suburban roadways. Roadway designers considered them effective in controlling left-turn movements, providing a storage space for left-turning vehicles, separating opposing traffic flows, providing an opportunity for aesthetic enhancements, and providing areas for pedestrian refuge. Increased congestion, limited right-of-way, high cost of construction, maintenance costs of raised medians, safety analyses, and the need for increased left-turn opportunities have resulted in the use of flush TWLT median lanes by a large number of agencies. The literature review indicates that TWLT median lanes have been successfully used on urban and suburban roadways with one or more of the following characteristics:

- When traffic volumes are not exceedingly high. There is no firm consensus on the upper-volume threshold at which the advantages of TWLT median lanes dissipate. The ITE survey of practice indicated that the upper level was an average daily traffic (ADT) count of 43,000, whereas other researchers indicated an ADT count of 25,000 (*5,6*).
- On roadways where vehicles make a relatively large number of left turns, commonly in areas with commercial development and frequent driveways. TWLT median lanes have also been successfully implemented in residential areas, combined commercial-residential areas, industrial areas, and in some states, rural areas (*7,8*).
- In areas where the predominant accident patterns are related to left-turn maneuvers and indirect left-turn access cannot be provided with a raised median (*9*).

The advantages and disadvantages of raised and flush medians are summarized in Tables 1 and 2, respectively. These tables were compiled from a 1990 report by Parker (*10*) in conjunction with a 1990 report by Squires and Parsonson (*11*) and are based on a consensus of the literature.

Safety Effectiveness

The majority of the literature reviewed described before-and-after accident studies of TWLT median lanes. Studies that compared the safety effectiveness of raised and flush median types provided mixed results. An inspection of these studies provides an insight into why some of these mixed results occurred.

- Frick (*12*) compared accident rates at two sites during 1968 in Springfield, Illinois. The results of the study indicated that the site with the flush median lane had an accident rate that was 2.65 times greater than that at the site with the raised median section. Since only two sites were used, the study conclusions are questionable because of the small sample sizes.
- Squires and Parsonson (*11*) compared accident occurrences between raised medians and TWLT median lanes in Georgia. They determined that there was no difference in accident rates between the two median types but found that there was a significant difference in the number of accidents per 1.61 km (1 mi). Parker (*13*), in a comparison of 19 raised and 17 flush median sites in Virginia, also determined that there was no significant difference in accident rates between the two median types. That 1983 study determined that the accident rate for raised medians was 275 accidents per hundred million vehicle km (442 accidents per hundred million vehicle mi) and that the rate for flush medians was 380 per hundred million vehicle km (611 per hundred million vehicle mi). Parker also determined that the accident frequency per mile was not significantly different. In a 1990 update to his study Parker (*10*) again determined that neither the accident rates nor the numbers of accidents per mile were significantly different. The studies by Parker (*10*) and Squires and Parsonson (*11*) were, however, too small to experimentally control for differences in traffic volumes, the number of intersections per mile, and the number of driveways per mile between the median types.
- In 1986 Harwood (*9*) analyzed data on accidents at sites in California and Michigan and found that accident rates at TWLT median lanes were 21 to 24 percent lower than accident rates at raised median sections. Harwood used a good experimental approach, but only used sites in California and Michigan with a total raised median length of 35 km (21.8 mi), with a total raised median length of 26 km (16.2 mi) in commercial areas.
- In 1993 Mukherjee et al. (*14*) reported on a comparative analysis of the models developed by Parker (*10*), Squires and Parson-

TABLE 1 Advantages and Disadvantages of Raised Medians (*10,11*)

Advantages:		Disadvantages	
1.	Discourages new strip development and encourages large planned development.	1.	Reduces operational flexibility for emergency vehicles and others.
2.	Allows better control of land use by local government.	2.	Increases left turn volume at major intersections and median openings.
3.	Reduced number of conflicting vehicle maneuvers at driveways.	3.	Increases travel time for vehicles desiring to turn left where median openings are not provided.
4.	Safer on major arterials with high (>60) number of driveways per mile (>37 driveways per km).	4.	Reduces capacity at signalized intersections.
5.	Increases traffic flow.	5.	Possible increase of accidents at intersections and median openings.
6.	Desirable for large pedestrian volumes.	6.	Usually increases fixed object accidents.
7.	Permits circuitous flow of traffic in grid patterns.	7.	Requires motorists to organize their trip making to minimize the need for U-turns and use the arterial only for relatively long through movements.
8.	Allows greater speed limits on through road.	8.	To minimize delay requires interparcel access, which may not be under government control or would be expensive to purchase and construct.
9.	Safer than TWLTL in 4 lane sections.	9.	Restricts direct access to adjoining property.
10.	Safer than TWLTL in 6 lane sections but depends on number of signals/mile, driveways/mile, ADT, and approaches/mile.	10.	Installation costs are higher.
11.	Encourages access roads and parallel street development.	11.	Can create an over concentration of turns at median openings.
12.	Reduces accidents in mid-block areas.	12.	Indirect routing may be required for some vehicles.
13.	Reduces total driveway maneuvers on the major roadway.	13.	When accidently struck, curb may cause driver to lose control of the vehicle.
14.	Low maintenance cost of raised medians, depending on final design.	14.	A median width of 25 ft (7.6 m) is needed to accommodate U-turns.
15.	Studies have shown that delay per left turning vehicle does not increase, up to the studied volume of 3700 vph.		
16.	Curbs discourage arbitrary and deliberate crossings of the median.		
17.	Reduces number of possible median conflict points.		
18.	Provides separation between opposing traffic flows.		
19.	Provides a median refuge area for pedestrians.		
20.	With raised grass medians, an open space is provided for aesthetics.		

son (*11*), and Harwood (*9*) and revealed conflicting results. The authors concluded that the models and procedures that had been developed were not applicable to all cases and locations.

Although there are problems in many of the studies that compared the safety effectiveness of raised and flush median types, a number of studies determined the safety effectiveness of raised medians and TWLT median lanes without comparison. The raised median safety effectiveness results are summarized below.

- A study of three installations with raised medians by Wooten et al. (*15*) in 1964 determined significant accident reductions; reductions were as high as 69 percent at one site.
- Harwood and Glennon (*16*), using data obtained by Mulinazzi and Michael (*17*), estimated that raised medians would reduce the number of accidents by 50 percent at major intersections and 60 percent of the left-turn accidents at low-volume driveways.
- Harwood (*9*), in his 1986 study, determined that accident rates on roadways with raised medians and four-lane undivided sections were nearly identical after adjustment for the type of development and the number of driveways per mile.

A summary of the safety effectiveness of TWLT median lanes is presented below.

- Sawhill and Neuzil (*18*) in 1963 reported a 25.8 percent decrease in the number of accidents, with only one head-on accident, after a TWLT median lane was installed.
- A 1-year-before and 1-year-after study conducted by Hoffman (*7*) at four sites with TWLT median lanes in Michigan determined that the total number of accidents decreased by 33 percent. The study sites were initially four-lane undivided facilities widened to accommodate the median left-turn lane. Before the installation of the TWLT median lane there were 14 head-on accidents in which 18 people were injured. After the TWLT median lane installation there were eight head-on accidents in which one person was injured.
- A 2-year-before and 2-year-after study was conducted by Thakkar (*19*) on a four-lane roadway on which a TWLT median lane was installed. That study indicated that the total numbers of accidents were reduced by 22.6 percent and that the accident rate was decreased by 27.7 percent.
- Seven sites in Arizona were studied in a 2-year-before and 2-year-after experimental design by Burritt and Coppola (*20*). They

TABLE 2 Advantages and Disadvantages of TWLT Median Lanes (*10,11*)

Advantages:		Disadvantages:	
1.	Left turning vehicles are removed from through traffic while maximum left turning access to side streets and driveways is still provided.	1.	There are conflicting vehicle maneuvers at driveways.
2.	Delay to left turning vehicles and others is often reduced.	2.	Poor operation of roadway if stopping sight distance is less than AASHTO minimum design.
3.	Operational flexibility for emergency vehicles and others is enhanced.	3.	No pedestrian refuge areas for pedestrians free from moving vehicles.
4.	When less than 60 commercial driveways per mile (37 driveways per km) are permitted to be constructed two-way left turn lanes appear to be safer.	4.	Operate poorly under high volume of through traffic.
5.	Roads with two-way left turn lanes are operationally safer than roadways with no separate left turn lanes in the median.	5.	Should not be used when access is required on only one side of the street.
6.	Detours can be easily implemented when required by maintenance in adjacent lanes.	6.	Visibility problem of painted median especially with snow and rain or when pavement markers outlive their design life.
7.	Provides spatial separation between opposing traffic flows.	7.	A safety problem when they are used as a passing lane.
8.	Eliminates the median island fixed object.	8.	High maintenance cost of keeping the pavement striped and raised pavement markers in proper operating condition.
9.	Provides temporary refuge for disabled vehicles.	9.	Must continually instruct the public on proper use and operation.
10.	Can be used as a reversible lane during peak hours.	10.	Delays to left turning vehicles increase dramatically when two way through volume reaches 2800 vpd.
11.	Permits direct access to adjoining properties.	11.	Limits operating speed to a maximum rate 45 mi/h (73 km/h).
		12.	Does not guarantee unidirectional use at high-volume intersections.
		13.	Are not aesthetically pleasing for some people.
		14.	Allows numerous potential traffic conflict points.

determined that the total numbers of accidents were reduced by 35.9 percent and the numbers of head-on accidents were reduced by 66.7 percent after flush median lanes were installed.

- Babcock and Foyle (*21*) examined more than 1,000 accident reports for TWLT median lanes in North Carolina and did not identify any head-on accidents attributed to the median lane.
- In a Virginia study Parker (*13*) determined that 1.05 percent of the accidents on facilities with raised medians were head-on collisions, occurring primarily at the median openings. Parker also determined that 0.98 percent of the accidents on TWLT median sections were head-on collisions with no fatalities involved.

A summary of the safety effectiveness of raised and TWLT median lanes on pedestrians is presented next.

- Billion and Parsons (*22*) reported in a 1962 publication that pedestrians crossing roadways with raised medians had a higher accident rate than those crossing roadways with flush medians. It was not possible to determine from the study, however, if the higher rate for raised medians was due to increased pedestrian activity.
- A 1977 study conducted in London, England, determined that pedestrian refuge islands increased the number of pedestrian accidents (*23*). Problems with the experimental design and the failure to consider changes in traffic and pedestrian volumes result in the questionable validity of the study's conclusions.
- Grayson performed a paired comparison between studies performed in 1962 and 1983 at 75 crossings in London, England (*24*). This comparison determined a reduction in the pedestrian accident rate between the 1962 and the 1983 studies. Because of geometric and traffic control changes that took place between the study periods, it is not possible to ascertain whether the decrease in the number of pedestrian accidents was due to an increase in the number of refuge islands.
- In a 1983 study performed in Virginia, Parker (*13*) determined that 17 of the 1,809 accidents (0.94 percent) occurring during a 3-year period involved pedestrians at raised-median roadway sections. For the TWLT median-lane roadway sections there were 29 pedestrian accidents.

Operational Effectiveness

The majority of the studies reviewed concentrated on the safety effects of medians on vehicular traffic. When operational studies were conducted the measures of effectiveness were speed, travel time, and delay measures. These measures of effectiveness are site specific and are heavily influenced by the number of lanes, type of development, number of driveways, number of intersections, and so on. The following summary groups those studies that had similar results.

- Delay to through vehicles has been determined to be considerably reduced by the use of both raised and flush medians (*6,8,13,25*). Both of these median types remove left-turning vehicles from the through lanes and separate opposing traffic flows.

- Left-turn operations on roadways with raised and flush medians have been determined to have different impacts on operations. Raised medians concentrate left-turn operations at median openings, requiring the driver to select an alternate route or make a U-turn to reach the destination. Harwood (*9*) used a simulation model developed by McCoy et al. (*26*) to compare the operational effectiveness of roadways with raised and flush medians. Harwood determined that the use of raised medians resulted in greater travel time and delay than the use of flush medians.
- Traffic volumes were considered by some researchers as being a warrant for median installation. Stover et al. (*27*) recommended that raised medians be used on all arterial roadways with two or more lanes and traffic volumes of at least 20,000 vehicles per day (vpd). Some researchers (*28,29*) suggested that TWLT median lanes be used when the volume ranged from 10,000 to 25,000 vehicles per day. Volume warrants were opposed by Nemeth (*8*) and others (*6,25*) because successful applications of flush medians were found for volume ranges of between 5,000 and 50,000 vehicles per day. This volume range is typical of the full range of volumes on facilities with four through lanes.
- Research conducted by Parker (*13*) in Virginia and that conducted in other states (*8,21,25*) indicates that TWLT median lanes have been successfully used for posted roadways with speed limits of between 40 km/hr (25 mph) and 89 km/hr (55 mph). TWLT median lanes have been successfully used on some median sections with speeds posted at 97 km/hr (60 mph) (*6,8*).
- Raised medians have resulted in observed wrong way movements when used in highly developed areas (*13,30*).
- Driver confusion and operational efficiency were observed at the openings of raised medians when more than one vehicle occupied the opening at the same time (*13,21*). These occurrences typically happened at unsignalized intersections in heavily developed areas.
- Improperly designed raised-median openings result in U-turn problems (*13,21,27*). The improper design can result in the operators of large vehicles starting their U-turn from the inside through lane instead of the left-turn lane. Some drivers, to avoid running over the curb, must perform a backing maneuver to complete their U-turn.

Installation Criteria

Raised and Flush Medians

- A median of some sort should be used to provide left-turn channelization at all at-grade intersections on high-speed, high-volume roadways (*31*).
- Bretherton et al. (*32*) reported that a raised median is always safer than a TWLT median lane on any four- or six-lane road, regardless of traffic volumes, the number of signals per mile or driveway frequency, or cross-street frequency.
- Squires and Parsonson (*11*) agreed that a raised median is safer than a TWLT median lane on four-lane sections, but claimed that on six-lane roadways with a driveway density of greater than 47/km (75/mi), two or fewer signals per 1.61 km (1 mi), and a maximum of five or six approaches per 1.61 km (1 mi), a TWLT median lane is preferable.
- A raised median works best when there is adequate provision for access between neighboring businesses, such as interconnecting parking lots (*32*).
- Reish and Lalani (*5*) recommended the installation of a raised median when traffic volumes exceed 25,000 vehicles per day.
- The use of some sort of median was recommended by Stover et al. (*27*) on all primary arterials and on secondary arterial roadways with two or more lanes in each direction, average speeds of greater than 56 km/hr (35 mph), and traffic volumes of at least 20,000 vehicles per day. If an existing arterial with a TWLT median lane has a volume of 24,000 to 28,000 vehicles per day, the reconstruction of the arterial to utilize a raised median should be considered, according to Bretherton et al. (*32*).
- Harwood (*9*) found that a four-lane divided facility was more appropriate than an undivided facility for major arterials when the peak flow rate is greater than 1,000 vehicles per hour in one direction and when the driveway density is less than 28/km (45/mi).
- Most agencies prefer to utilize raised or grass-covered flush medians on six-lane arterials (*5*).
- When major driveways or intersections are spaced more than 1.61 km (1 mi) apart, Harwood and Glennon (*16*) suggested that a median barrier be used.
- Parker (*10*) presented a method for selecting between a raised or a painted median.
- Parker (*10,13*) claimed that there is no evidence to limit the use of painted medians to a roadway with a particular volume range or to roadways with a speed limit of under 73 km/hr (45 mph).
- Cribbins et al. (*33*) attempted to use multiple regression to derive an equation for the optimum spacing of median openings but were unable to do so.
- An FHWA implementation package (*4*) reported that traffic-serving businesses appear to be affected by their accessibility to a median crossing. Minimum spacings between median openings were also given.
- Minimum spacings between median openings were also presented by Bretherton et al. (*32*).
- In urban areas, Bretherton et al. (*32*) concluded that median openings could be constructed when the minimum left-turn volume is 500 vehicles per day or 100 vehicles per hour during the peak hour on streets when the speed limit is less than 64 km/hr (40 mph). When the speed limit is over 64 km/hr (40 mph), median openings can be constructed when the minimum left-turn volume is 350 vehicles per day or 70 vehicles per hour during the peak hour.

Two-Way Left-Turn Median Lanes

- The addition of a TWLT median lane to an existing two-way four-lane street reduced the numbers of stops and delays for every combination of volume, average running speed, and left-turn percentage when estimated with a computer model developed by Ballard and McCoy (*34*). Stop and delay reduction isograms are presented. When these are used within the context of a cost-effectiveness analysis they can help to identify when an installation is justified.
- Ballard and McCoy (*35*) also tested 54 combinations of traffic volume, left-turn percentage, and driveway density. In every case the number of stops and the amount of delay were reduced. Those reductions in stops and delay were then used to develop equations to compute the operational benefits of adding a TWLT median

lane. One set of equations was for volumes of less than 800 vehicles per hour; the other set was for volumes greater than this.

- In a similar study conducted by McCoy et al. (*26*) the addition of a TWLT median lane to a two-way two-lane roadway decreased the number of stops and delays for all combinations of volumes and driveway density, with one exception. In this one exception there was no change. Under balanced flow conditions the addition of a TWLT median lane was particularly effective for roadways with volumes of greater than 700 vehicles per hour in each direction and with more than 70 left turns per 305 m (1,000 feet) from each direction. Isograms that could be used within the context of a cost-effectiveness analysis were presented to determine when an installation is justified.
- ITE Committee 5B-4 (*6*) concluded that TWLT lanes are best suited for use on roadways with 40- to 89-km/hr (25- to 55-mph) speed limits in areas of strip development.
- Harwood (*9*) reported, for a roadway with four through lanes, that TWLT median lanes are most appropriate for suburban highways with commercial development, a driveway density of more than 28/km (45/mi), low to moderate volumes of through traffic, high left-turn volumes, and/or a high rate of rear-end or angle accidents associated with left-turn movements.
- The use of a TWLT lane is warranted on arterial highways with an ADT volume of more than 10,000 vehicles per day, average traffic speeds above 48 km/hr (30 mph), a driveway density of more than 37/km (60/mi), fewer than 6 high-volume driveways per km (10/mi), and a left-turn percentage of at least 20 percent of through volume during peak periods, according to Harwood (*16*).
- Bretherton et al. (*32*) reported that TWLT median lanes are definitely warranted on roadways with volumes of more than 28,000 vehicles per day because of the inability of turning vehicles to find acceptable gaps.
- On roadways with four through lanes TWLT median lanes are cost-effective on the basis of operational savings alone, at an ADT volume of 16,200 vehicles per day, according to McCoy et al. (*36*). If accident cost savings are also considered, an installation is justified at volumes of more than 7,100 vehicles per day.
- Thakkar (*19*) also found that TWLT median lanes are safe and cost-effective on roadways with four through lanes as well as on roadways with two through lanes.
- Nemeth (*8*) stated that the use of TWLT median lanes is suitable for roadways with closely spaced driveways and high left-turn volumes, but not when the block lengths are short.
- Stover et al. (*27*) also concluded that TWLT median lanes were suitable for use on roadways with closely spaced driveways, but asserted that they could be effective only if the turning volumes into individual driveways from roadways with a speed limit of 73 km/hr (45 mph) or less were relatively low.
- Walton et al. (*25*) made claims similar to those of Nemeth (*8*), but thought that TWLT median lanes could operate efficiently only under moderate left-turn demands.
- A literature review conducted by Walton and Machemehl (*29*) revealed that a TWLT median lane is preferable to a one-way left-turn lane on roads with four through lanes and ADT volumes of between 10,000 and 20,000 vehicles per day and on roads with two through lanes and ADT volumes of from 4,000 to 12,000 vehicles per day. They also presented tables and equations to be used as guidelines for left-turn lane improvements or installations (*29*).
- The use of TWLT median lanes is not appropriate when there are high pedestrian volumes, the roadway is a major arterial, the block lengths are short, or there are unusual driveway configurations, according to McCoy et al. (*37*).

Refuge Islands

- Dunn (*38*) concluded that refuge islands should be provided if the roadway width exceeds 10 m (33 ft), on the basis of evidence that pedestrians reject headways of less than 4 sec using an average walking speed of 1.2 m/sec (4 ft/sec).
- A 1980 FHWA implementation package (*39*) recommended the consideration of refuge islands on roadways wider than 22.9 m (75 ft).
- A later FHWA implementation package (*40*), published in 1987, stated that a refuge island should be considered when the entire roadway width cannot be crossed within the signal phase at a 1.1-m/s (3.5-ft/s) walking speed and the signal timing cannot be lengthened or an alternate crossing cannot be designated.
- Smith et al. (*3*) recommended the use of refuge islands at locations when medians cannot be provided, traffic speeds are less than 73 km/hr (45 mph), and pedestrian volumes are greater than 100 persons per day. They should not be used for midblock pedestrian crossings across a high-volume streets when speeds are above 73 km/hr (45 mph). Refuge islands should be located every 92 to 153 m (300 to 500 ft).
- Zegeer and Zegeer (*41*) stated that refuge islands are necessary on wide, two-way streets with high vehicular volumes, high speeds, and high pedestrian crossing volumes. They should not be used on narrow streets, when there is a high turning volume of large trucks, when roadway alignment obscures the island, or in areas where snowplowing would be hampered.

STATE-OF-THE-PRACTICE SURVEY

A state-of-the-practice survey was mailed to 150 state and local highway agencies, of which 57 were returned, representing a 38 percent response. The method of analysis followed was to group state and county agencies together and to classify cities by population. The population categories used were 0 to 100,000, 100,000 to 150,000, 150,000 to 500,000, and more than 500,000. The upper and lower boundaries of each class were chosen to give approximately equal numbers of responses in each category.

Regarding the type of warrants or guidelines the agencies used to determine whether or not medians or refuge islands should be installed, the following responses were received. Twenty percent of the states use their own design criteria and 5 percent use the AASHTO Green Book criteria. Factors that states consider include accident history (20 percent), traffic volumes (15 percent), cost (10 percent), number and location of driveways (10 percent), and type of access control (10 percent). Ten percent of the state agencies do not regularly use any guidelines, and 30 percent did not respond to the question.

Mukherjee et al. (*14*) reported in a survey of state highway engineers that 25 percent of the states used some kind of guidelines for median-type decisions, but the material provided was not directly helpful in choosing between a nontraversable median and a TWLT median.

Criteria used by cities with populations of less than 100,000 include accident history (18 percent), AASHTO and Manual on Uniform Traffic Control Devices criteria (*2*) (36 percent), state design criteria (9 percent), and availability of right-of-way (18 percent). Thirty-six percent did not respond to this question.

Cities with populations of between 100,000 and 150,000 consider the following criteria: classification of street (20 percent), available safe gaps (10 percent), AASHTO criteria (10 percent), and the city's own standard plans (10 percent). Thirty percent use no guidelines, and 10 percent did not respond. Cities with populations ranging from 150,000 to 500,000 generally use medians to provide an orderly flow of traffic (20 percent) or install medians with newly constructed arterials (20 percent). Twenty percent do not use any guidelines; 30 percent did not respond.

Large cities (more than 500,000 population) consider traffic volumes (14 percent), pedestrian volumes (14 percent), available right-of-way (29 percent), and arterial classification of street (72 percent) as their criteria. Fourteen percent use their own guidelines.

Pedestrian refuge islands do not receive much attention from roadway agencies. Some agencies do not intend to use medians as pedestrian refuge areas. One agency stated that it does not specifically design medians to be used by pedestrians, although pedestrians use them. Other agencies have low pedestrian volumes, do not account for pedestrians in roadway design, and do not time traffic signal phases to allow pedestrians to cross the entire roadway. In some agencies, however, the needs of elderly and handicapped individuals are currently, or will soon be, included in their specifications for median design.

There was mixed response on the questions concerning acceptable widths for pedestrian refuge islands. Fifty-five percent of the states believe that 1.2 m (4 ft) is an acceptable minimum width for a pedestrian refuge. The results for cities, however, do not concur. The majority of cities in both the 100,000-to-150,000 population range and the 500,000-and-over range believe that 1.2 m (4 ft) is an acceptable minimum width. However only 36 percent of the cities with populations of less than 100,000 believe that 1.2 m (4 ft) is acceptable. Seventy percent of the cities in the 150,000-to-500,000 population range believe that 1.2 m (4 ft) is an unacceptable width for a pedestrian refuge island. All agencies in general believe that pedestrian refuge island widths of 1.8 to 4.9 m (6 to 16 ft) are desirable.

Many different criteria are used to prioritize median and refuge island installations. States typically use accident history (35 percent), traffic volumes (30 percent), or a case-by-case basis (15 percent). Twenty-five percent of the states do not prioritize median installation. City agencies, especially the smaller cities, typically do not prioritize median or refuge island installation. Those that do generally use political considerations, street classification, and traffic and pedestrian volumes. Most agencies do not have any difficulty in using their prioritization procedures. A few agencies commented that installation of a raised median can be a problem if it eliminates left-turn access.

In deciding what factors should be considered in developing new warrants or guidelines for the installation of medians and refuge islands, state officials believe that traffic volumes (65 percent), pedestrian volumes (55 percent), speed (30 percent), accident control (20 percent), number of lanes (10 percent), adjacent land use (10 percent), and the functional classification of the street (10 percent) should be considered. The responses from cities were similar to those from states. Officials in cities with populations of less than 100,000 consider traffic volumes (63 percent), pedestrian volumes (36 percent), street width (36 percent), available gaps (27 percent), and accident history (27 percent). Twenty-seven percent of the cities surveyed did not respond. Forty percent of cities in the 100,000-to-150,000 population range believe that traffic and pedestrian volumes should be considered; 30 percent did not respond. Cities in the 150,000-to-500,000 population range believe that pedestrian crossing time (20 percent) and roadway geometrics (20 percent) should be included, in addition to accident history (20 percent) and traffic volumes (20 percent). Traffic volumes were suggested by 57 percent of the large cities, and pedestrian volumes were recommended by 43 percent.

Most states have their own design specifications for medians. Cities generally use state or AASHTO and ITE guidelines, although some of the larger cities have their own specifications. Some state and city agencies sent copies of their specifications for median construction.

States were almost evenly split on the question of installing different types of medians on the basis of pedestrian use: 45 percent install different types of medians on the basis of pedestrian use, whereas 55 percent, do not. Most cities (at least 60 percent in each population category) do not install different types of medians on the basis of pedestrian use.

Only 10 percent of the states use warrants to determine what type of median should be installed. Nine percent of cities with populations of less than 100,000 use such warrants. None of the other cities use warrants.

Funding for median improvements usually comes from capital improvement funds; special tax districts; federal, state, and local funds; or private development funds. This is true for all states and cities.

Most agencies have not conducted operational studies on medians and refuge islands except for very informal before-and-after studies. A study by the Florida Department of Transportation, however, found that safety for both vehicles and pedestrians was greatly improved when four-lane undivided roads were converted to five-lane roads lanes plus TWLT (four lanes plus a TWLT lane).

In almost all classes of jurisdictions a majority of the agencies believe that flat medians increase pedestrian and vehicular safety. In the class of cities with fewer than 100,000 people, however, 45 percent believe that flat medians do not increase safety and 36 percent believe that flat medians do increase safety. Many agencies commented that flat medians increase vehicular safety, but not pedestrian safety, since they offer no physical protection from vehicular traffic (unlike raised medians).

CONCLUSIONS

Although the results of the safety analyses on medians and refuge islands are mixed, it appears that both raised and TWLT medians significantly reduce the number and severity of vehicular accidents. The literature review made it apparent that both raised and TWLT medians offer significant vehicular accident reductions and over those for comparable roadways without medians and offer vehicular benefits. Typical reductions in the total number of vehicular accidents for both median types are in the 25 to 35 percent range.

The literature did not provide a conclusive indication that medians improved pedestrian safety. This was due to the small number of pedestrian accidents encountered during the studies.

Both raised and TWLT medians result in a reduction in accident severity. The results were mixed with regard to whether raised or TWLT medians decreased accident severity by the same amount. Some researchers concluded that raised medians reduced vehicular accident severity slightly more than TWLT median lanes. Another researcher found that there was no discernible difference in the accident severity between roadways with raised medians and those with TWLT median lanes.

Rear-end and head-on accidents decreased with both raised median and TWLT median lane installation. More fixed-object and U-turn accidents occur on roadways with raised medians than on those with TWLT median lanes. Significantly higher numbers of midblock left-turn accidents occur on roadways with TWLT median lanes than on those with raised medians. The initial concern of researchers that TWLT median lanes would result in a larger number of head-on accidents was not determined to be true. Roadways with raised medians and TWLT median lanes have similar head-on accident experiences. The head-on accidents on roadways with raised medians occur at the median crossover points.

The current literature suggests that both raised and TWLT median lanes can be used on roadways with posted speed ranges of 40 to 89 km/hr (25 to 55 mph) and all volume ranges typically encountered on urban and suburban arterials. The use of raised medians results in more delay and travel time because of the need for U-turns to reach destination points. TWLT median lanes are appropriate for suburban roadways with commercial development and driveway densities greater than 28/km (45/mi).

The state-of-the-practice survey revealed that there is no universal set of factors that can be used to determine the need to install medians. Whereas states rely on accident history, traffic volumes, numbers and locations of driveways, type of access control, and cost, the larger cities rely on traffic volumes, pedestrian volumes, available right-of-way, and street classification. A greater divergence was found in the smaller cities.

The research described here revealed that there is a need to develop a definitive set of guidelines that can be used by cities and states to determine the most appropriate median treatment on arterials. These guidelines must be based on safety as well as operational criteria.

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