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16. Abstract

Three types of medians are typically used on four-lane rural highways in Texas: raised (or depressed) medians; two-way, left-turn lanes (TWLTLs); and flush medians. With flush medians, the area between the travel lanes is paved and can easily be traversed by a vehicle. This type of median is typically used in areas that transition from rural to suburban. The purpose of this research was to examine the differences in the operations and safety of four-lane rural highways with TWLTLs and four-lane rural highways with flush medians.

A review of accident rates found that there were no statistical differences in accident rates of highways with TWLTLs and highways with flush medians when driveway densities were low. Field studies also showed that there was no difference in the way these two median treatments operate in rural areas. Therefore, it was concluded that drivers see no difference in the way they should use flush medians and TWLTLs.

Texas state law states, however, that it is illegal for motorists to use flush medians as a storage and acceleration / deceleration area for turning left into and out of adjacent properties. The results of this research suggest that drivers ignore the meaning of the solid yellow lines used to mark flush medians. Therefore, in order to promote uniformity and consistency, it is recommended that flush medians be used only on highways where the frequency and spacing of driveways permit individual median openings at each driveway. In cases where this is not possible, it is recommended that TWLTLs be used on four-lane rural highways.

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AN EVALUATION OF FLUSH MEDIANS AND TWO-WAY, LEFT-TURN LANES ON FOUR-LANE RURAL HIGHWAYS

by

Kevin N. Balke
and
Kay Fitzpatrick

Research Report 1293-1
Research Study Number 0-1293

Study Title: The Use of Continuous Two-Way, Left-Turn Lanes on High Speed Rural and Suburban Highways

Sponsored by the

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IMPLEMENTATION STATEMENT

This research examined the operations and safety of flush medians and two-way, left-turn lanes (TWLTL) on four-lane rural highways. It was found that at low driveway densities [less than 9 driveways per mile (14.5 driveways per km)], there is no difference in the safety and operation of flush medians and TWLTLs on four-lane rural highways. Since data were not collected on highways with higher driveway densities, there is no evidence to support (or refute) that highways with either flush medians or TWLTLs will operate efficiently or safely at driveway densities greater than 9 driveways per mile (14.5 driveways per km). The research suggests that more consistent applications of TWLTLs and flush median pavement markings are required. Based on the research from this project, it is recommended that flush medians be used only where driveway spacings permit median openings to be installed at every driveway location. In areas where median openings cannot be provided at every driveway, the use of TWLTLs is recommended on four-lane rural highways.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The engineers in charge of the project were Mr. Kevin Neil Balke, P.E. #66529, and Dr. Kay Fitzpatrick, P.E. #PA-037730-E.

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SUMMARY

Three types of medians are typically used on four-lane rural highways in Texas: median islands; two-way, left-turn lanes (TWLTLs); and flush medians. With flush medians, the area between the travel lanes is paved and can easily be traversed by a vehicle. This type of median is typically used in areas that transition from rural to suburban. The purpose of this research was to examine the differences in the operations and safety of four-lane rural highways with TWLTLs and four-lane rural highways with flush medians.

A review of accident rates found that there were no statistical differences in accident rates of highways with TWLTLs and highways with flush medians when driveway densities were low. Field studies also showed that there was no difference in the way these two median treatments operate in rural areas. Therefore, the researchers concluded that drivers see no difference in the way they should use flush medians and TWLTLs.

Texas state law states, however, that it is illegal for motorists to use flush medians as a storage and acceleration/deceleration area for turning left into and out of adjacent properties. The results of this research suggest that drivers ignore the meaning of the solid yellow lines used to mark flush medians. Therefore, in order to promote uniformity and consistency, we recommend the use of flush medians only on highways where the frequency and spacing of driveways permit individual median openings at each driveway. In cases where this is not possible, we recommend the use of TWLTLs on four-lane rural highways.

CHAPTER 1. INTRODUCTION

Medians are used on both rural and urban highways to separate opposing traffic streams. Most highways that are divided with a median often operate better and safer than undivided highways that carry comparable traffic volumes. The type of median that is used on a highway depends on a number of factors, including the amount of traffic, the functional classification of the highway, the availability of right-of-way, the operating speed of the highway, and the type and intensity of the development along the side of the highway (1). This report examines the use of two-way, left-turn lanes and flush medians on four-lane highways that transition from rural to urban or suburban areas. The purpose of this report is to document the differences in safety and operations of these two median types and to provide recommendations as to which is the most appropriate for use in areas that are in transition from rural to urban development.

Background and Problem Statement

The American Association of State Highway and Transportation Officials (AASHTO) defines the median as "the portion of divided highway separating the traveled way for traffic in opposing directions" (1). Since medians increase the separation between two opposing vehicles, it can be argued that medians, regardless of the type, improve traffic safety by reducing the potential for head-on collisions and by providing an area for errant or out-of-control vehicles to recover before entering oncoming traffic lanes. Depending upon their width, medians also improve safety by reducing headlight glare and providing an area out of the traffic stream for disabled vehicles to stop in case of emergencies. Medians also serve to improve traffic flow by providing motorists with a place to store (or wait) while making a left turn. Many motorists use the median area to accelerate or decelerate when turning either onto or off of a highway. In some cases, medians are used to reserve right-of-way for future roadway expansion.

A plan and perspective view for each of the three median types is provided in Figures 1-1 through 1-3. Each median type is used in different situations to achieve different levels of control over left-turn access to adjacent properties. The type of median used on a highway depends on a number of factors, including the following (1):

- the functional classification and location of the highway,
- the availability of right-of-way,
- the design speed of the highway,
- the type and intensity of development adjacent to the highway, and
- the desired level of control over left-turn access.

Median islands offer the highest degree of control over left turns into adjacent properties. Median islands use a physical "barrier" or "island" to separate opposing directions of traffic (see

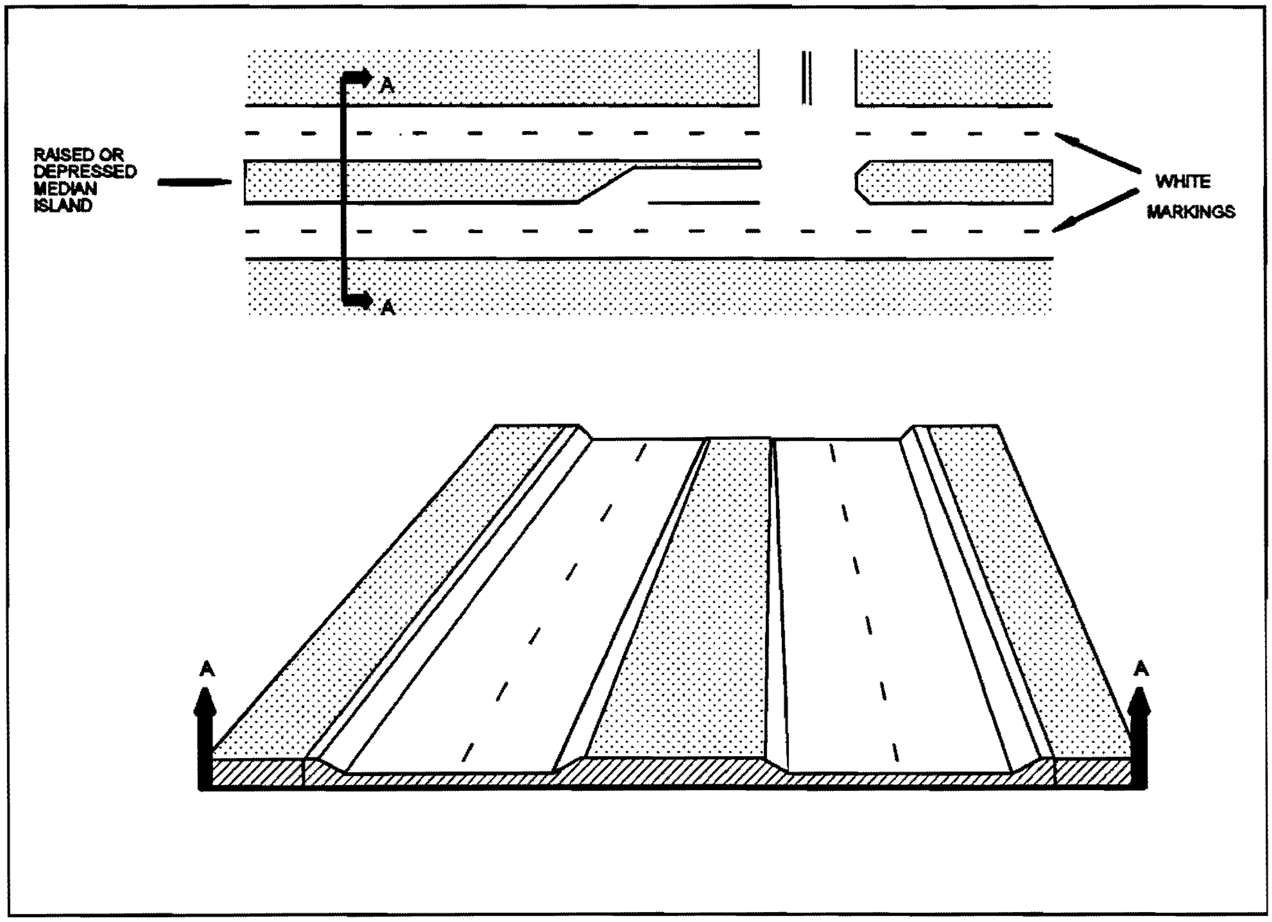

Figure 1-1. Plan and Perspective View of a Highway with a Raised Median Island.

Figure 1-1). Left-turn access is controlled through the placement of established breaks (or openings) in the median and at intersections. The median can range in width from as little as 4 feet (1.2 m) in highly developed areas, where right-of-way is extremely limited, to 76 feet (23.8 m) in suburban and rural areas, where right-of-way is typically less constrained. In general, raised medians are used on a higher functional class of highways, where it is desirable to maintain as little interruption to the through movement of traffic as possible. The Texas *Highway Design Division Operations and Procedures Manual* recommends that raised medians in urban areas "are most appropriate where driveways are infrequent and/or low volume (2)."

Two-way, left-turn lanes (TWLTLs) are at the other end of the spectrum in terms of the amount of control that can be exercised over left turns into adjacent properties. An example of a highway marked with a TWLTL is shown in Figure 1-2. With TWLTLs, left-turning vehicles have unlimited access to adjacent properties. TWLTLs can be used by left-turning vehicles from either direction on the highway. They are used as a storage area for left-turning vehicles waiting for appropriate gaps in the opposing traffic stream. Since the vehicle is physically removed from the main traffic stream, traffic engineering research has shown that both traffic safety and flow can be dramatically improved with the installation of a TWLTL on a highway (3, 4, 5). According to the Texas *Highway Design Division Operations and Procedures Manual*, TWLTLs should be used on urban highways where "there is a high demand for mid-block left turns, such as in areas with (or expected to experience) moderate or intense strip development (2)." AASHTO (1) provides the following recommendations concerning the use of TWLTLs:

> In general, continuous left-turn lanes should be used only in an urban setting where operating speeds are relatively low and where there are no more than two through lanes in each direction.

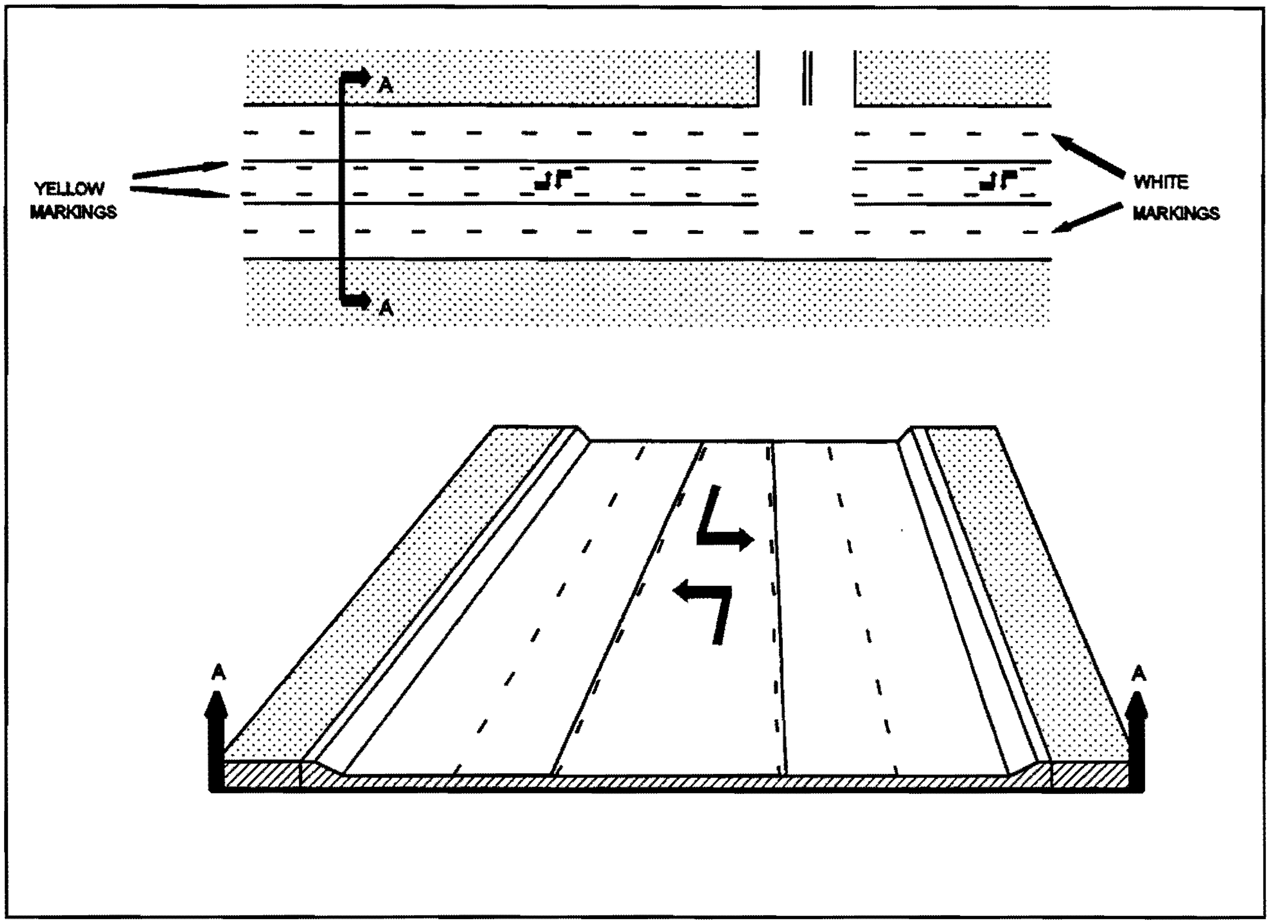

Figure 1-2. Plan and Perspective View of a Highway with a Two-Way, Left-Turn Lane.

The question arises as to what type of median is most appropriate on highways whose roadside development transitions from rural to urban or suburban conditions. The problem becomes particularly acute where rural highways enter small urban communities. As highways approach small urban communities, the amount of roadside development and, thereby, the left-turn demand begins to increase. There may be situations where it is desirable to separate opposing traffic streams and control access to adjacent properties without the expense of installing a median island.

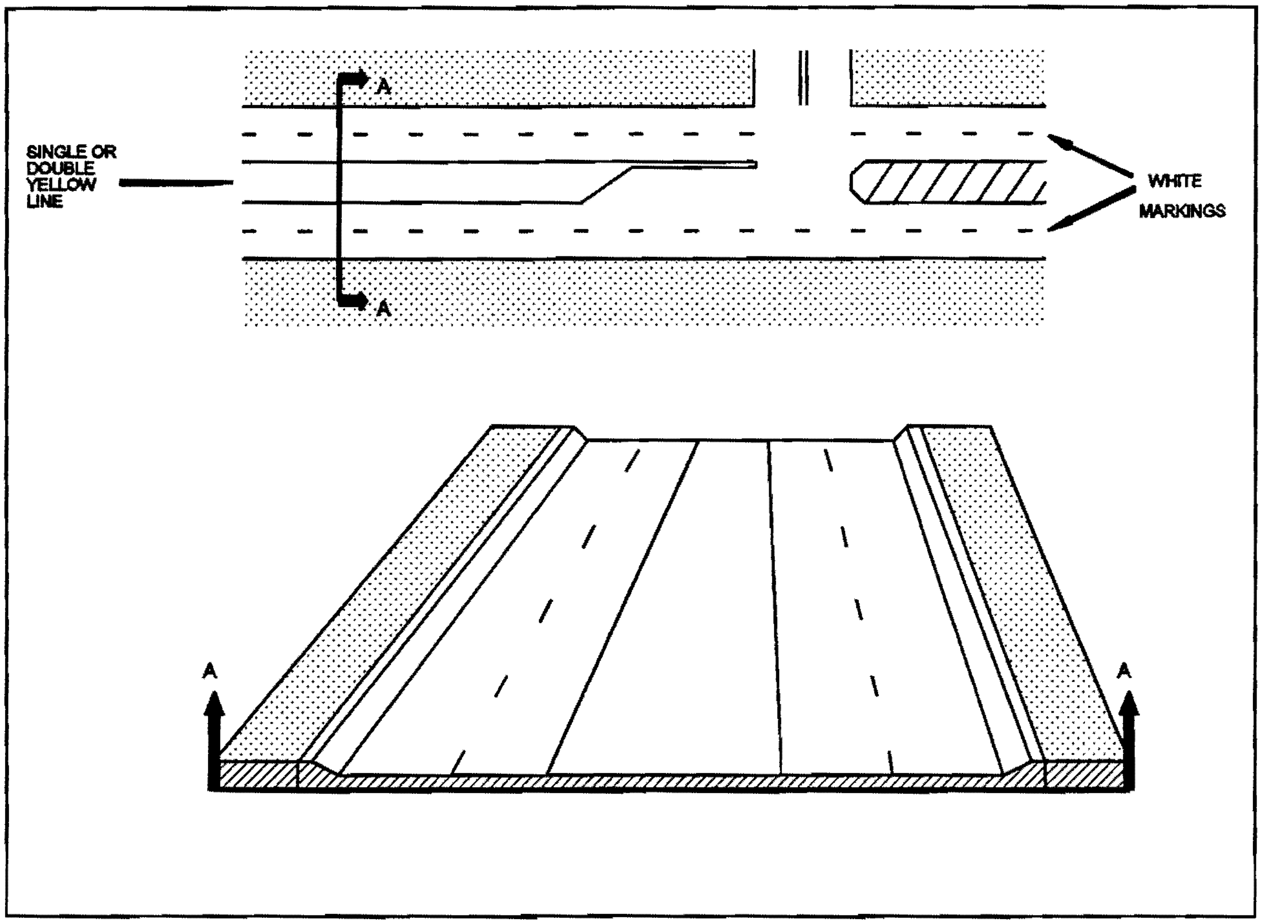

Figure 1-3. Plan and Perspective View of a Highway with a Flush Median.

In these situation, some jurisdictions use flush medians to separate opposing traffic streams. Flush medians combine many of the attributes and features of raised medians and TWLTLs. With the flush median design, the area between the travel lanes is at-grade (see Figure 1-3). The median area is marked with either a single solid yellow or double solid yellow line. Left-turn access to adjacent properties is provided at left-turn bays that have been striped at established locations. Since the median area is at-grade, it can be easily traversed by drivers turning into and out of adjacent properties. Many drivers tend to use flush medians like they are TWLTLs; however, this appears to be a violation of state law. Article VI, Section 62 "Driving on Divided Highway" of the *Texas Motor Vehicle Laws* (6) states:

> Whenever any highway has been divided into two (2) or more roadways by having an intervening space or by a physical barrier or clearly indicated dividing section so constructed as to impede vehicular traffic, every vehicle shall be driven only upon the right-hand roadway unless directed or permitted to use another roadway by official traffic-control devices or police officers. No vehicle shall be driven over, across or within any such dividing space, barrier or section, except through an opening in such physical barrier or dividing section or space or at a crossover or intersection as established by authority.

A recent legal opinion has interpreted this law as prohibiting the use of a flush median as a refuge area for left turns as well as prohibiting vehicles from turning across a flush median, except at established median openings (7). Therefore, there appears to be discrepancy between the legal interpretation and the physical way in which drivers use flush medians.

The purpose of this research was to examine the differences in the operations and safety between four-lane rural highways marked with TWLTLs and four-lane rural highways marked with flush medians. Researchers performed field studies in one TxDOT District (Lufkin) to measure how four-lane highways in fringe areas operate when they are marked with either a TWLTL or a flush median. A comparison of accidents on four-lane highways marked with TWLTLs and four-lane highways marked with flushed medians was also performed to determine whether or not there is a difference in the safety of highways with these types of median treatments. The results of these analyses were then used to provide recommendations on the application of flush medians on rural four-lane highways.

Organization of Report

The results of the evaluation of the operation and safety of TWLTLs and flush medians on rural four-lane highways is presented in the following chapters. Chapter 2 summarizes the results of safety evaluation of TWLTLs and flush medians on four-lane rural highways. Chapter 3 provides a summary of the procedures and finding of the operational evaluation. Conclusions and recommendations on the use of TWLTLs and flush medians on four-lane highways in rural areas are provided in Chapter 4.

CHAPTER 2. ANALYSIS OF ACCIDENTS

It is well-documented that installing a two-way, left-turn lane on a roadway that was previously undivided can dramatically improve both safety and operations. Research shows that accident rates decrease approximately 20 percent or more after installing TWLTLs on previously undivided highways (3, 4). Furthermore, installing TWLTLs can also reduce some types of accidents, such as rear-end and sideswipe accidents, by as much as 30 percent (4). This is because TWLTLs provide an area for left-turning vehicles to queue outside of the through travel lanes while waiting to turn. TWLTLs also provide a refuge and merging area for vehicles turning left out of adjacent properties.

However, little is known about the safety benefits of flush medians. A search of the literature did not reveal any studies evaluating the safety benefits of installing a flush median on a roadway that previously was undivided. Furthermore, we found no studies comparing the operational and safety effects of TWLTLs and flush medians.

This chapter provides a comparison of accident rates and accident severity for roadways marked with TWLTLs and flush medians. The comparison is based on three years of accident data. Both total accident and mid-block accident rates are used in the comparison. All of the sites used in the comparison were located near Lufkin, Texas in an attempt to control for regional differences between drivers.

Analysis Procedures

A comparative approach was used to evaluate the safety effects of TWLTLs and flush medians on four-lane rural highways in Texas. Accident rates from sites that experienced similar traffic volumes and roadside development, but had different median treatments (i.e., either a TWLTL or a flush median), were used in the comparison. Researchers used analysis of variance procedures to determine whether or not there was a statistical difference in the accident rates between the roadways marked with the different median treatments. Initially, the analysis sought to compare differences in accident rates and accident severity on four-lane rural highways with median islands, TWLTLs, and flush medians; however, the raised/depressed median sites had to be eliminated from the analysis because, as a group, they did not have the same operating characteristics (i.e., traffic volumes and roadside development levels) as the TWLTL and flush median groups for the sites available in the Lufkin District.

Study Sites

When using a comparative approach in studying accident statistics, it is important that the study locations have similar operating characteristics and roadside development levels. This is done to ensure that the effects of the different median treatments, not differences in study locations, are evaluated. For this reason, all of the sites used in the accident analysis were taken from the Lufkin District. By using study locations from the same District, it was believed that regional differences in driving population and growth patterns were controlled in the analysis. Also, the Lufkin District is primarily rural in nature. Since the emphasis of this study was on the operational and safety effects of TWLTLs and flush medians in rural areas, the study focused on the rural driving population. Finally (and perhaps most importantly), flush medians are a common type of median treatment used in the Lufkin District. This made locating potential study sites for both the safety and operational studies somewhat easier.

Potential sites were initially identified using TxDOT's Roadway Inventory Database. Candidate locations were identified based on pavement width, number of lanes, and roadway classification (i.e., rural versus urban). The Lufkin District was then asked to identify the type of median treatment used at each of the candidate locations. In addition, the Lufkin District provided drive-through video recordings of all the flush median and TWLTL sites. The video recordings were later used to estimate the driveway densities at each site.

Table 2-1 provides a summary of the locations used in the analysis. Initially, six sites were located on highways with TWLTLs, and three sites were on highways with flush medians.

Accident Rates

Accident frequencies were obtained for each of the study sites using the Texas Accident Database maintained by the Texas Department of Public Safety. We then converted accident frequencies to accident rates using the corresponding traffic volumes from each of the study sites. Accident rates were used to account for differences in the length of each of the study sites. Rates were developed using three years (1989, 1990, and 1991) of accident statistics at each of the sites. Both total accident rates and mid-block accident rates were computed for each year from these statistics.

To compute the total accident rate, we used all reported accidents occurring at a study location (including those accidents classified as intersection and intersection-related in the TxDOT Accident Database). It was believed that this rate provided a true representation of the total accident experience on highways with the different median treatments. This rate included accident data from both signalized and unsignalized intersections.

The researchers also used mid-block accident rates in an attempt to isolate the effects of the median treatment itself on safety. It was developed using the accidents identified in the database as occurring in the mid-block sections between intersection locations. It does not include accidents that were classified as occurring at signalized or unsignalized intersections. However, the rate does include accidents specifically related to vehicles entering and exiting adjacent properties through driveways. It was hypothesized that a high mid-block accident rate indicated potential problems with vehicles using the median to turn into and out of adjacent properties.

Table 2-1. Characteristics of Sites Used in Accident Analysis.

Highway	Control Section	Milepoint		Length (Miles [km])	County	Type of Median	Average Daily Traffic		
		Beginning	Ending				1989	1990	1991
US-59 / LP 495	17601	22.84	23.62	0.78 [1.25]	Nacogdoches	TWLTL	11971	11455	11605
FM 1275	140703	3.356	4.718	1.36 [2.19]	Nacogdoches	TWLTL	16216	17219	17503
US-59	17509	0	1.032	1.03 [1.66]	Rusk	TWLTL	5500	5700	5780
SH-103	33605	0	1.371	1.37 [2.21]	Angelina	TWLTL	8206	7694	7802
US-69	19904	21.6	23.06	1.46 [2.34]	Angelina	TWLTL	13100	12800	13010
LP 304	185401	6.3	7.37	1.07 [1.72]	Houston	TWLTL	7287	7232	7353
US-59	6306	0.600	2.165	1.56 [2.52]	Shelby	Flush	6960	6920	7017
US-69	19904	14.100	17.605	3.51 [5.64]	Angelina	Flush	6500	6700	6799
LP 224	256001	5.100	5.744	0.64 [1.04]	Nacogdoches	Flush	15400	17200	17486

In addition to examining the effects of the different median treatments on accident rates, the analysis also examined how the different median treatments may have affected the severity of accidents at a site. Since major accidents (i.e., fatalities) tend to be random events on rural highways, we grouped mid-block accident statistics into three severity categories based upon the severity rating assigned to each individual accident by the investigating police officer:

- *Severe* -- accidents resulting in a fatality or incapacitating injury,
- *Minor* -- accidents where the reporting officer noted a non-incapacitating or possible injury as a result of the accident, and
- *Non-injury* -- accidents that resulted in property damage only

Using these severity categories, we developed accident severity rates for each of the three years at each individual study site. Tables 2-2 and 2-3 summarize the total accident rates, mid-block accident rates, and the accident severity rates for each of the study sites.

Accident Analysis

Analysis of variance techniques were used to determine whether accident rates and severity differed between highways with flush medians and highways with TWLTLs. Using these techniques, it was possible to statistically determine what proportion of the total difference in the accident rates and severity on the highways could be attributed to the different median treatments, and what proportion was due to random effects within sites with similar median treatments. The analysis consisted of two phases:

- a comparison of traffic volumes between sites with different median treatments, and
- a comparison of accident rates and severity for highways with different median treatments (i.e., flush medians and TWLTLs).

Table 2-2. Summary of Accident Rates for Study Sites with TWLTL Median Treatments.

Highway	Control Section	Year	Accident Rate*		Severity (Mid-Block Accidents)*		
			Total	Mid-Block	Severe	Minor	Non-Injury
US-59/ LOOP 495	17601	1989	4.988 [(8.03]	2.347 [3.78]	0.000 [0.00]	1.174 [1.89]	1.174 [1.89]
		1990	2.760 [4.44]	0.920 [1.48]	0.000 [0.00]	0.307 [0.49]	0.613 [0.99]
		1991	4.843 [7.79]	2.724 [4.38]	0.303 [0.49]	0.908 [1.46]	1.513 [2.43]
FM 1275	140703	1989	5.582 [8.98]	2.605 [4.19]	0.124 [0.20]	0.496 [0.80]	1.985 [3.19]
		1990	7.009 [11.28]	3.972 [6.39]	0.234 [0.28]	1.402 [2.26]	2.336 [3.76]
		1991	6.781 [10.91]	3.448 [5.55]	0.000 [0.00]	0.690 [1.11]	2.758 [4.44]
US-59	17509	1989	0.000 [0.00]	0.000 [0.00]	0.000 [0.00]	0.000 [0.00]	0.000 [0.00]
		1990	0.000 [0.00]	0.000 [0.00]	0.000 [0.00]	0.000 [0.00]	0.000 [0.00]
		1991	0.919 [1.48]	0.919 [1.48]	0.000 [0.00]	0.000 [0.00]	0.919 [1.48]
SH-103	33605	1989	4.383 [7.05]	1.948 [3.13]	0.244 [0.39]	0.487 [0.78]	1.218 [1.96]
		1990	3.117 [5.02]	1.818 [2.93]	0.000 [0.00]	0.779 [1.25]	1.039 [1.67]
		1991	1.025 [1.65]	0.256 [0.41]	0.000 [0.00]	0.000 [0.00]	0.256 [0.41]
US-69	19904	1989	1.005 [1.62]	1.005 [1.62]	0.287 [0.46]	0.144 [0.23]	0.574 [0.92]
		1990	0.735 [1.18]	0.735 [1.18]	0.147 [0.24]	0.294 [0.47]	0.294 [0.47]
		1991	0.723 [1.16]	0.578 [0.93]	0.000 [0.00]	0.578 [0.93]	0.000 [0.00]
LOOP 304	185401	1989	1.757 [2.83]	1.757[2.83]	0.000 [0.00]	0.000 [0.00]	1.757 [2.83]
		1990	3.186 [5.13]	3.186 [5.13]	0.708 [1.64]	0.708 [1.14]	1.770 [2.85]
		1991	2.438 [3.92]	2.089 [3.36]	0.000 [0.00]	1.045 [1.68]	1.045 [1.68]

* Accidents per Million Vehicle Miles [Accidents per Million Vehicle kilometers]

Table 2-3. Summary of Accident Rates for Study Sites with Flush Median Treatments.

Highway	Control Section	Year	Accident Rate*		Severity (Mid-Block Accidents)		
			Total	Mid-Block	Severe	Minor	Non-Injury
US-59	6306	1989	2.012 [3.24]	1.006 [1.62]	0.503 [0.81]	0.252 [0.41]	0.252 [0.41]
		1990	1.012 [1.63]	0.506 [0.81]	0.000 [0.00]	0.506 [0.81]	0.000 [0.00]
		1991	0.499 [0.80]	0.249 [0.40]	0.000 [0.00]	0.000 [0.00]	0.249 [0.40]
US-69	19904	1989	0.722 [1.16]	0.601 [0.97]	0.241 [0.39]	0.000 [0.00]	0.361 [0.58]
		1990	0.583 [0.94]	0.467 [0.75]	0.117 [0.19]	0.233 [0.37]	0.117 [0.19]
		1991	0.690 [1.11]	0.345 [0.55]	0.000 [0.00]	0.115 [0.19]	0.230 [0.37]
US-59/ LOOP 224	256001	1989	0.829 [1.33]	0.829 [1.33]	0.000 [0.00]	0.552 [0.89]	0.276 [0.44]
		1990	1.731 [2.79]	1.731 [2.79]	0.000 [0.00]	0.495 [0.80]	1.237 [1.99]
		1991	0.730 [1.17]	0.730 [1.17]	0.000 [0.00]	0.243 [0.39]	0.487 [0.78]

*Accidents per Million Vehicle Miles [Accident per Million Vehicle kilometers]

Comparison of Volume Levels

Before the accident rates could be studied, the volume levels at the sites were first analyzed to determine whether or not changes had occurred over time. This was important because differences in traffic volumes may mask differences in accident rates for roadways with different median treatments. If the volume levels at the sites were relatively equal over time, then any changes in accident rates over time between sites with different median treatments could be attributed to the median treatment, rather than the differences in site characteristics. If, on the other hand, the volume levels changed over time for the sites, it would not be possible to tell whether differences in the accident rates could be attributed to differences in the safety performance of the median treatments or changes in the traffic volumes that were operating on the roadways.

Average Daily Traffic (ADT) volumes were compared for sites in each of the median treatment types. We retrieved these volumes from the TxDOT Roadway Inventory Database. We obtained ADT volumes for each of the three years used in the analysis. Analysis of variance techniques were used to test the following:

- whether the volume levels differed statistically over each of the three years for each of the sites with a particular category of median treatment, and

- whether the average ADT volumes of all the sites with flush median treatments and TWLTLs differed from one another.

As shown in Table 2-4, the results of the analysis of variance showed that the ADT volume levels remained relatively constant over the three year period (i.e., were not statistically different at a 95 percent confidence level). The results of the analysis of variance did show, however, that the ADT levels at the TWLTL and flush median sites were not statistically different. Because all the sites came from the same general area, any observed differences in accident rates or severity were assumed to be caused by the different median treatments, rather than by traffic volumes or other extraneous factors.

Table 2-4. Comparison of ADT Volumes for Highways with Different Median Treatments.

Median Treatment	Sample Size	Average Daily Traffic (ADT)			Significant Difference Between Years?	Average ADT (vph)	Significant Difference Between ADTs?
		1989	1990	1991			
TWLTL	6	10,380	10,348	10,412	No	10,412	No
Flush Median	3	9,620	10,273	10,434	No	10,109	No

Analysis of Accident Rates and Severity

Once we determined that the traffic volumes on the roadways with the TWLTLs and the flush medians were similar, we again used analysis of variance techniques to determine whether there was a significant difference between the accident rates and severity of highways marked with TWLTLs and highways marked with flush medians. Again, three years of accident statistics were used in the analysis. The analysis examined the total and mid-block accident rates, as well as severe, minor, and non-injury accident rates. Differences in accident rates were assessed at a 95 percent confidence level.

Table 2-5 summarizes the results of the comparison. As shown in this table, statistically significant differences were found in all of the accident rates, except in the rates of severe and minor accidents. This suggests that highways with TWLTLs typically experience higher accident rates, both in terms of total and mid-block accidents, than highways marked with flush medians. These results also suggest that, generally, the rates of non-injury accidents tend to be higher on roadways that have a TWLTL than those with a flush median.

Table 2-5. Comparison of Accident Rates for Rural Highways with TWLTLs and Highways with Flush Medians.

Type of Accident Rate	Average Accident Rates (Accidents/MVM [Accidents/MVkm])*		Significant Difference?
	TWLTL	**Flush Medians**	
Accident Rates			
Total	2.85 [4.85]	0.98 [1.58]	Yes
Mid-Block	1.68 [2.70]	0.72 [1.16]	Yes
Accident Severity Rates			
Severe	0.11 [0.18]	0.10 [0.16]	No
Minor	0.50 [0.80]	0.27 [0.43]	No
Non-injury	1.07 [1.72]	0.36 [0.58]	Yes

* MVM = Million Vehicle Miles
MVkm = Million Vehicle kilometers

However, these results were not supported by the results of the operational field studies (as discussed in Chapter 3). For this reason, we performed a more detailed review of the characteristics of the individual sites. As shown in Table 2-6, considerable differences existed between the characteristics of some of the TWLTL sites and the flush median sites. Specifically, several of the TWLTL sites had considerably higher driveway densities. Since the number of access points is anticipated to have a significant impact on accident rates on a highway, the TWLTL sites with the high driveway densities could not be considered comparable to the flush median sites. Therefore, we dropped from the analysis those TWLTL sites that had driveway densities above 9.0 driveways per mile (14.5 driveways per kilometer).

Table 2-6. Characteristics of Individual TWLTL and Flush Median Sites.

Median Treatment	Highway	Control Section	Length (Miles [km])	Posted Speed Limit (mph [kmph])	Driveway Density (Drwy/Mile [Drwy/km])
TWLTLs	US 59	17601	0.8 [1.29]	50 [80]	62.5 [100.6]
	FM 1279	140703	1.4 [2.25]	45 [72]	29.3 [47.1]
	US 59	17509	1.0 [1.61]	55 [88]	6.0 [9.6]
	SH 103	33605	1.3 [2.10]	45 [72]	19.2 [30.9]
	US 69	19904	1.0 [1.61]	55 [88]	1.50 [24.1]
	LP 304	185401	1.0 [1.61]	50 [80]	8.0 [12.9]
Flush Median	LP 224 / US 59	256001	0.6 [0.97]	55 [88]	8.3 [13.3]
	US 59	6306	1.5 [2.41]	55 [88]	8.7 [14.0]
	US 69	19904	3.5 [5.63]	55 [88]	7.7 [12.4]

After eliminating the TWLTL sites that had significantly higher driveway densities, accident and severity rates were compared again using analysis of variance techniques. As indicated in Table 2-7, the results of the analysis showed that there was no significant difference in either total accident rate or mid-block accident rate for highways marked with a TWLTL and highways using a flush median treatment. No statistical difference was observed between the rates of severe, minor, and non-injury accidents either. Therefore, it can be concluded that on highways with comparable characteristics (i.e., driveway densities and posted speed limits) one type of median treatment is not superior to the other, at least from a safety standpoint.

It should be noted, however, that this conclusion is only valid for highways with a relatively low level of development (i.e., with a driveway density of less than 9.0 driveways per mile [14.5 driveways per kilometer]). There may be a significant difference in the safety performance of highways using TWLTL and flush median treatments, where the driveway densities are higher. However, since highways with flush medians and high driveway densities could not be found for this analysis, this hypothesis remained untested in this study.

Table 2-7. Comparison of Accident Rates at TWLTL and Flush Median Sites with Low Driveway Densities.

Type of Accident Rate	**Average Accident Rate (Accidents/MVM [Accidents/MVkm])***		**Significant Difference ?**
	TWLTL	**Flush Median**	
Accident Rate			
Total	1.38 [2.22]	0.98 [1.58]	No
Mid-Block	1.33 [2.14]	0.72 [1.16]	No
Accident Severity Rate			
Severe	0.12 [0.19]	0.10 [0.16]	No
Minor	0.29 [0.47]	0.27 [0.43]	No
Non-Injury	0.92 [1.48]	0.36 [0.58]	No

* MVM = Million Vehicle Miles
MVkm = Million Vehicle kilometers

Findings

Comparisons of accident rates were performed on highways using two different median treatments: TWLTLs and flush medians. We used analysis of variance techniques to compare the total and mid-block accident rates from highways in the Lufkin District with these median treatments. The rates of severe, minor, and non-injury mid-block accidents were also compared.

The analysis found that, at low driveway densities, there was no statistical difference in the total or mid-block accident rates for highways with TWLTLs and highways with flush medians. Furthermore, the rates of severe, minor, and non-injury accidents were not statistically different for highways with these types of median treatments. Therefore, it was concluded that there was no difference in the way that these two median treatments function, from a safety standpoint, on rural four-lane highways where driveway densities were low.

However, this relationship may not be true as highways transition from rural to suburban fringe areas. Since no flush median sites with high driveway densities could be found to include in the comparison, there was no evidence to support (or refute) the premise that flush medians and TWLTLs have similar accident experiences at higher driveway densities.

CHAPTER 3. TRAFFIC OPERATING CHARACTERISTICS OF FLUSH MEDIANS AND TWLTLS IN RURAL AREAS

Field studies were performed to evaluate the traffic operational characteristics of flush medians and two-way, left-turn lanes on four-lane rural highways. The purpose of this chapter is to summarize the results of the field studies. The primary goal of the field studies was to determine whether or not there was any difference in the operations of flush medians and two-way, left-turn lanes on four-lane rural highways in Texas.

Methodology

For this operational study, it is reasoned that if the frequencies of traffic executing particular maneuvers (i.e., left turns from a through lane, left turns from within the median treatment, etc.) are similar at each type of median treatment, then the two median treatments are considered to be performing similar functions (i.e., serving as refuge or storage area for left turning vehicles, etc.). To test this hypothesis, we performed field studies to observe how vehicles use the two different median treatments in rural areas to make left turns into and out of adjacent businesses. We collected turning movement volumes at select driveway locations on four-lane rural roadways striped with a flush median or a two-way, left-turn lane. These data were then used to assess whether there was a difference in left turning traffic patterns for four-lane rural highways that were marked with a flush median and four-lane rural highways that were marked with a two-way, left-turn lane.

Study Sites

Operational data were collected at a total of four sites. Three of the sites were located on US 69 to the west of Lufkin, Texas. One of these sites was located in an area of US 69 that has been striped with a two-way, left-turn lane (Site #1). At this site, we observed traffic entering and exiting a gasoline station/convenience store. The two other sites on US 69 were located in a portion of the highway that has been striped with a flush median. One of these two driveways provides access to a laundromat (Site #2), while the other driveway (Site #3) provides access to a storage yard of a construction company. There were no high volume generators located in the flush median section of US 69 that could be used in the data collection effort.

The fourth site (Site #4) was located on US 59/Loop 224 on the outskirts of Nacogdoches, Texas. US 59/Loop 224 is, for the most part, a divided roadway that passes to the west of Nacogdoches. However, a portion of roadway [approximately a half mile (0.8 km) in length] is striped as a flush median. We collected operational data at a driveway that provides access to a gasoline station/convenience store. This particular site is very similar in characteristics and traffic volumes to the two-way, left-turn site on US 69 in Lufkin (Site #1). Table 3-1 summarizes the important characteristics of each of the sites examined during the study.

Table 3-1. Characteristics of Field Study Sites.

Characteristic	Site #1	Site #2	Site #3	Site #4
Designation	US-69	US-69	US-69	US-59/ Loop 224
Median Treatment	TWLTL	Flush	Flush	Flush
Location	Lufkin	Lufkin	Lufkin	Nacogdoches
Development Pattern	Urban Fringe	Rural	Rural	Urban Fringe
ADT (1990)	11000	6700	6700	17200
Driveway Access	Gas Station/ Convenience Store	Laundromat	Construction Company	Gas Station/ Convenience Store

Data Collection

Manual turning movement counts were performed at each of the four sites. We collected two hours of turning movement data during three data collection periods: A.M. (7:00-9:00), Noon (11:30-1:30), and P.M. (4:30-6:30). These time periods were assumed to have the greatest probability of traffic performing the desired turning movements into the selected study locations. We recorded turning movement volumes in 15-minute intervals for the entire duration of the two hour data collection period. Figure 3-1 illustrates the type of turning movements collected during the data collection effort.

Traffic volume and turning movement counts were performed both for traffic traveling on the highway and for traffic exiting the selected driveway at each site. For the highway traffic, we grouped vehicle turning movements into the following categories:

- *Total Traffic* = the sum of all through and turning traffic traveling in both direction on the highway at the driveway location;

- *Total Left-Turning Traffic Entering Driveway* = the sum of all left-turning traffic entering the study driveway by turning left from the through lanes, turning left from the median area, or turning right after executing a U-turn at a nearby median opening (Movements 6, 7, and 8 in Figure 3-1);

- *Left Turn from Median Area* = the number of vehicles entering the study driveway by turning left from within the median area (Movement 6 in Figure 3-1);

- *Left Turn from Through Lanes* = the number of vehicles entering the study driveway by turning left from a through travel lane (Movement 7 in Figure 3-1); and

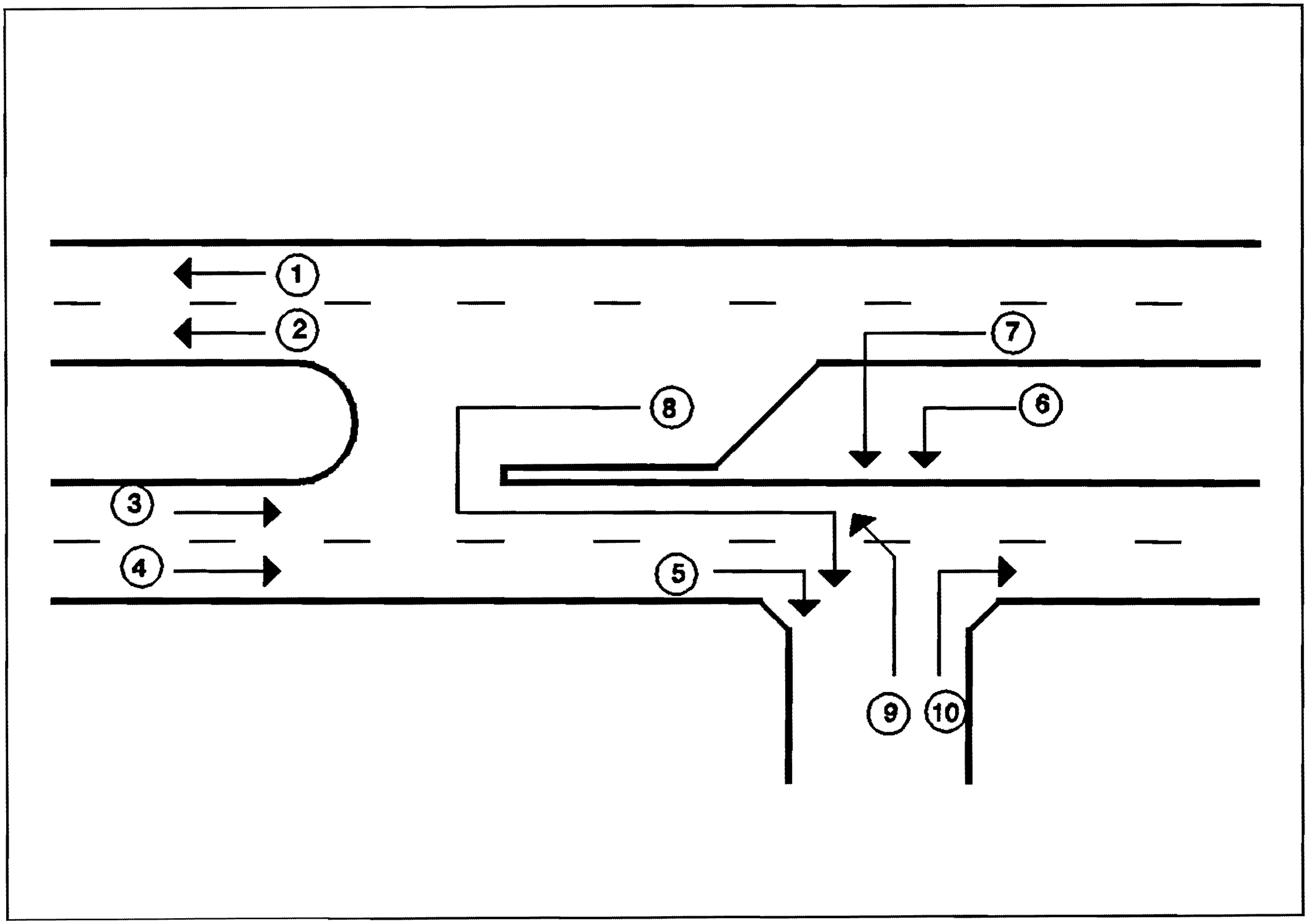

Figure 3-1. Vehicle Movements Collected During Field Studies.

- *Right Turn After U-turn at Median Opening* = the number of vehicles entering the study driveway by making a right turn after performing a U-turn at a nearby median opening (Movement 8 in Figure 3-1).

For vehicles exiting the study driveway, vehicle turning movements were grouped into the following categories:

- *Total Exiting Traffic* = the sum of all left-turning and right-turning traffic exiting the site through the study driveway (Movements 9 and 10 in Figure 3-1);

- *Exiting Left Turn* = the number of vehicles exiting the site through the study driveway by performing a left-turn maneuver (Movement 9 in Figure 3-1); and

- *Number of Two-Stage Movement* = the number of left-turning exiting vehicles that used the median either as an acceleration lane or as a storage (or waiting) area to execute a two-stage, left-turn maneuver.

We also recorded operations at each of the study sites on video tape during the times for which turning movement data were collected. The video tape served as a backup to the manual counts in case additional *post hoc* analyses were desired or if clarifications of the data were required.

Data Reduction

Summary tables showing the number of vehicles performing each type of maneuver are presented in Tables 3-2, 3-3, and 3-4 for the A.M., Noon, and P.M. data collection periods, respectively. These data were then used to compute the following operational measures:

Table 3-2. Summary of Turning Movements for A.M. Data Collection Period.

	Site #1	Site #2	Site #3	Site #4
Major Road				
Total Traffic	1784	902	815	1899
Total Left-Turning Traffic Entering Driveway	24	5	3	43
• Left Turn from Through Lane	0	0	0	0
• Left Turn from Median Area	24	3	3	42
• Right Turn After U-Turn at Median Opening	0	2	0	1
Minor Road				
Total Traffic	53	5	4	100
Exiting Left Turn	26	0	1	38
Number of Two-Stage Maneuvers	2	0	0	1

Table 3-3. Summary of Turning Movements for Noon Data Collection Period.

	Site #1	Site #2	Site #3	Site #4
Major Road				
Total Traffic	1597	871	726	2251
Total Left-Turning Traffic Entering Driveway	21	1	3	45
• Left Turn from Through Lane	0	0	0	0
• Left Turn from Median Area	21	1	3	45
• Right Turn After U-Turn at Median Opening	0	0	0	0
Minor Road				
Total Traffic	36	2	5	109
Exiting Left Turn	12	2	1	55
Number of Two-Stage Maneuvers	1	0	0	2

Table 3-4. Summary of Turning Movements for P.M. Data Collection Period.

	Site #1	Site #2	Site #3	Site #4
Major Road				
Total Traffic	2284	1489	909	2396
Total Left-Turning Traffic Entering Driveway	34	0	0	28
• Left Turn from Through Lane	0	0	0	0
• Left Turn from Median Area	34	0	0	28
• Right Turn After U-Turn at Median Opening	0	0	0	0
Minor Road				
Total Traffic	56	8	5	94
Exiting Left Turn	31	5	3	44
Number of Two-Stage Maneuvers	2	0	NA(1)	NA(1)

(1) Data are not available due to malfunction of video equipment.

- the percentage of left-turning traffic that turned from within the marked median (i.e., used the median as a storage area),
- the percentage of left-turning traffic entering the driveway that turned outside of the marked median (i.e., turned left from a through lane), and
- the percentage of exiting traffic that used the median for a two-stage left turn maneuver.

For the most part, traffic volumes, driveway density, and type of development were higher in the portion of US 69 that contained the two-way, left-turn lane site. The flush median sites were generally located in a more rural area with lower driveway densities and less traffic volumes. As a result, we observed a very limited amount of traffic entering and exiting the driveways for the two flush median sites on US 69.

Study Results

Tables 3-5 through 3-7 show the percentage of vehicles entering and exiting the sites for the three data collection periods, respectively. From these tables, it can be seen that, for the most part, the majority of drivers execute their turns from the median area, regardless of how it is striped. At all but one location, almost all of the traffic observed entering the four study sites did so using the median area.

Table 3-5. Percentage of Turning Traffic Utilizing Median Area During A.M. Period.

Movement	Site #1	Site #2	Site #3	Site #4
Left Turn from Median Area	100%	60%	100%	98%
Left Turn from Through Lane	0%	0%	0%	0%
Right Turn after U-Turn at Median Opening	0%	40%	0%	2%
Exiting Traffic Using Median as Storage Area	8%	0%	0%	3%

Table 3-6. Percentage of Turning Traffic Utilizing Median Area During Noon Period.

Movement	Site #1	Site #2	Site #3	Site #4
Left Turn from Median Area	100%	100%	100%	100%
Left Turn from Through Lane	0%	0%	0%	0%
Right Turn after U-Turn at Median Opening	0%	0%	0%	0%
Exiting Traffic Using Median as Storage Area	8%	0%	0%	4%

Table 3-7. Percentage of Turning Traffic Utilizing Median Area During P.M. Period.

Movement	Site #1	Site #2	Site #3	Site #4
Left Turn from Median Area	100%	-(1)	-(1)	100%
Left Turn from Through Lane	0%	-(1)	-(1)	0%
Right Turn after U-Turn at Median Opening	0%	-(1)	-(1)	0%
Exiting Traffic Using Median as Storage Area	6%	0%	N.A.(2)	N.A.(2)

(1) No vehicles were observed entering the driveways during the data collection period.
(2) Data were not available due to a malfunction with the video equipment.

It is important to note that no vehicles were observed turning left from the through lane at any of the flush median sites. The data suggest that drivers do not perceive the striped median as an area prohibited to travel and use the flush median as they would a two-way, left-turn lane.

Except for the A.M. period at Site #2, relatively few vehicles were observed traveling to an established median opening and performing a U-turn to access the sites. At Site #2, 40 percent of the vehicles entering the site did so after making a U-turn at a nearby median opening. However, it should be noted that this observation is based on an extremely limited number of vehicles entering the driveway. In terms of actual counts, the 40 percent of traffic entering the site after making a U-turn represents two of the five vehicles using the driveway.

We observed less than 10 percent of the left-turn exiting traffic at each of the sites using the median as a storage area or as an acceleration lane. A test of proportions was used to test if the difference in the observed percentages of exiting traffic using the median for storage or acceleration at Site #1 and Site #4 were statistically significant. Although a greater percentage of left-turn traffic exiting the driveway at the TWLTL site used the median, the test indicated that there was no statistical difference in the percentages for Site #1 and Site #4 in both the A.M. and Noon data collection periods. Due to a malfunction in the video recording equipment, we were not able to obtain data for the P.M. period at Site #4. Therefore, a comparison of the use of the median at Site #1 and Site #4 could not be performed for the P.M. peak. However, the comparison of the A.M. and Noon periods implies that there is no difference in the way in which motorists use a flush median or TWLTL when exiting the driveways.

Findings

We performed field studies to examine whether or not there is a difference in the way that flush medians and two-way, left-turn lanes function on four-lane, rural highways. Operational turning movement and median use data were collected at four driveway locations on two four-lane, rural highways in the Lufkin District in Texas. Three of the driveways were located on highways that had a flush median treatment while the fourth driveway was located in a section of rural highway that used a two-way, left-turn lane to separate opposing directions of traffic.

Traffic volume and turning movement data were collected at these study sites. We collected data for two-hours in each of the A.M., Noon, and P.M. peak periods at each of the four sites. These data collection periods were selected to maximize the potential of observing sufficient entering and exiting traffic at the study locations.

The results of the field studies indicate that for all practical purposes, there is no difference in the way that flush medians and two-way, left-turn lanes function on four-lane rural highways when comparing each of the periods observed. For the most part, the proportion of drivers using the flush median as a storage area (both when entering and exiting a driveway) were equal to the proportion of the drivers using the two-way, left-turn lane for the same purposes. In fact, nearly all of the vehicles observed entering the driveway at all of the sites were observed turning left from the median area. Very few vehicles were observed turning left from the through lanes or going to a nearby median opening to access the study sites. Therefore, we concluded that, based on the operational data that has been collected, there was no difference in how flush medians and two-way, left-turn lanes function on four-lane, rural highways.

Since drivers are using flush medians and TWLTL similarly, this suggests that the type of median used on these roadways should be similar. The Manual on Uniform Traffic Control Devices (MUTCD) (8) recognizes the need for the uniform application of traffic control devices, stating that similar situations should be treated in similar ways. Since it is illegal for drivers to use a flush median as left-turn lanes to access adjacent properties, the findings of this research suggest that in situations where denying access to adjacent properties is not needed, it may be more appropriate to use the TWLTL on a four-lane rural highway rather than a flush median. Using TWLTLs in these situations would promote the uniform application of pavement markings in situations where left turns are permitted to adjacent properties.

The use of flush medians should be reserved for situations where there are operational and safety concerns that require access to be controlled to adjacent properties. In cases where it is desirable to control access, however, a high level of enforcement will also be needed to assure that drivers use the flush median as intended. Without enforcement, flush medians do *not* appear to be effective in controlling access to adjacent properties. Therefore, to be effective, almost constant enforcement will be required to restrict left-turn access across flush medians. Since it is impractical to have constant enforcement in most situations, the only truly effective way of controlling left-turn access is by installing a physical barrier, such as a raised or depressed medians island or a median barrier. With this type of treatment, left-turn access to adjacent properties is restricted to established median openings, whose location and design can be controlled by the highway agency.

CHAPTER 4. SUMMARY AND RECOMMENDATIONS

Medians on both rural and urban highways serve many functions, including separating opposing streams of traffic, reducing headlight glare, providing a recovery area for errant vehicles, and providing storage and acceleration/deceleration areas for turning vehicles. The type of median (i.e, flush, raised or depressed, or TWLTL) used on a highway depends on a number of factors:

- the functional classification of the highway,
- the design speed of the highway,
- the amount and availability of right-of-way,
- the type and intensity of development adjacent to the highway, and
- the desired level of control over left-turn access into the properties adjacent to the highway.

The question arises as to what type of median is most appropriate on highways where the roadside development transitions from rural to suburban. In these situations, some TxDOT districts in Texas use flush medians to separate opposing traffic streams. Flush medians combine many of the attributes and features of raised or depressed medians and TWLTLs. Unfortunately, there are no clear guidelines indicating when flush medians are appropriate on four-lane rural highways.

The purpose of this research was to examine the differences in the operations and safety of four-lane rural highways with TWLTLs and four-lane rural highways with flush medians. Safety was evaluated by reviewing three years of accident records from four-lane rural highways with both of these types of median treatments in the TxDOT Lufkin District. Total accident rates, mid-block accident rates, and three levels of accident severity were analyzed. This review found that there was no statistical difference in accident rates and severity between highways with TWLTLs and highways with flush medians when driveway densities were low (i.e, less than 9 driveways per mile [14.5 driveways per kilometer]). Due to the limited number of flush median sites, however, it was not possible to determine if there is a difference in safety between these two median treatments at higher levels of development (i.e., with driveway densities greater than 9 driveways per mile[14.5 driveways per kilometer]).

We also performed field studies to evaluate the traffic operational characteristics of flush medians and TWLTLs on four-lane rural highways. Observations of how vehicles used the median area on highways with these two median treatments were performed. We collected turning movement volumes at select driveway locations on four-lane rural roadways striped with a flush median or a TWLTL. These data were used to assess whether there was a significant difference in the way that left-turning vehicles used the median area.

The field studies found that for all practical purposes, there was no difference in the way drivers used highways marked with TWLTLs and highways marked with flush medians. Generally, an equal number of drivers were observed using the flush median as a storage area and an acceleration lane as drivers that use the TWLTL. Based on the operational data, it was concluded that there was no difference in the way that flush medians and TWLTLs function on four-lane rural highways.

Recommendations

Based on the results of this study, it appears that drivers are ignoring the meaning of the flush median marking. The results have indicated that drivers perceive no difference in the way they should use a flush median and a TWLTL on four-lane rural highways. Therefore, it is recommended that in order to promote uniform application of traffic control devices, flush medians be used only in situations where the location and spacing of driveways permit left-turn bays to be installed at every driveway location. This would provide drivers with an area to store and decelerate when executing a left turn from the highway. If it is not possible to provide median openings at every driveway, then it is recommended that a TWLTL be used. Using TWLTLs in these situations would promote the uniform application of pavement markings in situations where left turns are permitted to adjacent properties. However, if there is an operational or safety need to prevent left turns from the median, it is recommended that some form of physical barrier (such as a raised or depressed median island, or a median barrier) be used to physically prohibit drivers from using the median area. Flush medians should not be used to control access to adjacent properties unless a high level of enforcement can also be provided.

5. REFERENCES

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