Discussion Paper No. 4

MEDIANS

prepared for the

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by the

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Discussion Paper No. 4

VARIANCES

DISCLAIMER

This discussion paper represents the viewpoints of the authors. Although prepared for the Oregon Department of Transportation (ODOT), they do not represent ODOT policies, practices nor procedures.

GENERAL OBJECTIVE

This and other discussion papers were prepared for the purpose of stimulating discussion among interested individuals representing a variety of agencies having an interest in Oregon's highways.

SPECIFIC OBJECTIVE

The specific objectives of this discussion paper are to:

1. Summarize the literature regarding the crash rates on undivided highways, those with continuous two-way left-turn lanes and, divided highways with medians.

2. Summarize the research on the effect of medians on traffic operations and the effect on business.

3. Identify research relative to medians which is in progress or is nearing completion.

4. Identify various questions as to the use and design of medians.

ACKNOWLEDGMENTS AND CREDITS

Mr. Del Huntington is project manager for ODOT. Dr. Robert Layton, Professor of Civil Engineering at OSU is project director for the TRI. This discussion paper was prepared by Dr. Vergil G. Stover, consultant to the TRI.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

Page

LIST OF FIGURES

Page

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LIST OF TABLES

Page

LIST OF TABLES (Continued)

Page

LIST OF TABLES (Continued)

Page

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Discussion Paper No. 4

MEDIANS

OVERVIEW

Content

This discussion paper summarizes the literature relating to the use of medians on major roadways. The primary focus is on safety due to the sizable amount of literature in this area and the very limited number of studies relating to such topics as the effect on business, the effect on traffic operations and public attitudes toward medians.

The summary includes data drawn from the significant, but limited number of studies, conducted in the 1950's and 1960's as well as from the relatively large body of research conducted in recent years. While there are a few before-and-after studies, most of the literature consists of comparisons of the average crash rates of roadways having different cross-sections.

Issues

The problems of applying access control to a developed arterial pose one of the greatest challenges to the traffic manager. Many studies have documented the damaging effects that access points have on the quality of traffic flow provided by a roadway. The official responsible for safe, efficient movement of traffic is certainly aware of increasing crash rates and reduced levels of service that occur with an increase in traffic, an increase in access points, or, as is usually the case, both.

Constraints to Retrofit Programs

- Physical Limitations
- Impacts on Business
- Traffic Flow Effects
- Cost and Benefits
- Legal Issues
- Political Considerations

OVERVIEW (Continued)

Issues (Continued)

Implementation of access control techniques on existing roadways is commonly very difficult. Right-of-way limitations and development in close proximity to the right-of-way are commonly encountered. Opposition by the owners of the adjacent properties and the affected businesses often makes it difficult to obtain the necessary political acceptance.

In many instances, however, congestion is evidenced by long queues at intersections, traffic crashes, and extensive travel delays often result in a public demand that improvements be made to existing major streets.

In many cases, it can be demonstrated that the benefits of fewer crashes, time savings and reduced fuel consumption exceed the cost associated with the implementation of access management improvements. Furthermore, the federally mandated air quality requirements can be expected to be an incentive for communities to implement access management techniques which will reduce vehicular emissions by improving traffic flow and reducing idling delay. Urban areas which are designated as nonattainment for air quality find such actions especially attractive, and perhaps essential.

Medians as an Access Management Technique

The installation of a nontraversable (restrictive) median provides positive control of left-turns and therefore have been found to be very effective in improving traffic safety.

It has been demonstrated that medial access control results in a substantial reduction in the number of crashes together with a reduction in the associated social and economic costs of deaths, injuries, and property damage. Other benefits include time savings and reduced fuel consumption. Furthermore, air quality improvement can be obtained through the implementation of access management techniques which will reduce vehicular emissions by improving traffic flow and reducing idling

OVERVIEW (Continued)

Medians as an Access Management Technique (Continued)

delay. Medial access control is also an effective congestion mitigation strategy as part of the Congestion Management Systems required by the 1991 Intermodal Surface Transportation Efficiency Act.

Medial access control measures include both modifications of route segments and point improvements. Route segment changes which are applicable to major roadways include the following:

1. Installation of a nontraversable median;
2. Replacement of a continuous two-way left-turn lane with a nontraversable median; and
3. Closure or redesign of a median opening along an entire section of roadway.

Point improvements/changes include:

1. Closure of a median opening;
2. Redesigning a median opening so as to permit a selected movement(s) only;
3. Adding a left-turn bay at a median opening; and
4. Increasing the length of an existing turn bay to provide adequate queue storage and to reduce the speed differential between turning vehicles and through traffic.

Implementation of median access control on existing roadways is commonly very difficult. Opposition by the owners of the adjacent properties and the affected businesses often make it difficult to obtain the necessary political acceptance. Concerns may also arise over the safety of resulting u-turn and weaving movements and the effect on business sales.

OVERVIEW (Continued)

Medians as an Access Management Technique (Continued)

Although the installation of a median, or replacement of a TWLTL with a nontraversable median may be expensive, it is commonly much less expensive than adding a lane in each direction of travel. Moreover, it is much less disruptive to the abutting development.

Discussion Topics

Topics for discussion include the following:

1. Definitions of median types (TWLTL) traversable, barrier/nontraversable.

2. The relative safety characteristics of undivided roadways and roadways having different median types.

3. The effect of continuous two-way left-turn lanes and nontraversable barrier medians on development patterns of abutting land.

4. The ability of Oregon highways to carry the increased traffic volumes resulting from large projected increase in the State's population. And, how existing major roadways can be modified to carry the projected increased volumes with minimum impact on the abutting developed land.

Questions to be Answered

The subject of medians raises several questions as to their application and design. Important policy decisions include the following:

1. In comparison to undivided roadways, how much safer are roadways having a continuous two-way left-turn lane (TWLTL).

2. Are roadways having nontraversable/barrier medians safer than those with TWLTL's? How much safer? Under what conditions?

Discussion Paper No. 4

MEDIANS

OVERVIEW (Continued)

Questions to be Answered (Continued)	3.	When should undivided roadways be reconstructed with a TWLTL? With a nontraversable median?
	4.	When should a TWLTL be replaced with a nontraversable median?
	5.	Does a protected left-turn bay improve safety? By how much?

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Discussion Paper No. 4

MEDIANS

SAFETY BENEFITS OF LEFT-TURN BAYS

Introduction

A left-turn bay is an auxiliary lane used to remove left-turning vehicles from the through traffic lane.

A left-turn bay reduces the speed differential between through traffic and left-turning vehicles, and hence improve safety. Left-turn bays reduce the "shock wave" effect caused by a speed differential. Shock waves occur when left-turning vehicles are forced to decelerate in the through lanes, thereby causing through traffic to decelerate. The flow of traffic through intersections will be improved by ensuring that left-turn bays are designed with lengths sufficient to meet storage and deceleration requirements.

Left-Turn Bays Improve Safety

Left-turns entering and exiting driveways account for the majority of total driveway crashes and a substantial amount of delay. In his studies in Skokie, Illinois, conducted in the mid-1960's, Box (10) found that 70% of driveway crashes occurred when left-turning vehicles were entering or leaving a driveway.

Agent (4), illustrated the desirability of medians in order to provide left-turn lanes at intersections. He compared crash rates (left-turn crashes per million left-turning vehicles) at signalized and unsignalized intersections in Lexington, Kentucky. At unsignalized intersections the average crash rate was 5.7 without a turn lane and 1.3 with a turn lane. Signalized intersections experienced an average crash rate of 7.9 crashes per million left-turning vehicles where a turn lane was not present and 3.6 with a left-turn lane but without a separate left-turn phase. The average crash rate was only 0.8 at signalized intersections with turn lanes and a separate left-turn phase. These data clearly suggest the value of a median on left-turn lanes on major roadways.

SAFETY BENEFITS OF LEFT-TURN BAYS (Continued)

Left-Turn Bays Improve Safety (Continued)

Left-turn maneuvers have been found to be involved in a disproportionately high percentage of crashes as illustrated by Figure 1. For streets without medians or sufficient left-turn storage provisions, left-turns delay through traffic and reduce street capacity.

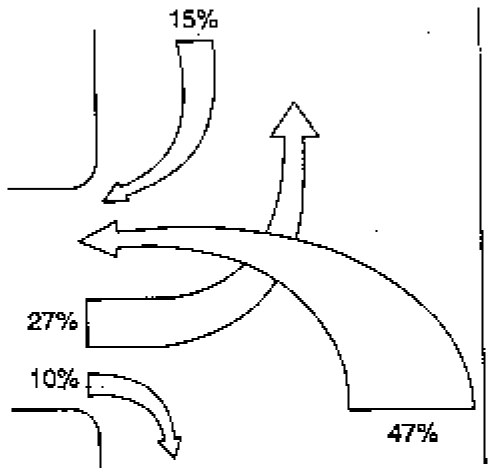


Figure 1. Percentage of Driveway Crashes by Movement

Source: Adopted from Reference (42)

A before and after study of crashes on a 4-mile section of street in Denver, Colorado, by Thomas (57), also published in 1966, found that channelized left-turns achieved a 6% reduction in crashes involving left-turning vehicles compared to the before condition with no median. This study also showed a 52% decrease in rear-end crashes, as well as decreases in pedestrian accidents, parked car accidents, and accident severity.

SAFETY BENEFITS OF LEFT-TURN BAYS (Continued)

Effect on Crash Rates

As shown by the data in Table 1, left-turn bays resulted in lower crash rates of both signalized and unsignalized access points. It is to be noted that total crashes as well as left-turn crash rates are lower when a left-turn bay is provided. The benefit of having left-turn bays at unsignalized access locations is particularly evident.

Table 1: Effect of Left-Turn Bays on Crash Rates

	Crash Rates			
	Unsignalized		Signalized	
Type of Crash	No Left Turn Lane	With Left Turn Lane	No Left Turn Lane	With Left Turn Lane
Left Turns	1.20	0.12	0.65	0.37
All Other	3.15*	0.92*	1.82*	1.17
TOTAL	4.35*	1.04*	2.47*	1.54*

* Indicates a statistically significant difference

Source: Reference (19) Hagenauer, et al, 1982

The data in Table 2 indicate that the retrofit of existing restrictive medians has a positive effect on safety in both day-time and night-time conditions.

SAFETY BENEFITS OF LEFT-TURN BAYS (Continued)

Effect on Crash Rates (Continued)

Table 2: Crash Rates[1] Before and After Construction of Left-Turn Bays

	Signalized			Unsignalized		
Light Conditions	Rate Before	Rate After	Percent Change	Rate Before	Rate After	Percent Change
Day	0.94	0.73	-22	1.12	0.50	-55
Night	1.12	1.00	-11	1.24	0.73	-41
TOTAL	1.00	0.82	-18	1.16	0.58	-50

[1]Crash rates are per million entering vehicles

Source: Adapted from Reference (19)

Vancouver, B.C.

Arterial streets in Vancouver, British Columbia are spaced at approximately one kilometre intervals. The initial street system was constructed without left-turn bays. The city's engineering department developed a benefit/cost measure to evaluate and rank various turn bay projects. Each year the city spends about $2.5 million to construct 6 to 10 left-turn bays. These improvements are reported to have resulted in a 20% increase in through capacity and a 25% to 50% reduction in crash rates (51), 1988.

Discussion Paper No. 4

MEDIANS

UNDIVIDED -V- DIVIDED ROADWAYS

Accident Frequency

Analysis by Glennon et al. (18), 1975, found that the continuous two-way left-turn lane (TWLTL) is inferior to the raised median where frequent driveways are found in combination with high arterial street volumes. They found the raised median to be a more effective technique under higher traffic volumes (see Table 3).

Data collected by Walton et. al. (61), 1978, clearly show that crashes on sections of urban streets having continuous two-way left-turn lanes increase as the following increase: the number of access points per mile, the population of the urban area, and the average daily traffic (see Table 2). The regression equation developed is:

Crashes per mile = -43.5 + 0.00203(ADT) + 0.000175(City Population) + 0.491(Number of Driveways per Mile) + 0.920(Number of Signals per Mile)

$R^2 = 0.75$

Standard Error ≈ 33 crashes per mile

Inspection of Table 4 indicates that an increase in average daily traffic (ADT) from less than 15,000 vehicles per day (average 10,500) to over 20,000 (average 24,500) results in an increase of approximately 30 crashes per mile for all city sizes and numbers of signalized intersections. Also, for a given population and ADT, increasing the number of driveways from less than 40 to over 60 results in an increase of about 30 crashes per mile. Although the grouping of the reported data mask the variation in individual routes, the data clearly show crash experience increases as ADT and the number of access points increases.

UNDIVIDED -V- DIVIDED ROADWAYS (Continued)

Accident Frequency (Continued)

Table 3: Effectiveness of Raised and TWLTL's as a Function of ADT and Driveways Per Mile

Conditions		Estimated Annual Reduction in Crashes Per Mile	
Level of Roadside Development	Highway ADT	Raised Median Divider	Continuous Two-Way Left-Turn Lane
Low <30 driveways Per Mile	Low <5,000	22	4.4
High >60 driveways Per Mile	High >15,000	31.2	28.1

Source: Reference (18)

This research also obtained data on 11 sections of roadways with medians and channelized left-turn lanes in Texas. In view of the small number of observations, the researchers did not develop a regression equation for the type of design. However, the equation for the continuous two-way left-turn lane was used to estimate the number of crashes that might be expected if a TWLTL were used instead of a raised median. The regression equation estimated that the number of crashes per mile with a TWLTL would be substantially larger than the number of crashes actually occurring with the raised, nontraversable median (see Table 5).

Table 4: Estimated Crashes Per Mile on Urban Four-Lane Roadways Having a Continuous Two-Way Left-Turn Lane

Signals per Mile	Driveways per Mile	Under 15,000 ADT (10,500)			15,000 - 20,000 ADT (17,500)			Over 20,000 ADT (24,500)		
		50,000 pop.	250,000 pop.	400,000 pop.	50,000 pop.	250,000 pop.	400,000 pop.	50,000 pop.	250,000 pop.	400,000 pop.
Over 3 (4.63)	Over 60 dpm (87.7)	72.3	107.3	133.5	86.4	121.4	147.6	100.6	135.6	161.8
	40-60 dpm (50)	53.9	88.9	115.1	68.0	103.0	129.2	82.2	117.2	143.4
	Under 40 dpm (22.7)	40.4	75.4	101.6	54.5	89.5	115.7	68.7	103.7	129.9
1 - 3 spm (2.0)	Over 60 dpm	48.1	83.1	109.3	62.2	97.2	123.4	76.4	111.4	137.6
	40-60 dpm	29.7	64.7	90.9	43.8	78.8	105.0	58.0	93.0	119.2
	Under 40 dpm	16.2	51.2	77.4	30.8	65.3	91.5	44.5	79.5	105.7
0 spm	Over 60 dpm	29.7	64.7	90.9	43.8	78.8	105.0	58.0	93.0	119.2
	40-60 dpm	11.3	46.3	72.5	25.4	60.4	86.6	39.6	74.6	100.8
	Under 40 dpm	0.0	32.8	59.0	11.9	46.9	73.1	26.1	61.1	87.3

Source: Reference (61), 1978 ADT = weekday average daily traffic

spm	=	signals/mile
dpm	=	driveways/mile
( )	=	average values used for table development
.44 mile	=	average section length

UNDIVIDED -V- DIVIDED ROADWAYS (Continued)

Table 5: Estimated Crashes with Continuous Two-Way Left-Turn Lanes Compared to Actual Crashes with Channelized Left-Turn Bays

Number of Through Lanes	ADT	Population	Signals Per Mile	Driveways Per Mile	Estimated TWLTL Crashes Per Mile	Actual Crashes Per Mile	Error (Estimated TWLTL -Actual)
6	29562	407,000	4.17	39.6	145.5	166.7	-21.2
6	31134	"	4.65	39.5	153.2	127.9	+25.3
6	32706	"	3.13	84.4	164.3	253.1	+88.7
4	15483	"	0.0	16.1	67.1	41.9	+25.2
4	13921	"	0.0	31.3	71.4	12..5	+58.9
4	13591	"	0.0	0.0	55.4	9.4	+46.0
4	14477	"	0.0	81.8	97.3	65.9	+31.4
4	14477	"	0.0	100.0	106.3	76.3	+30.0
4	14477	"	2.1	62.5	107.0	64.9	+42.4
4	8323	283,700	0.0	17.0	31.4	36.2	-4.8
6	13660	"	3.2	35.5	81.0	29.0	+52.0
4	17197	407,000	0.0	23.3	74.1	46.4	+27.6
2	13223	283,700	2.0	56.0	78.9	66.0	+12.9
2	11367	"	2.9	5.9	59.2	35.3	+23.9

Source: Reference 61), 1978

Recent (1989) research sponsored by the Georgia DOT concluded that on high-volume roadways, nontraversable medians have a lower crash experience than roadways with continuous two-way left-turn lanes (11). As shown in Figure 2, this is true for both 4-lane and 6-lane facilities. The average crash rate for 4-lane divided roadways was about 15% lower than those having 4 traffic lanes plus a TWLTL. The crash rate on 6-lane divided roadways was about 25% less than comparable facilities with a TWLTL.

UNDIVIDED -V- DIVIDED ROADWAYS (Continued)

Accident Frequency (Continued)

Studies in Florida (29), 1993 and Michigan (14), 1988 also found that roadways with nontraversable medians have a much better safety experience than those with TWLTL's. Again, this is true for both roadways with 4 through lanes as well as 6 through traffic lanes. The Florida data, Figure 3, show that the 4-lane sections with traversable medians have an average crash rate which is 25% lower than those with a TWLTL. For 6-lane roadways, the crash rate is about 12% less.

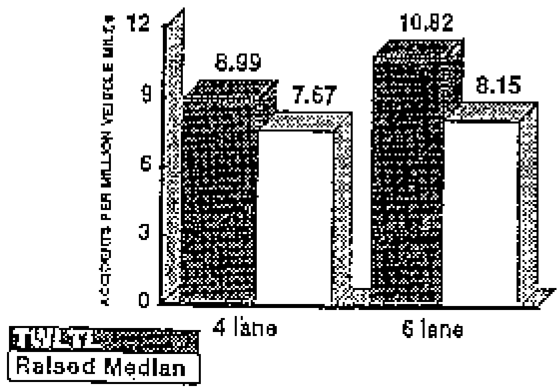
The Michigan data, Table 6, shows that roadways with nontraversable medians have substantially lower average total crash rates as well as injury and fatal crash rates. The lower average crash rates on facilities with 4 through traffic lanes may be partially explained by the lower average traffic volumes on the 4-lane divided facilities. However, it is to be noted that the 6-lane roadways have a total average crash rate which is only 51% of that for the 7-lane facilities (6 through lanes plus a TWLTL).

The small number of fatal crashes probably accounts for the fact that the ratio of fatal crash rates is 0.69 for 4-lane and 0.25 for 6-lane roadways.

In 1992, Gwinette County, (Atlanta Metropolitan Area), Georgia, adopted a policy that all new and reconstructed principal and major thoroughfares should be designed with raised medians. Also, raised medians should be considered as retrofit treatment on all arterials having a TWLTL if the traffic volume reaches or exceeds 24,000 to 28,000 vehicles per day (47).

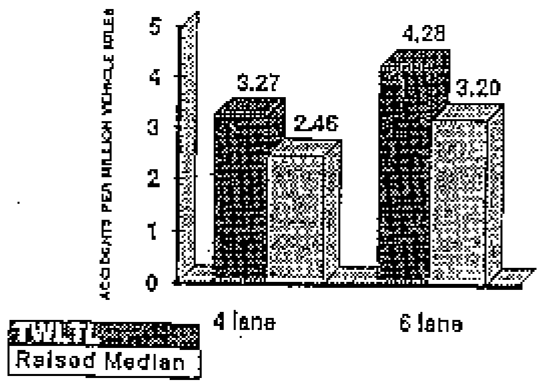
UNDIVIDED -V- DIVIDED ROADWAYS (Continued)

Accident Frequency (Continued)



Source: Adapted from Reference (53), 1989, by Florida DOT, Reference (15)

Figure 2: Comparison of Crash Rates on Georgia Roadways with Raised Medians and Two-way Left-Turn Lanes



Source: Adapted from Reference (29), 1993, Florida DOT, Reference (15)

Figure 3: Crash Rates for Raised Medians and Two-Way Left-Turn Lanes in Florida

UNDIVIDED -V- DIVIDED ROADWAYS (Continued)

Table 6: Michigan Statewide Crash Rates for Selected Types of Arterials, 1985-1987

Arterial Type	Average ADT	Length Miles	Reported Crashes per 100 Million Vehicle-Miles Total	Injury	Fatal
5-lane[1]	22,000	223	956	276	2.55
4-lane divided	17,000	286	407	118	1.77
ratio, 4-lane divided/5-lane			0.42	0.43	0.69
7-lane[1]	35,000	29	1107	357	3.75
6-lane divided	50,000	44	563	166	0.94
ratio, 6-lane divided/7-lane			0.51	0.46	0.25

[1]The odd lane is a continuous 2-way left-turn lane
Source: Adapted from Reference (7), 1988

The average statewide crash rates in Georgia, Michigan and especially Florida are quite different. However, as shown in Table 7, the average crash rate on divided highways as a ratio of that on TWLTL roadways in Georgia and Florida are similar. The Michigan data indicate that divided highways have an even greater safety advantage than the Georgia and Florida data.

UNDIVIDED -V- DIVIDED ROADWAYS (Continued)

Table 7: Comparison of Average Statewide Total Crash Rates on Divided Highways -v- TWLTL's

Study	4 Traffic Lanes			6 Traffic Lanes		
	TWLTL	Divided	Divided as a Ratio of TWLTL	TWLTL	Divided	Divided as a Ratio of TWLTL
Georgia	8.99	7.67	0.85	10.82	8.15	0.75
Florida	3.27	2.46	0.75	4.28	3.20	0.75
Michigan	9.56	4.07	0.42	11.07	5.63	0.51

Comparison of the crash rates of suburban streets shows that raised medians have a lower midblock crash rate than TWLTL's. It is also important to note that the intersection crash rate is also lower for raised medians (see Table 8).

Table 8: Midblock[1] and Intersection[2] Vehicular Crash Rates by Median Type

Location	Median Type: Raised	Median Type: TWLTL[3]
Midblock	189.23	311.37
Intersection	87.43	136.36

[1]Crashes per one-hundred million vehicle-miles
[2]Crashes per one-hundred million vehicle entering intersection
[3]Continuous two-way left-turn lane
Source: Adapted from Reference (8), 1994

UNDIVIDED -V- DIVIDED ROADWAYS (Continued)

Accident Frequency (Continued)

As Table 9 indicates, the crash rates by severity for raised medians are less than those for TWLTL's. However, the percentage of crashes by severity are very similar. Also, as shown in Table 10, raised medians experience lower crash rates for all types of crashes.

Table 9: Summary of Suburban Vehicle Crash Rate[(1)] Severity by Median Type

Severity	Variable	Raised	TWLTL
PDO	frequency	2649	4855
	crash rate	131.12	221.43
	% of crashes	69.3	71.1
Injury	frequency	1169	1962
	crash rate	57.86	89.48
	% of crashes	30.6	28.7
Fatal	frequency	5	10
	crash rate	0.25	0.46
	% of crashes	0.1	0.2

[(1)]Midblock segment crash rate in crashes per 100-million vehicle-miles
Source: Adapted from Reference (8), 1994

UNDIVIDED -V- DIVIDED ROADWAYS (Continued)

Accident Frequency (Continued)

Table 10: Summary of Suburban Midblock Vehicular Crash Rates[1] by Crash Type

Crash Type	Raised	TWLTL
Rear-end	80.98	139.61
Right Angle	35.05	63.26
Head-On	1.34	2.55
Left Turn	24.35	52.50
Other	47.52	53.45

[1]Crash rate in crashes per 100-millon vehicle-miles
Source: Adapted from Reference (8), 1994

The Georgia, Florida and Michigan data clearly demonstrate that 4-lane and 6-lane divided roadways with nontraversable medians have a much better safety record (lower average crash rates) than 5-lane and 7-lane roadways where the odd lane is a TWLTL. Research comparing roadways with raised medians with TWLTL's with undivided roadways summarized in the next section substantiates these findings.

Discussion Paper No. 4

MEDIANS

RAISED -V- TWLTL -V- UNDIVIDED

FHWA Study

An extremely well designed and executed study by Bowman and Vecellio (8), 1994, compared the crash experience on urban arterials in Atlanta, Georgia; Phoenix, Arizona; and Los Angeles/Pasadena, California. Fifteen homogeneous sections each of raised median, continuous two-way left-turn lane (TWLTL) and undivided roadways were studied. Most of the mileage (84.7%) was located in suburban areas.

Bowman and Vecellio concluded that, in suburban areas, raised medians are safer than TWLTL's or undivided roadways (see Table 11).

Table 11: Comparison of Vehicular Crash Rates on Suburban Arterials

Comparison	Mean Crash Rates	Crash Rates Significantly Different[2]
Raised -v- TWLTL[1]	373.00 -v- 676.29	yes
Raised -v- Undivided	373.29 -v- 409.22	yes
TWLTL -v- Undivided	676.29 -v- 409.22	no

[1]Continuous two-way left-turn lane
[2]95% confidence level, Scheffe multiple comparison test
Source: Adapted from Reference (8), 1994

These results indicate that suburban arterials having a raised median are significantly safer than either the TWLTL or an undivided roadway.

Florida Study

Table 12 presents data from a Florida study (29) which compared crash rates by severity. The fatal crash rates are not meaningful because the number of fatal crashes for most median types was very small. Inspection of Table 16 reveals the following:

RAISED -V- TWLTL -V- UNDIVIDED (Continued)

Florida Study (Continued)

- Undivided roadways have substantially higher crash rates (both total crashes and midblock crashes) than roadways with TWLTL's
- The average total and midblock crash rates are about the same for TWLTL's and flush paved medians
- Flush grass medians have the lowest crash rates
- The crash rates for restrictive medians are about one-third lower than for non-restrictive medians

These findings are compatible with previous research. As shown in Table 13 crash severity was reduced where left-turn lanes were added to existing facilities. The percent reduction in crash rates is much larger at unsignalized median openings than at signalized intersections.

Table 12: Crash Rates per Million Vehicle-Miles of Travel on 4-Lane Urban Arterials

Accident Severity	Median Type: Undivided	TWLTL	Flush Paved	Non[1] Restrictive	Flush Grass	Raised	Restrictive[2]	
All Crashes								
Total	4.44	3.20	3.25	3.21	1.80	2.46	2.09	2.09
Fatal	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.02
Injury	2.36	1.73	1.79	1.74	1.01	1.35	1.16	1.16
PDO[3]	2.05	1.45	1.44	1.45	0.77	1.09	0.91	0.91
Midblock Crashes								
Total	2.43	1.66	1.71	1.67	0.97	1.26	1.09	1.09
Fatal	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Injury	1.28	0.90	0.95	0.90	0.54	0.69	0.60	0.60
PDO[3]	1.13	0.75	0.75	0.75	0.42	0.56	0.47	0.47

(1)TWLTL plus flush paved
(2)Flush grass plus raised
(3)Property damage only
Source: Adapted from Reference (29), 1993

RAISED -V- TWLTL -V- UNDIVIDED (Continued)

Florida Study (Continued)

Table 13: Crash Rates[1] After Construction of Left-Turn Bays

	Signalized			Unsignalized		
Severity	Before Rate	After Rate	Recent Change	Before Rate	After Rate	Recent Change
Property Damage	0.62	0.48	-23	0.67	0.37	-45
Injury	0.37	0.34	-8	0.47	0.20	-57
Fatal	0.00	0.01	-	0.02	0.01	-50

[1]Crash rates are per million vehicle-miles
Source: Adapted from Reference (19), 1982

Research on midblock crash rates on 4-lane urban arterials found that a TWLTL roadway experience a lower midblock crash rates for all crash types than undivided roadways (see Table 12).

A study by Long, Gan and Morrison (29) found that the total crash rates per million vehicle-miles was lower for flush grass medians than for raised medians on 4-, 6-, and 8-lane urban freeways in Florida. Injury and property damage only crash rates were much lower on flush grass median sections whereas fatal accident crash rates were essentially the same. Midblock crashes were also lower with the flush grass median design.

The Florida research found that midblock head-on crashes on 4-lane urban arterials having a TWLTL are much lower (0.020) than an undivided 4-lane roadways (0.037). However, the head-on crash rates for TWLTL's are higher than for urban arterials with flush paved medians and are much higher than for urban roadways having restrictive medians (see Table 14).

RAISED -V- TWLTL -V- UNDIVIDED (Continued)

Florida Study (Continued)

Table 14 - Midblock Crash Rates[(1)] on Urban Arterials In Florida by Median Type and Crash Type

Type of Crash	Number of Lanes	Median Type: Undivided	TWLTL	Paved	Flush Grass	Flush Raised	
Head-on	4	0.037		0.020	0.012	0.008	0.009
	6	NA[(2)]		0.017	0.009	0.008	0.009
Sideswipe	40.174		0.092	0.087	0.054	0.071	
	6	NA		0.161	0.110	0.104	0.118
Left-Turn	40.491		0.358	0.371	0.164	0.220	
	6	NA		0.578	0.355	0.290	0.353
Rear-End	40.672		0.513	0.603	0.336	0.458	
	6	NA		0.686	0.620	0.660	0.713
Angle	4	0.378		0.317	0.228	0.218	0.223
	6	NA					
Right-Turn4	0.089		0.122	0.100	0.080	0.090	
	6	NA					
Run-Off-Road	4	0.021		0			
	6	NA		0.012	0.004	0.031	0.018

[(1)]Per million vehicle-miles
[(2)]There are no 6-lane undivided roadways
Source: Adapted from Reference 2(9), 1993

RAISED -V- TWLTL -V- UNDIVIDED (Continued)

Rural Highways, California Study

The data presented in Table 15 which was reported by Moskowitz in (38), 1961, are some of the earliest information which demonstrated the safety advantage of divided highways and access control.

These data for multilane highways are summarized in Table 16 for ready comparison. This comparison table clearly shows the safety benefit of divided roadways and marginal as well as median access control. The total average crash rate for 4-lane divided highways was found to be only 58% of the 4-lane undivided roadway. The additional benefit of marginal access control shows that the divided controlled access highways had a crash rate which is only 41% of the 4-lane undivided roadways and 58% of the 4-lane divided highways (i.e., median access control but without marginal access control).

The safety advantage of a median is evidenced by the relatively low head-on crash rates which are only 30% of that for the 4-lane undivided highways. Also, it is to be noted that the divided highways had much lower intersection crash rates than the 4-lane undivided highways. The 4-lane divided highways experienced an average intersection crash rate which is 67% of the 4-lane undivided. More interestingly, the intersection crash rate of the divided controlled access highways was a mere 24% of that for the 4-lane undivided highways and only 36% of that for 4-lane divided highways. The fact that median access control results in reduced intersection crash rates has been verified by other research (47, 53, 54).

The findings that median access control reduces midblock crashes is to be expected because of the elimination, or restriction of left-turns. The lower midblock crash rate for the divided controlled access highways compared to the 4-lane divided rates (1.08 compared to 1.22) indicates that the control of marginal access in addition to median access provides an additional safety benefit. This probably results from the larger separation of right-in/right-out conflict area where marginal access control is exercised.

RAISED -V- TWLTL -V- UNDIVIDED (Continued)

Rural Highways, California Study (Continued)

Table 15: Crash Rates On Rural Highways

	4-Lane Undivided	4-Lane[1] Divided	Divided[2] Controlled Access	Freeway[3]
Miles	167	210	794	430
Million Vehicle-Miles	976	1,234	3,543	3,052
Average Daily Traffic	15,997	16,130	12,224	19,449
Rates[4]				
Total Reported Crashes	4.09	2.91	1.69	1.00
Single-Vehicle Crashes	0.38	0.40	0.43	0.28
Collisions Between 2 or More Vehicles:				
(a) Between Intersections:				
(1) Head-on	0.20	0.06	0.06	0.045[5]
(2) Non-Head-on	0.99	0.77	0.59	0.63
(b) At Intersections	2.52	1.69	0.61	0.045
Total Excluding Intersection Accidents	1.57	1.22	1.08	0.95

(1)4-lane divided roads have a median separating opposing traffic but roadside access is controlled

(2)Divided controlled-access roads are nearly all 4-lanes with a few miles of 6-lane. Opposing traffic is separated and there is no access except at intersections. However, intersections at grade are frequent and traffic enters and exits at large angles, approximating 90°. All State highways except freeways require approaching traffic on cross roads to stop before entering or crossing the State highway, unless the intersection is controlled by traffic signals and the light is green

(3)Access via grade separated interchanges only

(4)Rate is number of accidents per million vehicles-miles

(5)Accidents at ramps

Source: Adapted from Reference (38)

RAISED -V- TWLTL -V- UNDIVIDED (Continued)

Rural Highways, California Study (Continued)

Table 16: Comparison of Crash Rates on Rural Highways

Type of Crash	4-Lane Undivided Rate	4-Lane Divided	
		Rate	Percent of 4-Lane Undivided Rate
Total Reported	**4.09**	**2.91**	**0.58**
Head-On Between Intersections	**0.99**	**0.06**	**0.30**
Non-Head-On Between Intersections	**.99**	**0.77**	**0.78**
At Intersections	**2.52**	**1.69**	**0.67**
Total Excluding Intersections	**1.57**	**1.22**	**0.78**

Source: Calculated from Table 13

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Discussion Paper No. 4

MEDIANS

SAFETY BENEFITS OF REPLACING A TWLTL WITH A RAISED MEDIAN

Case Studies

The continuous 2-way left-turn lanes (TWLTL's) on Memorial Highway and Jimmy Carter Boulevard, both in the Atlanta, Georgia Metropolitan Area were retrofitted with raised medians.

Memorial Drive

A TWLTL on a 4.34 mile section of Memorial Drive in Atlanta, Georgia, was replaced with a raised median. The general features are listed in Table 17. Six through traffic lanes were provided before and after the median retrofit. Construction was completed between the end of July 1989 and the end of September 1990.

Table 17: Memorial Drive Features

- 4.34 Mile Section
- Before

  TWLTL Lane Replaced by Raised Median
- After

  No Median Break at 7 Public Roads
- 14 Signalized Intersections with Public Roads and Major Driveways

Source: Reference (47), Parsonson, Waters and Fincher, 1993

No median opening was provided at 7 minor street intersections when the raised median was installed. Fourteen signalized median openings were provided with public roads and major private access drives. All except one provided for u-turns. The median design involved a 6-inch

SAFETY BENEFITS OF REPLACING A TWLTL WITH A RAISED MEDIAN (Continued)

Memorial Drive (Continued)

mountable curb and a 2-foot gutter; thus the face of the curb is 2 feet from the edge of the traffic lane.

A before-and-after study was performed to assess the impact on safety. Table 18 summarizes the changes in crash rates. The total crash rate was reduced by 37%; the injury crash rate dropped 48%. The fact that crash rates decreased at those intersections which remained open demonstrates that improved design and traffic control can result in lower rates in spite of the increased turning traffic at these openings. Total injury crashes decreased by 40%. The total left-turn crash rate decreased by 50% (from 0.40 crashes per 100-million vehicles to 0.20). This demonstrates that improved design and traffic operation can reduce crash expectancy even though a raised median will result in increased u-turn volumes. The lower crash rate probably results from a separation of conflict areas (longer spacing between median openings) and simplified driver information work load.

Table 18: Summary of Percent Change in Crash Rates on Memorial Drive

	Total Crashes		"Left-Turn" Crashes Only	
	Total Crash Rate	Injury Rate	Total Crash Rate	Injury Rate
Midblock	-55	-59	-90	-92
Intersections	-24	-40	-50	-48
Total	-37	-48	-64	-65

Source: Reference (47), 1993

SAFETY BENEFITS OF REPLACING A TWLTL WITH A RAISED MEDIAN (Continued)

Memorial Drive (Continued)

Other "lessons learned" from the Memorial Drive project include the following:

1. It is essential to have an effective public participation program and develop support for replacement of a TWLTL with a nontraversable median.

2. Sidewalks should be included in the reconstruction of a major urban arterial.

3. Substantial effort should be made to develop interconnections between properties. This will reduce the inconvenience to clientele patronizing roadside businesses.

Jimmy Carter Blvd.

Jimmy Carter Blvd. is located in Gwinnett County in the greater Atlanta, Georgia, metropolitan area. A section of approximately 3.5 miles in length was reconstructed from 5 lanes (4 through lanes plus a TWLTL) to 6 lanes with a raised median (see Table 19). Traffic volumes prior to the reconstruction ranged from 11,000 to 14,600 vpd in 1987 and up to 12,000 vpd after the reconstruction in 1991. A "Jersey Barrier" was used temporarily (27 April 1987 through 21 August 1988).

Comparison of the crash frequencies and crash rates indicates that the "Jersey Barrier" was more effective than the permanent 10-inch raised barrier median (see Tables 20 & 21).

Table 19: Jimmy Carter Blvd. Features

- 3.5 ± Mile Section
- Before: 5-lane
- After: 6-lane with Raised Median

Source: Reference (47), 1993

SAFETY BENEFITS OF REPLACING A TWLTL WITH A RAISED MEDIAN (Continued)

Jimmy Carter Blvd. (Continued)

Table 20: Number of Crashes on Jimmy Carter Blvd.

	North Section		South Section	
Condition	Total	Injury	Total	Injury
Before[(1)]	198	69	193	37
Jersey Barrier	155	34	109	23
10" Raised Median	213	79	37	50

[(1)] 5-lane Section; 4 through lane plus a continuous two-way left-turn lane

Source: Reference (47) Parsonson, Waters and Fincher, 1993

Table 21: Percent Change in Crash Experience on Jimmy Carter Blvd.

	Crash Frequency			Crash Rate	
Condition	Overall	North Section [(1)]	South Section [(2)]	North Section	South Section
Total Crashes:					
● w/Jersey Barrier	-32%*	-22%*	-44%*	-27%*	-47%*
● After 10" Raised Median	-2%	+8%	-11%	-9%	-35%*
Injury Crashes:					
● w/Jersey Barrier		-51%	-23%	-54%	-27%
● After 10" Raised Median		+16%	+16%	-1%	+22%

(1) North of I-85
(2) South of I-85
Note, * indicates change in statistically significant at = 0.05

Source: Reference (47) Parsonson, Waters and Fincher, 1993

SAFETY BENEFITS OF REPLACING A TWLTL WITH A RAISED MEDIAN (Continued)

Jimmy Carter Blvd. (Continued)

Inspection of Table 21 shows that installation of the Jersey median resulted in a substantial reduction in the number of crashes and the crash rates. The total number of crashes decreased by 32% and the crash rates decreased by 27% on the north section and by 47% on the south section when the TWLTL was replaced with the Jersey Barrier. The reduction in the number of crashes and crash rates were statistically significant. However, the total number of crashes was only 2% less with the raised 10 mph median than with the TWLTL. Total crashes on the north section increased by 8% although the increase was not statistically significant.

In contrast to the reduction in injury crashes with the Jersey Barrier, the 10-inch raised median resulted in an increase, although not statistically significant, in injury crashes and injury crash rate in comparison to the TWLTL. This may be due to the following: 1) The Jersey Barrier is large and hence quite visible to drivers and is designed to redirect the errant vehicle, and 2) the 10-inch raised median does not have high visibility either by its physical bulk (the Jersey Barrier has) or by landscaping (the raised median is paved), hence it is not highly visible - especially at night. However, the 10-inch height results in a high likelihood that the driver may lose control of the vehicle when the median is struck.

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Discussion Paper No. 4

MEDIANS

PEDESTRIAN SAFETY

Introduction

Measures to increase vehicular capacity such as a continuous two-way left-turn lane, intersection channelization, right-turn on red, multiple through lanes, and short signal phases may result in potential problems for pedestrians. The pedestrian-vehicular conflict problem becomes increasingly acute as vehicular and pedestrian volumes increase.

Medians are commonly used on major urban arterial to separate opposing traffic, to provide space for left-turn bays and restrict or prevent left-turns and/or crossing maneuvers of unsignalized intersections of public streets or private access drives. Medians also provide refuge for pedestrians and improved pedestrian safety. The medial refuge allows pedestrians to cross one traffic stream at a time. This in turn permits the use of shorter pedestrian clearance intervals.

Pedestrian Vehicle Crashes by Median Type

Bowman and Vecellio (8) studied the pedestrian-vehicle crash experience of arterial streets in Atlanta, Georgia; Phoenix, Arizona; and Los Angeles/Pasadena, California. Data for 15 street segments for each of three median types (raised, continuous two-way left-turn lane and undivided) were analyzed. Table 22 summarizes the crash rates and statistical comparisons. The crash rates are illustrated graphically in Figure 4. Inspection shows that the mean average crash rates for raised medians is much less than for streets with continuous two-way left-turn lanes (TWLTL's) and no median (undivided).

PEDESTRIAN SAFETY (Continued)

Pedestrian Vehicle Crashes by Median Type (Continued)

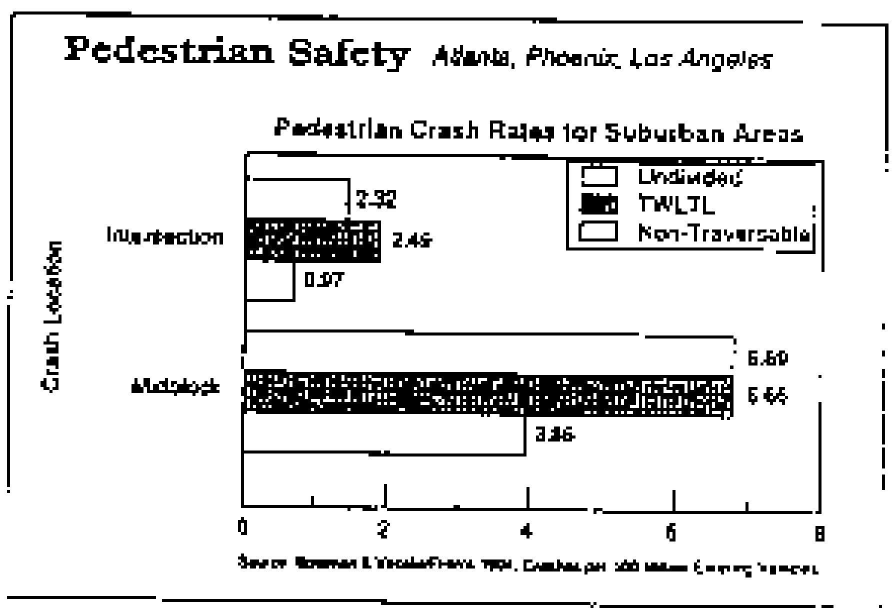

Figure 4: Comparison of Pedestrian-Vehicle Crash Rates on Suburban Arterials

PEDESTRIAN SAFETY (Continued)

Pedestrian Vehicle Crashes by Median Type (Continued)

Statistical comparisons of pedestrian-vehicle crash rates for midblock locations and at intersections are shown in Table 23. Raised medians in suburban areas experienced much lower midblock and intersection crash rates than TWLTL's in CBD's. Perhaps this difference between the two types of areas is that CBD's have high pedestrian volumes and relatively very slow speed traffic flow. Whereas in suburban areas, speeds are high and drivers do not constantly expect pedestrian conflicts because of very low pedestrian volumes.

Table 23: Comparison of Pedestrian-Vehicle Crash Rates

Discussion Paper No. 4

MEDIANS

Comparison	Mean Crash Rates [1]
CBD Arterial	
Raised -v- TWLTL	19.1 -v- 41.1
Raised -v- Undivided	19.1 -v- 87.3
TWLTL-v- Undivided	41.1 -v- 87.3
Suburban Arterial	
Raised -v- TWLTL	6.3 -v- 12.9
Raised -v- Undivided	6.3 -v- 13.9
TWLTL -v- Undivided	12.9 -v- 13.9

[1]Crashes per 100-million vehicle-miles

Source: Adapted from Reference (8) Bowman and Vecellio, 1994

Pedestrian Vehicle Crashes by Median Type (Continued)

Long, Gan and Morrison also investigated crashes involving pedestrians on urban arterial (29). The data shown in Table 24 indicates that the total pedestrian-vehicle crash rate on undivided 4-lane urban arterials is about double that of nonrestrictive (traversable) medians and nearly 5 times that of restrictive (nontraversable) medians. Also, as may be expected, midblock pedestrian-vehicle crash rates are much lower with restrictive (nontraversable) medians than undivided roadways and those with TWLTL's.

The data in Table 24 and Figure 5, also show total pedestrian crash rates on 6-lane arterial are slightly higher than on 4-lane arterial for nonrestrictive medians. Except for TWLTL's, midblock crash rates are about double the rate on 4-lane roadways.

Table 24: Crash Rates (per 100 million vehicle-miles) Involving Pedestrians on Urban Arterials in Florida

Discussion Paper No. 4

MEDIANS

PEDESTRIAN SAFETY (Continued)

Type	4-Lane		6-Lane	
	Total	Midblock	Total	Midblock
Undivided[(1)]	18	11	NA[(5)]	NA
TWLTL[(2)]	10	6	11	7
Flush Paved	9	4	12	8
NonRestrictive[(3)]	10	5	11	7
Flush Grass	3	2	5	4
Raised	4	2	8	4
Restrictive[(4)]	4	2	7	4

[(1)]No median
[(2)]Continuous two-way left-turn lane
[(3)]Undivided plus TWLTL
[(4)]Flush grass plus raised
[(5)]There were no 6-lane undivided urban arterial

Source: Adapted from Reference (24) Long, Gan and Morrison, 1993

Pedestrian Vehicle Crashes by Median Type (Continued)

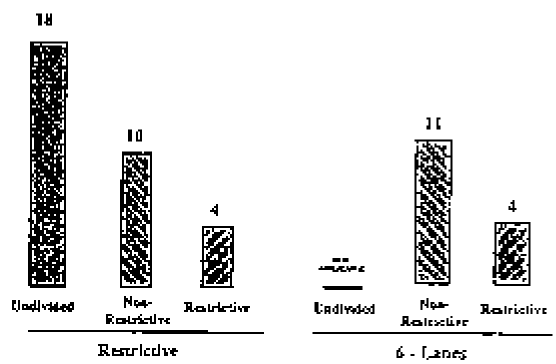

Figure 5: Comparison of Crashes Involving Pedestrians on Urban Arterials in Florida

Source: Summarized from Table 24

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Discussion Paper No. 4

MEDIANS

MEDIAN DESIGN

Median Width

There are three primary reasons for requiring a minimum median width: 1) separate opposing traffic streams; 2) provide auxiliary lane(s) to decelerate vehicles and store left-turning vehicles and u-turners; and 3) provide pedestrian refuge. These factors reduce congestion and increase the capacity of the arterial by limiting conflicts between through traffic, cross traffic, and turning vehicles. Limiting these conflicts increases capacity and improves safety by minimizing the speed differential between through vehicles and turning vehicles. This enhances a constant speed along the arterial.

In 1951 Telford (55), reported the advantages of narrow medians compared to undivided roadways. A 4-foot median separating two 33-foot roadways was installed on a major street through a central business district. Head-on collisions were reduced 65% after the median installation. Both the total number and the severity of crashes were reduced. The median also provided a pedestrian refuge area, as a result the pedestrian accident rate was reduced 70%.

In 1964 Priest (48), reported on the value of having a median of sufficient width to "shadow" a left- turn or crossing vehicle on a major roadway. Crash frequency was found to have an inverse relationship to the median width and the magnitude of an exposure index. The exposure index is a measure based on arterial ADT, cross street ADT, and the exposure time of a crossing vehicle.

Wilson (62), evaluated 12 types of simple intersection improvements at 1,160 different locations in a 1967 Highway Research Board Special Report. He reported a significant crash reduction with curbed, nontraversable medians and intersection channelization.

Curbed Medians

Box (10), analyzed the crash experience for a 2-year period at 1238 access points to streets in Skokie, Illinois. The data from the 1967 report summarized in Table 25 illustrate the value of nontraversable medians in reducing crashes occurring at driveways.

MEDIAN DESIGN (Continued)

Curbed Medians -v- Painted Medians

Table 25: Two-Year Driveway Crash Experience as a Function of Median Control

	Service Station	Commercial & Industrial	Residential	Alley
Routes with Barrier Median Curb (Study Length, 5.8 Miles)				
Number of Driveways	25	30	244	13
Number of Crashes	0	5	6	0
Crashes/Driveway/Year	-	0.08	0.01	-
Routes with Nonbarrier Median Curb (Study Length, 33.9 Miles)				
Number of Driveways	150	422	325	29
Number of Crashes	41	234	17	6
Crashes/Driveway/Year	0.17	0.28	0.03	0.07
Ratio of Crash Rates Barrier/Nonbarrier Median Curb	-	0.29	0.33	-

Source: Adapted from Reference (10), 1967

An even earlier 1953 report by Hanna (27), concluded that where medians in the urban area were not curbed, damage to grass, trees, and shrubs was frequent. Also, the control of parking was impractical, especially near churches and shopping centers. The occurrence of both angle and parallel parking in the median area caused confusion, congestion, and high crash rates.

MEDIAN DESIGN (Continued)

Curbed Medians -v- Painted Medians (Continued)

In one of the earliest studies (reported in 1968) showing the safety advantages of nontraversable medians over traversable medians in urban areas, Frick (16), compared the crash experience on two multilane streets in Springfield, Illinois. Inspection of Table 16 shows that the crash rate on the painted (traversable) median was 2.63 times (11.43 : 4.34) that of the curbed (nontraversable) median. Inspection of the data in Table 25 also shows that the street having the curbed median had lower crash rates at all locations (i.e., intersections, midblock other than driveways, and private driveways).

MEDIAN DESIGN (Continued)

Curbed Medians -v- Painted Medians (Continued)

Table 26: Comparison of Crash Experience Between Streets with Curbed Medians and Painted Medians

Crash Location	Number of Crashes	Number of Openings	Crash Rates[1]
Intersections			
Curbed Median[2]	64	21	3.23
Painted Median[3]	105	14	5.74
Midblock (Other than Driveways)			
Curbed Median[2]	19	8	0.96
Painted Median[3]	54	12	2.95
Private Drives			
Curbed Median[2]	3	56	0.15
Painted Medians(3)	50	188	2.73
Totals			
Curbed Median[2]	86	85	4.34
Painted Median[3]	209	214	11.43

[1]Crash Rate - Crashes per million vehicle-miles
[2]Stevenson Drive - 14,300 ADT, 1.9 mile length, two-year period
[3]MacArthur Boulevard - 16,700 ADT, 1.5 mile length, two-year period
Source: Adapted from Reference (16), 1968

MEDIAN DESIGN (Continued)

Curbed Medians -v- Painted Medians (Continued)

Frick suggested that where there is a choice as to cross section, the use of curbed medians and intersection channelization have the following advantages:

Primary Advantages

- Operational Safety
- Increased Capacity

Other Advantages

- Smoothes and enhances the highway traffic flow
- Decreases conflicts by providing a positive separation of opposing lanes of traffic
- Permits the regulation of traffic, through the prohibition of certain movements
- Controls the angles of conflict more adequately
- Provides a protection and storage area for heavy vehicle directional movements
- Gives better indication to motorists of the proper use of travel lanes and intersections
- Provides an opportunity to favor a predominate movement
- Provides a protected area for the location of traffic control devices
- Controls the speed of turning vehicles through the intersection area
- Serves as a protected refuge area for pedestrians

Frick concluded that the installation of curbed medians and intersection channelization will pay dividends far exceeding the original cost, mainly by substantially reducing certain types of crashes and increasing the capacity.

MEDIAN DESIGN (Continued)

Curbed Medians -v- Painted Medians (Continued)

A study by the California Division of Highways, reported by Moskowitz (31), 1964, compared medians of different design. Crash data were analyzed for 12 roadway sections having curbed medians and 9 sections having painted medians. Left-turns were legal only at median openings for both median types (i.e., physical breaks in the curbed medians and breaks in the solid double yellow paint lines on the painted medians). All sections were within developed areas. Crashes occurring between intersections involving left-turning vehicles accounted for 2% of all crashes on sections with curbed medians and 5% of all crashes on sections with painted medians. It was concluded that the curbed medians had better crash experience in the cases studied.

In 1967 Wilson (62), also found a significant reduction in crashes where channelized left-turn lanes were added at unsignalized medial access points (intersections and high-volume driveways). Before-and-after studies were made at locations where the left-turn lanes were delineated using raised bars, curbs, and paint. As shown in Table 27 all three methods produced a significant reduction in crashes. Painted channelization produce a 32% reduction whereas curbed and raised bars (rumble strip) resulted in 59% and 67% reduction in crash frequency and 64% and 69% reductions in crash rates.

MEDIAN DESIGN (Continued)

Curbed Medians -v- Painted Medians (Continued)

Table 27: Before-and-After Crashes by Left-Turn Channelization at Unsignalized Access Points

Type Channelization	Number of Projects	Condition	Million Vehicle-Miles	Total Crashes	Severity: Property Damage	Severity: Injury	Severity: Fatal	Time of Day: Day	Time of Day: Night
Painted	27	before	134.5	157	84	71	2	98	51
		after	134.1	106*	64	50*	2	58*	48
		% change		-32	-24	-30	0	-41	-6
Curbed	7	before	68.8	61	61	15	2	38	23
		after	77.7	25*	25*	3*	0	18*	7*
		% change	-50	-50	-50	-80	-	-53	-70
Raised	6	before	64.4	95	54	40	1	67	28
		after	69.6	31*	18*	12*	1	18*	13*
		% change		-67	-67	-70	0	-73	-54

[(1)]The number of crashes by severity and/or time of day may not equal the total number of crashes due to incomplete severity or time of day information.
*Reduction in number of crashes is statistically at the 90% confidence level using Chi Square Test
Source: Adapted from Reference (62), James E. Wilson, "Simple Types of Intersection Improvements", Special Report 93, Highway Research Board, 1967

Landscaping significantly improves the visibility of medians and channelizing islands. This enhanced visibility is instrumental in reducing crashes involving medians hits. Landscaping also greatly improves the aesthetic qualities of the roadway.

MEDIAN DESIGN (Continued)

Depressed Medians -v- Raised Medians

In rural areas, depressed medians are usually preferred over raised medians because they provide better drainage.

Garner and Deen (17), 1973, compared the crash histories of depressed and raised medians. They indicated that medians should be a minimum of 30 to 40 feet wide for high-speed facilities. Flat slopes, 6:1 or flatter, should be provided as 4:1 slopes are inadequate for medians less than 60 feet wide. They stated that raised medians provided unsuitable vehicle recovery areas on rural highways and were undesirable from the standpoint of roadway surface drainage.

Discussion Paper No. 4

MEDIANS

EFFECT OF MEDIANS

Introduction

The introduction of a raised median on an existing roadway in a developed area is often controversial. It is generally recognized that crashes and delays will be reduced if the median is installed. However, owners of businesses abutting the highway commonly believe that they will suffer a loss in business -- especially if their access drive is not directly opposite a median opening.

In spite of the considerable interest in the effect of medians and closure of median openings on business, very little research has been reported on this subject.

Texas Case Studies

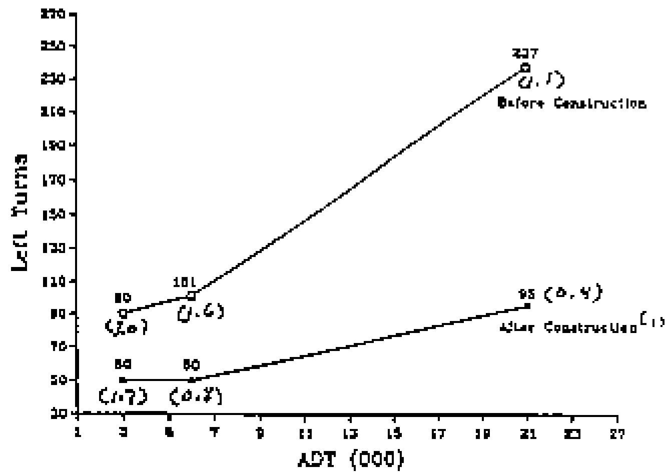
Restrictive medians were constructed on previously undivided roadways in three Texas cities in the early 1960's. Observers were positioned to observe traffic entering and leaving the roadside businesses prior to construction of the median and after. Figure 6 shows that fewer left-turns were made after construction of the median (u-turns followed by a right-turn or a right-turn followed by a u-turn were counted as a "left-turn" after the installation of the median).

However, inspection of Figure 7 indicates that businesses in the aggregate, abutting the low volume roadways suffered a loss in business both during construction and after. However, business abutting the high did not experience a decrease. In fact, as a whole, a slight increase in sales was reported. This suggests that a restrictive median is not necessarily detrimental to business abutting high volume roadways. (It should also be noted that: a) 21,000 vpd is not a high volume in comparison to major arterials in moderate to large urban areas, and b) the ADT of 21,000 is close to that where the research by Parsonson, et al, (47) recommend replacing a TWLTL with a restrictive median.) Moreover, experience shows that, whereas left-turn ingress movement can be made a relatively high roadway volumes, the ability to make left-turn egress movements is limited even at moderate volumes.

EFFECT OF MEDIANS (Continued)

Texas Case Studies (Continued)

Thus, the positive correlation found in the Texas cities is not expected to exist at high volumes (say ADT's of 40,000 and more).



- Numbers in parentheses are the left-turns as a percent of ADT
- Left-turns after installation of the restrictive median are u-turns followed by a right-turn or a right-turn followed by a u-turn.

Figure 6: Relationship Between Total Number of Left-Turns Before and After Construction of a Raised Median and Average Daily Traffic

Source: Reference (42)

EFFECT OF MEDIANS (Continued)

Texas Case Studies (Continued)

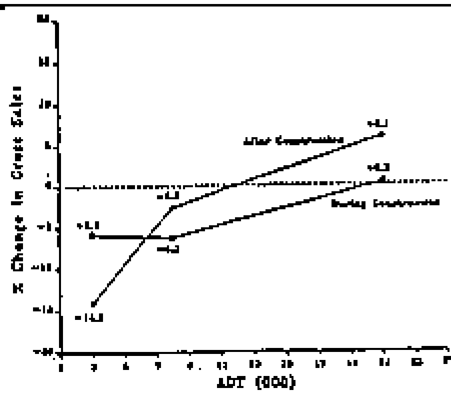


Figure 7. Percent Change in Gross Business Sales During and After Construction of a Raised Median Compared to Gross Sales Before Construction

Source: Reference (42)

Oakland Park Blvd.

Merchants along the section of Oakland Park Blvd. where the full median openings at 330-foot intervals were eliminated and replaced by left-turn/u-turn only openings at 660-foot intervals were surveyed following the change (42). Seventy percent of the merchants indicated that the retrofit median did not adversely affect the truck deliveries. Most merchants (72%) also reported no change in property value. Interestingly, 13% of the owners of commercial property reported an increase in property value. A majority (nearly 60%) of merchants reported no change (62.5%) or a slight increase (5.2%) in business. A response was not received from 5.3%.

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Discussion Paper No. 4

MEDIANS

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Discussion Paper No. 4

MEDIANS

APPENDIX A: MODELS

Existing Models

Various researchers have developed regression models for calculating the expected number of crashes per mile per year for different median treatments (9, 22, 34, 45, 53, 60). Walton and Machemehl (60), and McCoy and Ballard (34), developed models for continuous two-way left-turn lanes (TWLTL's) only. Howard (22) and Squires and Parsonson (53), developed models for crashes per mile per year as well as crashes per million vehicle miles. Parker first developed a prediction model in 1983 (46), and a revised model in 1991 (45). The several variables included in the various models are identified in Table A-1 (undivided roadways), Table A-2 (TWLTL's) and Table A-3 (raised medians).

Calculated crashes per mile per year are given in Table A-4 for the following conditions:

- 100,000 population
- 50 driveways per mile
- 2 signals per mile
- 8 unsignalized intersections per mile
- 5% trucks
- commercial development adjacent to roadway
- 4 through lanes
- $250 crash report threshold
- 16-foot median
- 40 mph speed limit

It should be noted that the last three variables are unique to the Bowman-Vecellio model.

Inspection of Table A-1 reveals the following:

1. The various models give quite different results for the same conditions.

APPENDIX A: MODELS (Continued)

Existing Models (Continued)

2. The Bowman-Vecellio model consistently predicts fewer crashes on roadways with raised medians than on TWLTL's and fewer crashes on roadways having a TWLTL than on undivided roadways.

3. The raised median typically has the lowest predicted number of crashes. The exceptions are the Squires-Parsonson model for 20,000 and 30,000 ADT's. And the Harwood model (midblock and unsignalized intersections only) which predicts fewer crashes on a TWLTL for all four ADT levels.

4. The average of the various models (excluding Harwood) generally result in fewer crashes on roadways with raised medians than with TWLTL's. When the Bowman-Vecellio model is included in the average, the predicted total number of crashes is consistently lower for the raised median and highest for the undivided roadway.

5. Inspection of the average number of total crashes, including the Bowman-Vecellio model suggests that the number of predicted crashes increases in a linear manner from an ADT of 10,000 to 40,000. Whereas the rate of increase in the predicted crashes for raised median begins to level off from 30,000 to 40,000.

The fact that the different models produce quite different results is probably due to the localized data base from which each regression model was developed. The consistency of the Bowman-Vecellio model in predicting total crashes may be explained by the large and geographically diverse data base. The size of the various data bases is given at the bottom of Tables A-2, 3, and 4. The logic of the pattern of total crashes is supported by various studies which show that raised medians are safer than TWLTL's and TWLTL's are safer than undivided

APPENDIX A: MODELS (Continued)

Existing Models (Continued)

roadways (8, 13, 16, 20, 27, 37, 38, 46, 53, 59).

If the various models were used to predict crashes for a variety of other conditions (population sizes, driveways per mile, signals per mile, unsignalized intersections per mile, etc.) a different pattern between the various models may result. Or, the relative values of the predicted crashes may be consistent (i.e., the model giving the largest value for say, 20,000 ADT) and raised medians may be consistently higher than the others over a range of conditions.

The following may explain some of the differences in the number of crashes predicted by various models:

1. The number of crashes will decrease as the reporting threshold increases. Bowman and Vecellio included this variable since their data base included data from three cities in three different states. This will explain some of the difference between the Walton-Mechemehl (Texas) and Parker (Virginia) models for example.

2. Bowman-Vecellio considered the number of signalized intersections per mile but found it not to be statistically significant. Presumably because the number of signals per mile is correlated with other variables in the model such as the number of driveways and unsignalized intersections per mile and type of adjacent land development. McCoy-Ballard also found signals to be not significant for undivided on TWLTL roadways as did Chatterjee, et al for both raised medians and TWLTL's and Squires-Parsonson for raised medians.

3. Crashes tend to decrease as speed increases. Bowman and Vecellio (92) explain this apparent conflict with logic by noting that higher speeds generally occur where development, and traffic conflicts, are lower. It may be due to speeds being higher where

APPENDIX A: MODELS (Continued)

Existing Models (Continued)

there is good median and marginal access control.

The Bowman-Vecellio model (Table A-2) appears to be the best by virtue of its logical and consistent results. Again, this may be due to its large, geographically diverse data base. It may therefore be the most transferable.

The results produced by the Harwood model are not consistent with logic on other research (8, 13, 16, 20, 27, 37, 38, 46, 53, 59). Similarly, some of the proposals regarding TWLTL's and medians in NCHRP Report 330 (23) also seem to be counter-intuitive and in conflict with other research.

Table A-1. Variables Included in Undivided Roadway Crash Prediction Models

Variable	Crashes Per Mile Models		Crashes Per MVM Models
	Parker 1983	McCoy & Ballard	Harwood
ADT	X	X	X
Population	O		
Driveways Per Mile	X	X	X
Signals Per Mile	X	O	
Unsignalized Approaches Per Mile		O	X
Public Street Approaches Per Mile	X		
Percent Trucks			X
Left-Turn Volume			C
Development Type			X
Reporting Threshold			
Office Land Use			
Business Land Use			
Area Type			
Median Width, Feet			
Crossovers Per Mile			
Speed Limit, MPH			
Years of Crash Data	3	4	5
Number of Sections	14	5	129
Total Section Length, Miles	16.6	6.4	73.3
Through Traffic Lanes	4	4	4
R^2	0.79	0.82	na

(1)public street approaches include all minor cross-streets at signalized or unsignalized intersections
X - variable included in model
O - variable considered by not statistically significant and thus not included
C - variable is significant but correlated with another more significant variable
Blank - variable not included
na - not reported

Table A-2. Variables Included in CLTL Crash Prediction Models

Variable	Crashes Per Mile Models			
	Parker 1983	Parker 1991	Squires & Parsonson	Chatterjee, et al
ADT	X	X	X	X
Population	X			
Driveways Per Mile	O	O	O	O
Signals Per Mile	X	X	X	O
Unsignalized Approaches Per Mile				O
Public Street Approaches Per Mile	X	X	X	
Percent Trucks				
Left-Turn Volume				
Development Type				
Reporting Threshold				
Office Land Use				
Business Land Use				
Area Type				X
Median Width, Feet				
Crossovers Per Mile				
Speed Limit, MPH				
Years of Crash Data	3	3	3	3-4
Number of Sections	17	5	42	12
Total Section Length, Miles	12.2	na	62.5	19.7
Through Traffic Lanes	4	4	4	4
R^2	0.75	0.73	0.60	0.65

(1)public street approaches include all minor cross-streets at signalized or unsignalized intersections
X - variable included in model
O - variable considered by not statistically significant and thus not included
C - variable is significant but correlated with another more significant variable
Blank - variable not included
na - not reported

Table A-2. Variables Included in CLTL Crash Prediction Models

			Crashes per MVM Models	
Bowman & Vecellio	Walton & Machemehl	McCoy & Ballard	Harwood	Squires & Parsonson
X	X	X	X	X
	X			
X	X	O	X	O
	X	O		X
X		O	X	X
			X	
			C	
			X	
X				
X				
O				
O				
X				
O				
X				
3-5	na	4	5	3
178	na	4	135	42
55.1	na	4.35	91.2	62.5
4 & 6	4	4	4	4
na	0.75	0.84	na	0.44

Table A-3. Variables Included in Raised Median Crash Prediction Models

Variable	Crashes Per Mile Models					Crashes Per MVM Models	
	Parker 1983	Parker 1991	Squires & Parsonson	Chatterjee, et al	Bowman & Vecellio	Harwood	Squires & Parsonson
ADT	X	X	X	X	X	X	X
Population	X						
Driveways Per Mile	X	O	O	O	O	X	O
Signals Per Mile	X	X	X	O			X
Unsignalized Approaches Per Mile			O	O	O	X	O
Public Street Approaches Per Mile	O	O					
Percent Trucks						X	
Left-Turn Volume						O	
Development Type				X		X	
Reporting Threshold					X		
Office Land Use					X		
Business Land Use					O		
Area Type					O		
Median Width, Feet					X		
Crossovers Per Mile					O		
Speed Limit, MPH					X		
Years of Crash Data	3	3	3	3-4	3-5	5	3
Number of Sections	19	3	15	11	178	44	15
Total Section Length, Miles	28.2	na	24.7	19.9	55.1	21.8	24.7
Through Traffic Lanes	4	4	4	4	4, 6	4	4
R^2	0.73	0.84	0.77	0.65	na	na	0.80

(1) public street approaches include all minor cross-streets of signalized or unsignalized intersections
X - variable included in model
O - variable considered by not statistically significant and thus not included
blank - variable not included
na - not reported

Table A-4. Number of Crashes Per Mile Per Year Predicted by Various Models

ADT	10,000			20,000		
Median	Undivided	CLTL	Raised	Undivided	CLTL	Raised
Total Crashes						
Parker (86)		27	18		43	32
Squires & Parsonson (11)			37		31	56
Chatterjee, et al (84)		55	46		90	81
Walton & Machemehl (88)		37			88	
McCoy & Ballard (89)	31	33			90	81
Bowman & Vecellio (92)	63	43	25		58	
Average						
w/Bowman	47	39	32	126	60	55
w/o Bowman		38	28		55	56
Midblock and Unsignalized Intersections Only						
Harwood (90)	26	20	26	52	39	52

blank - indicates that a model not developed for this treatment or independent variable is outside of the range used to develop the model

Table A-4. Number of Crashes Per Mile Per Year Predicted by Various Models

30,000			40,000		
Undivided	CLTL	Raised	Undivided	CLTL	Raised
	58	45		73	59
	69	75		108	94
	125	116			
	78			98	
190	128	75	253	170	101
190	92	78	253	112	85
	82	79		93	76
80	59	78	105	78	104

Table A-5. Bowman - Vecellio Accident Prediction Model

Variable		Variable Name	Median Type		
			Undivided	TWLTL	Raised Median
Exposure	B_0	intercept	0.000365	0.000365	0.000365
	B_1	ADT	1	1	1
	B_2	Segment Length, Len	1	1	1
Explanatory	C_0	intercept	1.88	3.71	7.21
	C_1	Reporting Threshold, Thr	-0.00303	-0.00278	-0.00788
	C_2	Office Land Use, Off	1.06	-0.0723	-0.448
	C_3	Business Land Use, Bus	0.657	0[b]	0[b]
	C_4	Area Type, Area	0.457	0[b]	0[b]
	C_5	Median Width, Med	0[b]	0.0354	-0.0276
	C_6	Unsig. Approach Density, Unsig	0[b]	-0.0606	0[b]
	C_7	Driveway Density, Drv	0.0132	0.0129	0[b]
	C_8	Crossover Density, Cross	0[b]	0[b]	0.0962
	C_9	Speed Limit, Spd	0[b]	-0.0339	-0.070
Database		Years of Accident Data	3-5		
		Number of Sections	152	178	150
		Total Section Length (mi)	38.9	55.1	51.9
		Through Lanes	4 and 6[b]		

b - considered, but not found to be statistically significant
Source: Bowman-Vecellio (12)

$$A = B_0 ADT^{B1} LEN^{B2} e^{\text{(explanatory terms)}}$$

$$\textit{explanatory terms} = C_0 + C_1 Thr + C_2 Off + C_3 Bus + C_4 Area + C_5 Med + C_6 Unsig + C_7 Drv + C_8 Cross + C_9 spd$$

where,

A = number of crashes per mile per year;
ADT = average daily traffic;
Len = road segment length, miles;

Table A-5. Bowman - Vecellio Accident Prediction Model (Continued)

Thr	=	accident reporting threshold, $;
Off	=	type of development adjacent to roadway (1 if office, 0 if other);
Bus	=	type of development adjacent to roadway (1 if business, 0 if other);
Area	=	area type (1 if CBD, 0 if suburban);
Med	=	median width, ft;
Unsig	=	unsignalized intersection approach density, number of approaches/mile;
Drv	=	driveway density, number of driveways/mile;
Cross	=	median crossover density, number of crossovers/mile;
Spd	=	speed limit, mph;
B_i	=	regression coefficients for exposure variables; and
C_i	=	regression coefficients for explanatory variables.

APPENDIX A: MODELS (Continued)

Research in Progress

NCHRP Project 3-49 includes an evaluation of the various crash prediction models developed to date. The project will also develop a safety model for the following midblock left-turn treatments:

- Undivided
- Continuous two-way left-turn lane (CLTL)
- Raised median with left-turn bays

NCHRP Project 3-49 is also to develop an operations model which will consist of the following 5 models:

1. Mainline volume adjustment models to provide an initial check of left-turn volume to capacity.
2. Mainline left-turn module - calculate the capacity, delay and queue length of mainline left-turns; also to calculate the impedance among overlapping left-turn queues.
3. Mainline thru-lane modules - to evaluate the impact of left-turns on mainline operations the module will calculate the delays and stops of through traffic and the through lane capacity.
4. Midblock section modules - the total through traffic delay and stops as well as average travel speed in each direction will be calculated.
5. Access point module - this module will utilize the unsignalized intersection capacity developed under NCHRP Project 3-46 "Capacity and Level of Service at Unsignalized Intersections."

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