TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-TX-81/31+265-2F		

4. Title and Subtitle OPERATIONAL AND SAFETY EFFECTS OF DRIVING ON PAVED SHOULDERS IN TEXAS	5. Report Date January 1981 6. Performing Organization Code
7. Author(s) D.B. Fambro, D.S. Turner, and R.O. Rogness	8. Performing Organization Report No. 265-2F
9. Performing Organization Name and Address Texas Transportation Institute Texas A&M University College Station, TX 77843	10. Work Unit No. 11. Contract or Grant No. 2-18-79-265
12. Sponsoring Agency Name and Address Texas State Department of Highways and Public Transportation; Transportation Planning Division P. O. Box 5051 Austin, Texas 78763	13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with the U.S. Department of Transportation, Federal Highway Administration.
Research Study Title: Operational Effects of Driving on Paved Shoulders

16. Abstract

Paved shoulders in Texas are used by many drivers for making a large variety of traffic maneuvers and for satisfying numerous driving task demands. Unfortunately, there is little information as to the types and frequencies of this usage and the impacts and conditions under which they occur. This report documents research that was directed at providing answers to these questions.

A combination questionnaire and personal interview technique was used to gain additional insight into this issue. Responses from twenty-four engineers provided credible shoulder usage information on intended functions, operational and safety problems, field experiences and relative benefits. A laboratory study was designed to assess motorist understanding of the legal issues involved with driving on paved shoulders. In addition, the study investigated driver preferences for and experiences with shoulder usage. This study was administered to 96 "average" motorists and 91 law enforcement officers.

Accident histories were determined for three different types of rural Texas highways - two-lane without paved shoulder roadways, two-lane with paved shoulder roadways and undivided four-lane without paved shoulder roadways. Both a comparative analysis and a before-after technique were used to determine the safety benefits associated with paved shoulders. Field measurements were made to quantify the operational characteristics on these roadways. Data were collected on 21,000 vehicles at 18 different sites. Recommendations for more efficiently utilizing and controlling paved shoulder usage are presented.

17. Key Words	18. Distribution Statement
Shoulder Usage, Paved Shoulders, Traffic Operations, Traffic Safety	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	219	

Form DOT F 1700.7 (8-69)

METRIC CONVERSION FACTORS

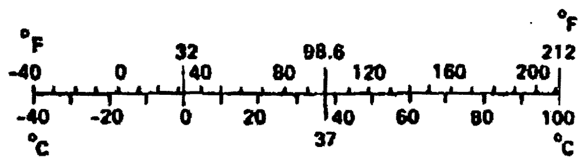
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



OPERATIONAL AND SAFETY EFFECTS OF DRIVING ON PAVED SHOULDERS IN TEXAS

by

Daniel B. Fambro
Engineering Research Associate

Daniel S. Turner
Assistant Research Engineer

and

Ramey O. Rogness
Assistant Research Engineer

Research Report 265-2F

Operational Effects of Driving on Paved Shoulders

Research Study Number 2-18-79-265

Sponsored by the Texas
State Department of Highways and Public Transportation
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

Texas Transportation Institute
Texas A&M University
College Station, Texas

January 1981

265-2F

ABSTRACT

Paved shoulders in Texas are used by many drivers for making a large variety of traffic maneuvers and for satisfying numerous driving task demands. Unfortunately, there is little information as to the types and frequencies of this usage and the impacts and conditions under which they occur. This report documents research that was directed at providing answers to these questions.

A combination questionnaire and personal interview technique was used to gain additional insight into this issue. Responses from twenty-four engineers provided credible shoulder usage information on intended functions, operational and safety problems, field experiences and relative benefits. A laboratory study was designed to assess motorist understanding of the legal issues involved with driving on paved shoulders. In addition, the study investigated driver preferences for and experiences with shoulder usage. This study was administered to 96 "average" motorists and 91 law enforcement officers.

Accident histories were determined for three different types of rural Texas highways - two-lane without paved shoulder roadways, two-lane with paved shoulder roadways and undivided four-lane without paved shoulder roadways. Both a comparative analysis and a before-after technique were used to determine the safety benefits associated with paved shoulders. Field measurements were made to quantify the operational characteristics on these roadways. Data were collected on 21,000 vehicles at 18 different sites. Recommendations for more efficiently utilizing and controlling paved shoulder usage are presented.

KEY WORDS: Shoulder Usage, Paved Shoulders, Traffic Operations, Traffic Safety

SUMMARY

Paved shoulders in Texas apparently are used by many motorists for making a large variety of traffic maneuvers and satisfying numerous driving task demands. Texas motorists commonly pull onto the paved shoulders of rural two-lane highways at relatively high speeds as a courteous gesture to let faster vehicles pass. Paved shoulders may also be used by through traffic to bypass left-turning vehicles at driveways or non-channelized intersections. Furthermore they are sometimes used as an auxiliary lane by some road users. While motorists are apparently benefiting from these maneuvers, there has been little documentation as to the types and frequencies of shoulder usage and the impacts and conditions under which they occur. The objective of this study was to quantify benefits and/or disbenefits associated with shoulder usage in the state of Texas.

A combination questionnaire and personal interview technique was used to gain additional insight and credible information regarding field experience with driving on full-width paved shoulders. Highway design, traffic operations and roadway maintenance personnel from the SDHPT district offices were surveyed in this manner. They provided shoulder usage information on intended functions, operational and safety problems, field experiences and relative benefits. Although much useful data were obtained, there was a wide range of answers for many of the questions. The most common responses were as follows:

- Intended Function - Accomodation for emergency stops.
- Operational Problems - Shoulder usage as a passing lane (passing on right).
- Safety Problems - Shoulder usage near narrow bridges.
- Field Experience - Most drivers will use a paved shoulder.

A laboratory study was designed to test motorist understanding of the legal issues involved with driving on paved shoulders. This study also investigated driver preferences for and experiences with shoulder usage. The same basic study was used to ascertain DPS patrolmen's interpretation of the legal issues involved and their observations of shoulder usage throughout the state. Ninety-six "average" drivers and ninety-one law enforcement officers participated in the study. The most significant findings were as follows:

- Texas drivers perceive a difference between using a paved shoulder to pass vehicles turning left into a driveway and using the same shoulder to pass vehicles turning left at an intersection.
- Both the general public and the DPS patrolmen seem certain it is legal to pass someone that is driving on the shoulder; however, the motorists are uncertain whether it is legal for someone to simply drive on the paved shoulder or whether it is a legal requirement to pull onto the paved shoulder to let a faster vehicle pass.
- Texas drivers and DPS patrolmen seem certain that to use the paved shoulder to pass non-turning vehicles on the right is dangerous and should not be legal.

Two separate accident investigations were conducted as a portion of this study. Their objective was to determine the safety effects of paved shoulders on three types of rural Texas highways. The initial investigation was a comparative analysis of accident rates, patterns and characteristics on roadways with and without paved shoulders. The second was a before and after study to determine the safety impacts of adding paved shoulders to a two-lane road, or converting paved shoulders to additional travel lanes. These analyses indicated that the accident rate for each roadway type increases as the volume increases, that the addition of paved shoulders to a two-lane roadway is effective in reducing the total number of accidents that occur, and that the conversion of a shoulder to an additional travel lane increases the total number of accidents on low volume facilities.

Field measurements were made to quantify the operational characteristics on the same three types of rural highways. Operational characteristics from over 21,000 vehicles were observed and recorded. These data were used to quantify the operational benefits attributable to the presence or absence of a paved shoulder. Significant findings were as follows:

- The operational benefits derived from a full-width paved shoulder increase as the volume increases.
- These benefits are minimal at low and moderate volumes; however, at volumes greater than 200 vehicles per hour, provision of a paved shoulder will increase the speed on the roadway by at least 10 percent.
- At any one location, only about 5 percent of the traffic actually use the shoulder.
- Conversion of the shoulder to an additional travel lane offers no apparent operational benefits until the volume reaches 150 vehicles per hour.
- Such a conversion will result in more than two-thirds of the traffic using the outside or "shoulder" lane.

Implementation

The types and frequencies of shoulder usage and the impacts and locations under which they occur have been documented. In addition, motorist understanding of the legal issues involved with driving on paved shoulders have been investigated. Results from this study can be used for recommending wording changes concerning shoulder usage in the Texas Motor Vehicle Laws. These results can also be used to develop a consistent design policy for upgrading two-lane highways with and without paved shoulders.

TABLE OF CONTENTS

TABLE OF CONTENTS, continued

LIST OF TABLES

LIST OF TABLES, continued

LIST OF FIGURES

LIST OF FIGURES, continued

CHAPTER I. PROJECT BACKGROUND

Introduction

A shoulder can be defined as "that portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use and for lateral support of base and surface courses (1)." The term "paved shoulder" applies to any one of a wide range of all-weather surfaces - bituminous surface treated shoulders, bituminous aggregate shoulders, full-depth asphalt shoulders and portland cement concrete shoulders. They are constructed next to mainline pavements of equal or better type. In general, the provision of such a shoulder will enhance both the safety and the operational characteristics of the nation's highways; however, their effects on rural two-lane highways has been the subject of much controversy and considerable debate.

Problem Statement

The Texas State Department of Highways and Public Transportation needs to develop an overall efficient shoulder management strategy based on statewide operational and safety data. Paradoxically, the need for such a strategy is partially the result of too many good rural highways and too many friendly, courteous Texas drivers who frequently drive on the shoulder. The Department's design policies and practices concerning the alternatives for upgrading two-lane highways with paved shoulders needs to be based on documented data of Texas driving practices. Criteria and warrants are needed to define those conditions where each option would be beneficial. As traffic volumes increase, other design options must be considered. Design criteria and warrants are needed to define the volume conditions and circumstances within which the four-lane "poor-boy" (four-lane undivided without paved shoulders) design is an acceptable betterment alternative to the two-lane highway with paved shoulders.

Operational and safety problems exist in some areas due to motorists using the paved shoulders as a driving lane. There also appears to be some uncertainty, if not a problem, with the question of desirable "traffic control" policies along paved shoulders. Concerns have been expressed as to how, when and where driving on paved shoulders in Texas should be permitted (or prohibited). Traffic control techniques, regulations and enforcement policies, procedures and practices are in need of review and possibly revision. Documented accident and operational experience on the impacts of shoulder driving is needed to form a basis for formulating an effective shoulder management strategy. In addition, there is little documentation regarding the range of interpretation and practices among Texas drivers, highway engineers, law enforcement personnel, and educators.

Background

Paved shoulders in Texas apparently are used by many drivers for making a large variety of traffic maneuvers and for satisfying numerous driving task demands. Texas motorists commonly pull onto the paved shoulders of two-lane rural highways at relatively high speeds as a courteous gesture to let faster vehicles pass them. Since Texas has numerous truck-climbing (passing) lanes in several areas of the state, many motorists are accustomed to pulling over on hills (or expecting slower traffic to do so) to minimize the delay to queued vehicles. Paved shoulders also may be used by through traffic to bypass left-turners at driveways or non-channelized intersections.

Paved shoulders also serve in an ad hoc manner as pseudo acceleration/deceleration lanes on high-speed, high-volume highways. Motorists have been observed upon leaving their driveway (or junction intersection) to accelerate along the paved shoulder until a safe speed and an acceptable gap have been found. Likewise, motorists approaching their destination may also use the paved shoulders as a deceleration lane near their driveway or junction intersection. Furthermore, paved shoulders are used sometimes as an auxiliary lane by certain road users. Examples in this category include: farm vehicles, mail carriers, school buses, police (DPS), partially disabled vehicles, wreckers and bicyclists.

Many operational benefits accrue to motorists due to these traffic maneuvers being made on paved shoulders. Most benefits are apparent to the shoulder users since they voluntarily use the shoulder. Traffic congestion and delays are reduced and fuel is saved. The potential for some types of accidents is reduced. Paved shoulders also serve many other highway design and traffic functions. They serve as a recovery area for vehicles drifting from the traveled way. In addition, paved shoulders provide a stable location for vehicles to make emergency stops. Disabled vehicles also may remain stopped on the shoulder for considerable periods of time. In summary, advantages and benefits of several potential shoulder usages can be readily identified for Texas highways.

Potential operational, safety and traffic control problems exist in the usage of paved shoulders on two-lane highways, however. Several types of traffic operations could possibly occur on the paved shoulders. A wide range of vehicle operating speeds may occur together with a large variety of vehicle types and highway conditions. There is an apparent potential for vehicle conflicts and accidents to occur. Fortunately, the speed differentials existing between vehicles headed in the same direction and the frequency of occurrence of multiple shoulder users is thought to be relatively low in most cases, but presently is unquantified.

Several other problems or deficiencies may exist with shoulder usage.

One may occur at intersections where paved shoulders may be squeezed-out or laterally displaced by the addition of an auxiliary lane intended for turning movements. Increases in sideswipe accidents between the shoulder user and turning vehicle may occur due to the unexpected termination or displacement of the paved shoulder. Another potential problem at intersections may arise when cross-road vehicles stop beyond the stopline and are then exposed to vehicles driving along the shoulder of the mainline road.

In general, there exist numerous potential advantages and disadvantages from a traffic operations viewpoint to the usage of paved shoulders by motor vehicles. The basic problem is that there is little documentation as to the types and frequencies of shoulder usage and the impacts and conditions under which shoulder usage occurs in Texas. Benefits and disbenefits need to be quantified to the extent possible.

Objectives

The goal of this study is to improve the traffic safety and capacity of highways (non-freeway facilities) in Texas by providing effective design guidelines and management strategies for efficiently utilizing and controlling traffic operations along paved shoulders. To satisfy this broad goal, the following specific study objectives were formulated:

- Identify existing shoulder usage experience.
- Document the accident experience of several highway types as related to shoulder design options.
- Quantify the magnitude and conditions under which shoulder usage occurs along rural and suburban highways (non-freeway facilities).
- Determine the benefits and disbenefits of shoulder usage.
- Determine driver understanding of the traffic laws governing shoulder usage and driver preferences for using paved shoulders.
- Develop suitable criteria, warrants, guidelines, policies and procedures for design, implementation, regulation and enforcement of paved and unpaved shoulder usage.

CHAPTER II. PAVED SHOULDER USAGE: EXPERIENCE, LEGALITY AND UNDERSTANDING

Introduction

There is little doubt that the high quality design of Texas highways and the "drive friendly" attitude of Texas motorists have resulted in a relatively high rate of driving on the shoulder of two-lane highways with full-width (8 to 10 feet in width) paved shoulders. It can be stated with a high degree of confidence that the frequency of shoulder driving is higher in Texas than in most other states. As a consequence, the advantages and disadvantages of shoulder usage together with the methods for traffic control and driver training must be clearly identified if the capacity and safety of shoulder usage is to be maximized. Unfortunately, there appears to be some confusion regarding the proper and/or legal usage of paved shoulders in the State. The following sections of this paper examine the positions of the three groups of people involved - the Texas State Department of Highways and Public Transportation (SDHPT), the Texas Department of Public Safety (DPS) and the Texas motorist.

SDHPT Questionnaire

There have been numerous papers and reports published regarding paved shoulders, and shoulder practice in general. Most studies deal with the basic questions of shoulder design, field performance and safety improvement; however, few look at operational considerations. Three studies have attempted to identify current practices. A national survey (2) conducted in 1973 revealed that Texas was one of four states which allowed slower traffic to drive on the shoulder area in order to facilitate passing maneuvers. Unfortunately, the reasons for allowing this maneuver have been neither investigated nor reported. A comprehensive state-of-the-art review on paved shoulders was published in 1976 (3). It noted that the provision of shoulders has been observed to affect traffic in the following ways:

1. They improve (increase) the lateral separation between oncoming vehicles by increasing the "effective width" of mainline pavement.

2. They ease driver tension by giving the driver a sense of openness and ensure a space for emergency maneuvers.

3. They maintain highway capacity by providing an area for stopped vehicles.

4. They increase highway capacity *in those parts of the country* where the paved shoulder serves as a courtesy lane for slower moving traffic to allow faster moving vehicles to pass or as an auxiliary lane during peak periods.

5. They obtain a more uniform speed by allowing motorists to leave the traffic lane at higher speeds so that following vehicles do not have to slow down considerably.

Results from a 1979 nationwide questionnaire study on the design and use of highway shoulders (4) indicate that five states permit regular use of shoulders for slow moving vehicles and ten additional states permit such use under certain conditions. All states make use of a four-inch white reflectorized edge stripe to delineate the outside shoulder on some of their roadways; however, a number of states supplement the edge stripe with contrasting color, different texture or rumble strips on the shoulder.

In order to gain additional insight and credible information regarding Texas field experience with driving on full-width paved shoulders, the 25 SDHPT district offices were surveyed by a combination questionnaire and personal interview. Highway design, traffic operations and roadway maintenance personnel were queried. Twenty-four engineers, from 23 of the districts, provided shoulder usage information on intended functions, operational problems, safety problems, field experience and relative benefits. Although much useful data were obtained, there was a wide range of answers for most of the questions. The following is a presentation of the results for each question. A copy of the cover letter and the original survey form are contained in Appendix A.

Survey Results

1. *In your district, what are the intended functions of a full-width paved shoulder on rural two-lane highways?*

In response to this question, 83 percent (20/24) of the respondents indicated that accomodations for emergency stops was an intended function of a paved shoulder on a rural two-lane highway (See Table 1). Two shoulder uses were indicated as intended functions by 50 to 75 percent of the engineers. These were a travel lane for farm vehicles (58 percent) and room for slower vehicles to permit passing (50 percent). Surprisingly, four districts reported that the latter was not an intended function of a paved shoulder. An additional three uses were indicated as intended functions by 25 to 50 percent of the respondents. These include parking of disabled vehicles (42 percent), temporary use during maintenance, construction or emergencies (42 percent), and a travel lane for bicycles and/or hikers (33 percent). Three shoulder uses - travel lane for mail carriers, climbing lane on hills and an extra lane for added capacity - were indicated functions by less than 25 percent of the engineers. A travel lane for school buses was not indicated as a shoulder function by any of the respondents. Two engineers listed other functions of a paved shoulder as providing recovery or emergency areas and as a turning lane at intersections.

Table 1. Intended Functions of Paved Shoulders On Rural Two-Lane Highways.

Intended Function	Frequent	Sometimes	Never
Accomodations for Emergency Stops	20	4	0
Travel Lane for Farm Vehicles	14	8	2
Room for Slower Vehicles to Permit Passing Maneuvers	12	8	4
Parking of Disabled Vehicles	10	14	0
Temporary Use During Maintenance, Construction or Emergencies	10	14	0
Travel Lane for Bicycles and/or Hikers	8	13	3
Travel Lane for Mail Carriers	6	12	6
Climbing Lane on Hills	2	14	8
Extra Lane for Added Capacity	1	11	12
Travel Lane for School Buses	0	9	15

2. *What, if any, operational problems result with full width paved shoulders on two-lane rural highways in your district?*

The respondents provided a wide range of answers to this question. Several engineers reported no operational problems resulting from full width paved shoulders on rural two-lane highways. In fact, they cited improved operations. One respondent indicated that confusion had been eliminated by paving the entire roadway, including shoulders, and striping it as four lanes. Two operational problems were mentioned by eight of the respondents. These were shoulder usage as a passing lane (passing on right) and as an extra lane (four-lane highway). Both maneuvers were mentioned as being dangerous and concern was expressed as to the lack of enforcement by the enforcement agencies. One engineer pointed out that "the courts will not accept our definition of edge of pavement." Another frequently mentioned problem was shoulder usage by heavy vehicles; however, this results in a maintenance rather than an operational problem. Two additional areas of concern were lack of shoulder usage by school buses at any time, thus blocking the entire roadway, and the use of shoulders as a turning lane at intersections.

3. *How are paved shoulders on rural two-lane highways in your district delineated from the main lanes?*

As shown in Table 2, the most frequent method of delineating between the main lanes and paved shoulders on rural two-lane highways is contrasting colors. Edge lines are used extensively in 14 of the districts. Surprisingly, one district does not use edge lines on this type of highway. Different textures were indicated as frequent type of delineation in ten of the districts. Raised pavement markings, no distinction and jiggle bars are seldom used for shoulder delineation on rural two-lane roads.

Table 2. Delineation Between Main Lanes and Paved Shoulders on Rural Two-Lane Highways.

Type of Delineation	Frequent	Sometimes	Never
Contrasting Color	18	6	0
Edge Lines	14	9	1
Different Textures	10	12	2
Raised Pavement Markings*	1	5	17
No Distinction*	1	5	17
Jiggle Bars*	0	7	16

*One respondent did not answer this question.

4. *Based on your experience, indicate whether the following drivers would pull onto a full width paved shoulder of a two-lane rural highway in your district to let a faster vehicle pass?*

Based on the response to this question, Texas drivers are much more likely to perform this driving maneuver than are out-of-state drivers (See Table 3). Among all vehicle operators, 88 percent of the respondents felt farm equipment drivers would pull over, 58 percent felt truck drivers would pull over, 50 percent felt passenger car drivers would pull over and 17 percent felt school bus drivers would pull over. It is interesting to note that 21 percent of the respondents indicated that school bus drivers would never pull over.

Are there locations in your district where this type of shoulder usage by vehicular traffic is discouraged? If so, where and why was it done and how was it accomplished?

Although the original intent of this question was to locate specific sites for further study, several respondents listed general situations where this type of shoulder usage is discouraged. The situations noted were approaches to narrow bridges (twice), roads with heavy trucks (twice), roads with deteriorated shoulders and roads with 10,000 to 25,000 vehicles per day. Signing, edge lines and raised pavement markings have been used to discourage shoulder usage. One respondent pointed out that signing had proved to be "not very successful".

Are there locations in your district where this type of shoulder usage is known to exist and seems to work well? If so, list several of these locations.

Again, the intent of this question was to locate specific sites for further study. No general situations were identified.

Table 3. Drivers Who Would Pull Onto a Paved Shoulder of a Rural Two-Lane Highway to Let a Faster Vehicle Pass.

Type of Driver	Frequently	Sometimes	Never
Texas Drivers	17	7	0
Out-of-State Drivers	2	19	3
Farm Equipment Drivers	21	3	0
Truck Drivers	14	9	1
Passenger Car Drivers	12	12	0
School Bus Drivers	4	15	5

5. *In your district, how frequently are safety problems associated with driving on the paved shoulder of rural two-lane highways at the following locations?*

As shown in Table 4, the respondents indicated bridges as the locations where safety problems are most frequently associated with driving on the paved shoulder of a rural two-lane highway. However, only 17 percent of the engineers felt that safety problems exist. Intersections and driveways were indicated as locations with frequent safety problems by one respondent each, whereas curves and hills were not identified as locations with frequent safety problems by any of the respondents. One engineer did indicate that safety problems were associated with "passing on the shoulder".

Table 4. Locations Where Safety Problems Are Associated With Driving on the Paved Shoulder of a Rural Two-Lane Highway.

Location	Frequent	Sometimes	Never
Bridges[a]	4	13	5
Intersections[b]	1	12	10
Driveways[b]	1	12	10
Curves[b]	0	15	8
Hills[b]	0	10	13

[a] Two respondents did not answer this question.
[b] One respondent did not answer this question.

6. *What factors create maintenance problems for paved shoulders on rural two-lane highways in your area?*

Truck traffic, with an average rank of 9.5, was indicated as the factor which created the most maintenance problems for paved shoulders on rural two-lane highways (see Table 5). Two weather related factors - freeze-thaw (average rank of 6.0) and rain (average rank of 4.4) - were the second and third rated factors. The respondents indicated that initial construction (average rank of 2.2) did not create shoulder maintenance problems. Other factors that were listed include lack of traffic - faster asphalt deterioration (twice) -, vegetation damage and initial design.

Table 5. Factors Which Create Maintenance Problems for Paved Shoulders on Rural Two-Lane Highways.

Factor	Average Rank on a Scale of 1 to 10 (1 is no problem and 10 is a big problem)
Truck Traffic	9.5
Freeze-Thaw	6.0
Rain	4.4
Initial Construction	2.2

7. *Do paved shoulders on two-lane rural highways have the same priorities as the rest of the highway for maintenance dollars?*

The main lanes, with an average rank of 10, were rated as the highway part with the highest priority for maintenance dollars, as shown in Table 6. Traffic control devices (an average rank of 8.8) were rated higher than were shoulders (an average rank of 7.2). Sideslopes (an average rank of 4.7) were the lowest rated roadway part. Two other items - drainage and mowing - were mentioned as competition for highway maintenance dollars.

Table 6. Priorities for Maintenance Dollars.

Highway Part	Average Rank on Scale of 1 to 10 (1 is low priority and 10 is high priority)
Mainlanes	10.0
Traffic Control Devices	8.8
Shoulders	7.2
Sideslopes	4.7

Laboratory Studies

Concern has been expressed that motorists do not adequately understand the road marking code, nor do they totally agree on the legality of driving on the shoulder. Gordon (5) examined this hypothesis in a laboratory study which used 254 motorists from the Washington, D.C. area. Depending upon the circumstances, he found that as high as 60 percent of the subjects thought it was legal to use the shoulder to pass a disabled vehicle located in the main lane. This brief study lacks generalization to Texas drivers and conditions, but it indicates the need to determine what Texas drivers believe to be the law and under what circumstances they would use the shoulder to pass another vehicle or pull over onto the shoulder to allow a faster vehicle to pass.

The accepted document for correct interpretation and application of the road marking code is the Manual for Uniform Traffic Control Devices for Streets and Highways - 1978 (6). Two definitions contained in the publication are applicable to this study. They are the following:

Section 3A-7: Types of Longitudinal Lines

"3. A normal solid white line is used to delineate the edge of a travel path where travel in the same direction is permitted on both sides of the line but crossing the line is discouraged and to mark the right edge of the pavement."

Section 3B-6: Pavement Edge Lines

"Pavement edge line markings provide an edge of pavement guide for drivers. They have a unique value as a visual reference for the guidance of drivers during adverse weather and visibility conditions. They also may be used where edge delineation is desirable to reduce driving on paved shoulders or refuge areas of lesser structural strength than adjacent pavement. Edge lines shall not be continued through intersections and should not be broken for driveways."

Rules governing the passing of vehicles appear to be the central set of regulations which define the legality of driving on paved shoulders, subject to the basic regulations of traffic control devices. These rules, to the layman as well as the professional, seem to be unclear, contradictory and in conflict to some unknown degree with common driving practice in Texas. The following Texas Motor Vehicle Laws were taken from V.C.S.6701d - Uniform Act Regulating Traffic on Highways (7):

"Section 13. (c) Roadway. That portion of a highway improved, designed or ordinarily used for vehicular travel, *exclusive* of the berm or shoulder. In the event a highway contains two or more separate roadways the term "roadway" as used herein shall refer to any such roadway separately, but not to all such roadways collectively."

"Section 52. (b) Upon all roadways any vehicle proceeding at less than the normal speed of traffic at the time and place and under the conditions then existing shall be driven in the right-hand lane then available for traffic, or as close as practicable to the right-hand curb or edge of the *roadway*, except when overtaking and passing another vehicle proceeding in the same direction or when preparing for a left-turn at an intersection or into a private road or driveway."

"Section 54. (b) Except when overtaking and passing on the right is permitted, the driver of an overtaken vehicle *shall give way to the right* in favor of the overtaking vehicle on audible signal and shall not increase the speed of his vehicle until completely passed by the overtaking vehicle."

"Section 55. (a) The driver of a vehicle may overtake and pass upon the right another vehicle only under the following conditions:

1. When the vehicle overtaken is making or about to make a left-turn.

2. Upon a street or highway with *unobstructed pavement* not occupied by parked vehicles or *sufficient width for two or more lines of moving vehicles in each direction.*"

"Section 55. (b) The driver of a vehicle may overtake and pass another vehicle upon the right only under conditions permitting such movement in safety. In *no event* shall such movement be made by driving off the pavement or main traveled portion of the *roadway.*"

A related regulatory area of traffic maneuvers wherein potential conflict and confusion may exist among driving practice, traffic control and traffic regulations is the legal restriction to passing within 100 feet of any intersection or bridge (Section 57. (a) 2 and 3), both of which are common driving practices on high-type rural highways. The exact wording of all aforementioned laws can also be found in Chapter 1, "Words and Phrases Defined", and Chapter 11, "Rules of the Road", of the Uniform Vehicle Code and Model Traffic Ordinance: Revised 1968 (8). Based upon the existing state laws, it is not surprising that the legality of driving on the paved shoulder of a rural two-lane highway has been questioned.

It was anticipated that Texas drivers were not aware of the legal aspects involved with driving on paved shoulders. As a result, a laboratory study was designed to test their understanding of the legal issues. In addition, the study investigated driver preferences for and experiences with shoulder usage. The same basic study was also used to ascertain DPS patrolmen's interpretation of the legal issues involved and their observations of shoulder usage throughout the state. The following sections discuss the methodology and findings of the laboratory study.

Methodology

Ninety-six subjects characteristic of the general driving population in the state were tested in a laboratory study at Texas A&M University. The actual breakdown of the subjects' ages and educational levels is shown in Table 7. For comparison, the theoretical distribution of all Texas' drivers is also shown. The survey was administered approximately 30 times to groups of from two to five people each. Each group of subjects was shown ten sets of slides which depicted several different shoulder usage situations. An example of one of the scenarios is illustrated in Figure 1. As each set of slides was displayed, a verbal description of the driving maneuver was given by a test administrator. After viewing a set of slides, the motorists were asked questions such as these:

"Have you ever made this driving maneuver before?"

"Do you think it is dangerous to drive like this?"

"Do you think it is legal to drive like this?"

Subjects indicated their answer - no, don't know, or yes - by pushing the appropriate button on a student responder unit. The individual responses were automatically displayed on a master consol and a laboratory assistant manually recorded them on an answer sheet. A copy of the script, slides and data forms used for this study are contained in Appendix B.

The same basic study was used to test 91 DPS patrolmen at an in-service training seminar in Austin. This group represented a cross-section of the troopers from around the state. It contained at least ten officers from each of the six DPS regions. Twenty-five percent of the counties in the state were represented. The experience level of the patrolmen varied greatly (See Figure 2).

Table 7. Age and Education Level of the Motorists Used in the Laboratory Study*

Male Subjects	Educational Level					
Age Group	Elementary	High School 1 - 3	High School 4	College 1 - 3	College 4	TOTAL
18 - 24	- (3)	2 (5)	6 (4)	7 (2)	1 (1)	16 (15)
25 - 34	- (1)	3 (2)	1 (4)	3 (2)	2 (2)	9 (11)
35 - 44	1 (1)	1 (2)	6 (3)	2 (1)	2 (1)	12 (8)
45 - 54	3 (2)	3 (2)	2 (3)	- (1)	1 (1)	9 (9)
55 - 64	1 (2)	1 (2)	1 (2)	2 (1)	1 (1)	6 (8)
≥ 65	- (4)	- (1)	- (1)	- (1)	1 (1)	1 (8)
Total	5 (13)	10 (14)	16 (17)	14 (8)	8 (7)	53 (59)
Female Subjects						
18 - 24	- (2)	1 (4)	6 (3)	7 (2)	1 (0)	15 (11)
25 - 34	- (1)	1 (1)	3 (3)	- (1)	4 (1)	8 (7)
35 - 44	2 (1)	2 (1)	3 (3)	1 (1)	3 (1)	11 (7)
45 - 54	1 (1)	2 (1)	1 (2)	2 (1)	- (1)	6 (6)
55 - 64	1 (2)	- (1)	1 (1)	- (0)	1 (0)	3 (4)
≥ 65	- (4)	- (1)	- (1)	- (0)	- (0)	0 (6)
Total	4 (11)	6 (9)	14 (13)	10 (5)	9 (3)	43 (41)
GRAND TOTAL	9 (24)	16 (23)	30 (30)	24 (13)	17 (10)	96 (100)

*Numbers in parentheses represent the theoretical distribution of Texas drivers (1973).

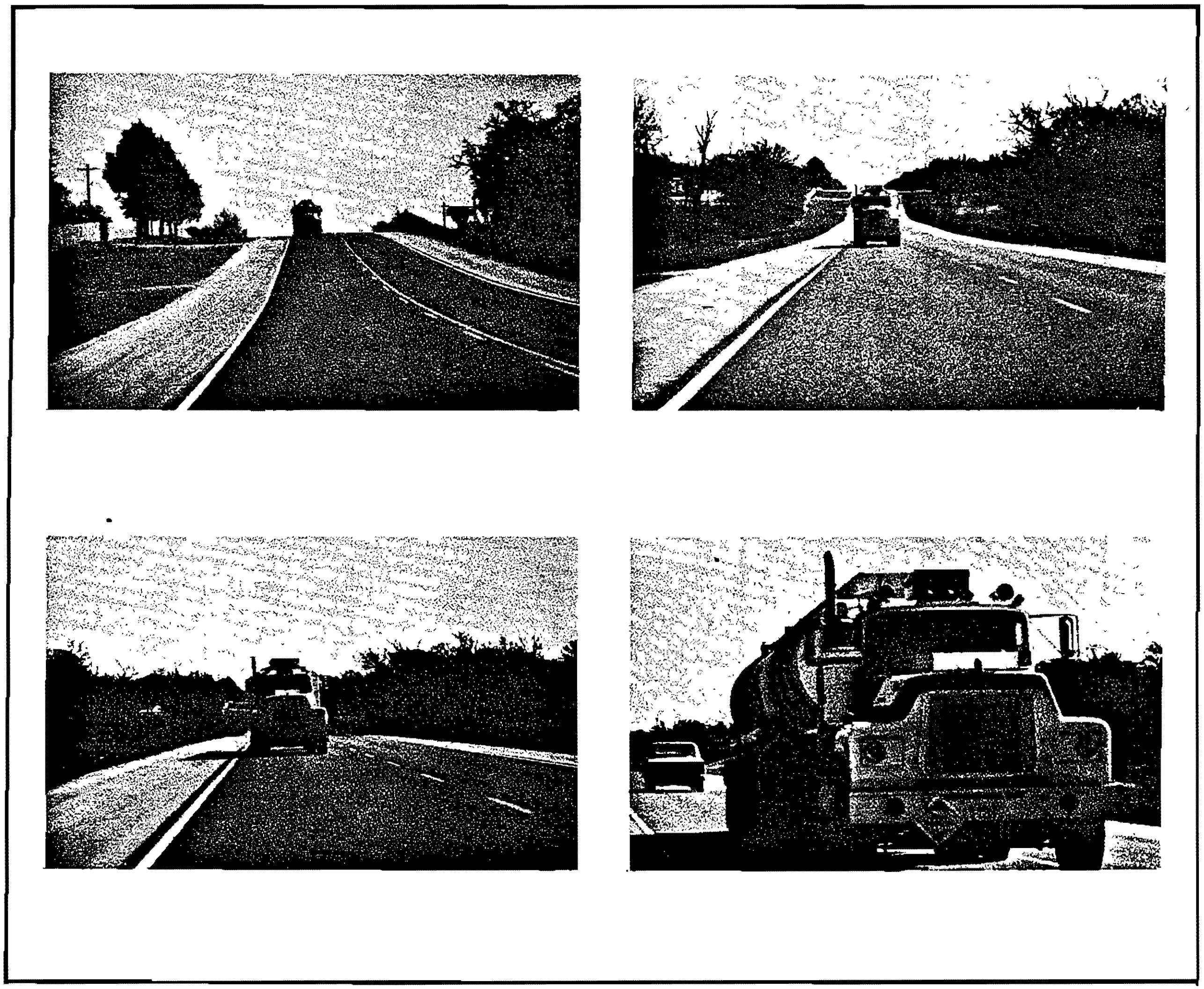


Figure 1. Example of Scenario That Was Presented in the Laboratory Study.

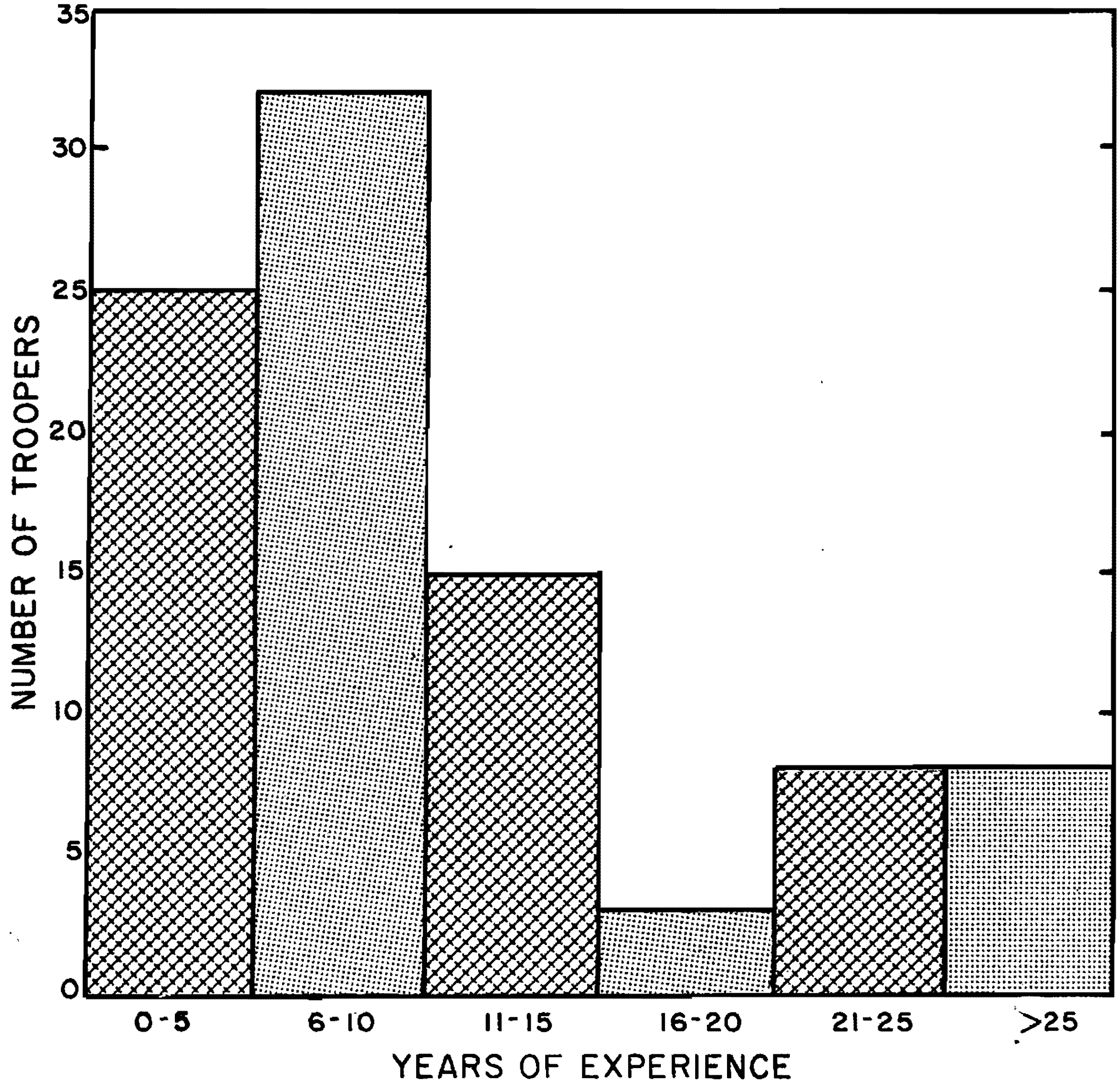


Figure 2. Experience Level of the DPS Patrolmen Used in the Laboratory Study.

The slide survey was given to the entire group of troopers at once and used the same slides as the previous study did. Verbal descriptions of the driving maneuver were the same; however, the questions and methods of response were slightly different. After viewing a set of slides, the patrolmen were asked questions such as these:

"Have you ever seen a motorist make this driving maneuver before?"

"Do you think it is dangerous to drive like this?"

"Is it legal to drive like this?"

The officers answered these questions by writing their response on an answer sheet. A copy of the script, slides and data forms used for this study also are contained in Appendix B.

Study Results

In order to better understand the results from this study, the subject's responses have been tabulated and grouped with those from similar questions. A quantile test was used to ascertain either the certainty or uncertainty of the answers to specific questions. Because of the way people respond to these types of questions, unanimous answers were neither expected nor essential for a "certain" response. Therefore, an extension of the design driver concept was used to select an 85 percent positive or negative response as the threshold value for driver certainty. Maximum uncertainty would be indicated whenever the responses to a specific question were split 50 percent yes - 50 percent no. A confidence interval significant to the 0.975 percent level was constructed around these two points. These limits were used to determine statistically the responses that were certain and those that were uncertain.

As a further analysis, the general driving public's responses to each question were compared to responses of DPS patrolmen. Where applicable, response to similar questions by the same population were compared. In all comparisons, Pearons's Chi-Square statistic was used in order to determine whether or not differences in response were statistically significant. All differences reported in this discussion are significant at the 95 percent confidence level. The responses to each group of nine questions will be discussed and the important finding(s) from each group will be pointed out.

Group 1. WOULD YOU? (WOULD MOTORIST?)

- A significantly larger number of motorists would use the shoulder to pass vehicles turning left into an intersection than turning left into a driveway.

The intent of this group of questions was to determine driver preference for shoulder usage in a variety of driving situations. The percentages of positive responses are shown in Table 8. The general public was certain that they would perform the driving maneuvers described in scenarios number 3, 4 and 5; however, they were uncertain whether they would cross the center line to pass a vehicle driving 50 miles per hour in the main lane. As this maneuver involved crossing the center line of the highway, this uncertainty should have been anticipated. Statistically, scenarios number 1 and 2 fall into neither the certain nor uncertain categories.

When the responses by the public were compared to those by the DPS, significant differences in responses were noted for scenario numbers 1, 4, 5 and 6. It appears that law enforcement officers are not good predictors of what motorists say they would do. When considering passing at driveways and intersections, a significantly larger number of motorists would use the shoulder to pass vehicles slowing to turn left into an intersection. Responses by the DPS officers did not indicate a difference in the two situations. In situations of vehicles driving 50 miles per hour on the shoulder to pickups driving 20 miles per hour on the shoulder, no differences were indicated in

Table 8. Laboratory Responses for Experience and Preference Questions*.

	General Public			Law Enforcement Officers		
	Female Drivers	Male Drivers	All Drivers	< 5 Yrs. Experience	> 5 Yrs. Experience	All Law Officers
WOULD YOU? (WOULD MOTORIST?)						
1. Pass Using Shoulder a Vehicle Slowing to Turn Left Into a Driveway	70%	72%	71%	94%	98%	97%[a]
2. Pass Without Crossing Center Line a Vehicle Driving 50 mph on Shoulder	72%	70%	71%	71%	63%	65%
3. Pass Without Crossing Center Line a Pickup Driving 20 mph on Shoulder	77%	79%	78%[a]	79%	74%	76%
4. Pass Using Shoulder a Vehicle Slowing to Turn Left Into an Intersection	86%	96%	92%[a]	100%	98%	99%[a]
5. Pass by Crossing Center Line a Vehicle Driving 50 mph in a Lane	47%	72%	60%[b]	88%	89%	89%[a]
6. Pull Onto Shoulder to Let a Large Truck Pass	84%	94%	90%[a]	71%	54%	59%[b]
HAVE YOU EVER? (HAVE YOU SEEN?)						
1. Pass Using Shoulder a Vehicle Slowing to Turn Left Into a Driveway	75%	85%	80%[a]	100%	100%	100%[a]
2. Pass Without Crossing Center Line a Vehicle Driving 50 mph on Shoulder	81%	94%	89%[a]	100%	100%	100%[a]
3. Pass Without Crossing Center Line a Pickup Driving 20 mph on Shoulder	98%	98%	98%[a]	100%	100%	100%[a]
4. Pass Using Shoulder a Vehicle Slowing to Turn Left Into an Intersection	91%	100%	96%[a]	97%	100%	99%[a]
5. Pass by Crossing Center Line a Vehicle Driving 50 mph in a Lane	67%	85%	77%[a]	100%	100%	100%[a]
6. Pull Onto Shoulder to Let a Large Truck Pass	74%	98%	88%[a]	100%	100%	100%[a]
IS IT DANGEROUS?						
1. Pass Using Shoulder a Vehicle Slowing to Turn Left Into a Driveway	40%	32%	35%	26%	18%	21%[a]
2. Pass Without Crossing Center Line a Vehicle Driving 50 mph on Shoulder	33%	40%	36%	44%	26%	34%
3. Pass Without Crossing Center Line a Pickup Driving 20 mph on Shoulder	23%	30%	27%	38%	23%	30%
4. Pass Using Shoulder a Vehicle Slowing to Turn Left Into an Intersection	21%	13%	17%[a]	32%	13%	20%[a]
5. Pass by Crossing Center Line a Vehicle Driving 50 mph in a Lane	49%	40%	44%[b]	50%	39%	43%[b]
6. Pull Onto Shoulder to Let a Large Truck Pass	26%	23%	24%	38%	23%	29%

*Percent yes answers; [a]Certain answers; [b]Uncertain answers.

the likelihood of a motorist passing these vehicles without crossing the center line of the highway. As before, the DPS officers did not indicate a difference in the two situations.

Group 2. HAVE YOU EVER? (HAVE YOU SEEN?)

- The general public has performed and the law enforcement officers have observed the six driving maneuvers described in the laboratory study.
- A significantly larger number of motorists have used the shoulder to pass vehicles turning left into an intersection than turning left into a driveway.

The intent of this group of questions was to determine driver experience with shoulder usage in a variety of driving situations. The percentages of positive responses are shown in Table 8. The results indicate that Texas motorists have performed and DPS patrolmen have observed the six driving maneuvers that were described. The least performed maneuver was scenario number 5 - cross the center line to pass a vehicle that is driving 50 miles per hour in the main lane. This response helps explain why the motorists were uncertain as to whether or not they would actually perform the maneuver. Some of them had no experience with this particular situation. Not surprisingly, almost all of the law enforcement offices had observed each of the six driving maneuvers.

When the responses by the public were compared to those by the DPS, more law enforcement officers had observed a particular maneuver than motorists reported they had performed. These increases were significant for scenario numbers 1, 2, 5 and 6. When comparing passing experience at driveways and intersections, a significantly larger number of motorists have used the shoulder to pass vehicles slowing to turn left into an intersection. Responses by the DPS officers did not indicate a difference in their observance of the two driving maneuvers. When comparing passing of vehicles driving 50 miles per hour on the shoulder to passing of pickups driving 20 miles per hour on the shoulder, a significantly larger number of motorists had passed the slower moving vehicle without crossing the center line of the highway. Again, responses by the DPS officers did not indicate a difference in their observance of the two driving maneuvers.

Group 3. IS IT DANGEROUS?

- Both the general public and the law enforcement officers seem certain it is not dangerous to use the shoulder to pass a vehicle slowing to turn left into an intersection.
- Both the general public and the law enforcement officers were uncertain as to whether it was dangerous to cross the center line to pass a vehicle driving 50 miles per hour in the main lane.
- A significantly larger number of motorists feel it is more dangerous to use the shoulder to pass a vehicle turning left into a driveway than turning left into an intersection.

The intent of this group of questions was to determine perceived danger with shoulder usage in a variety of driving situations. The percentages of positive responses are shown in Table 8. Both Texas drivers and DPS patrolmen seem certain it is not dangerous to use the shoulder to pass a vehicle that is slowing to turn left into an intersection. In addition, the law enforcement officers seem certain it is not dangerous to pass a vehicle that is slowing to turn left into a driveway. Uncertainty is indicated by both groups for scenario number 5 - crossing the center line to pass a vehicle driving 50 miles per hour in the main lane. Based upon the previous results, this should be expected. Statistically, the other driving situations fell into neither category.

When the responses by the public were compared to those by the DPS, a significant difference was noted for only one situation. More motorists than DPS officers indicated that using the shoulder to pass a vehicle slowing to turn left into a driveway was dangerous. When comparing perceived danger of passing at driveways and intersections, a significantly larger number of motorists felt that it was more dangerous to use the shoulder to pass a vehicle that was slowing to turn left into a driveway. Responses by the DPS officers did not indicate a difference in the amount of danger involved with the two maneuvers. When comparing passing vehicles driving 50 miles per hour on the shoulder and passing pickups driving 20 miles per hour on the shoulder, motorists did not indicate a difference in the danger involved with the two situations. As before, the DPS officers did not indicate a difference in perceived danger.

Group 4. LEGAL TO PASS SOMEONE DRIVING ON SHOULDER WITHOUT CROSSING CENTER LINE

- Both the general public and DPS patrolmen feel certain it is legal to pass someone that is driving on the shoulder without crossing the centerline of the highway.
- When comparing the two groups of respondents, a significantly smaller number of motorists feel it is legal to perform this driving maneuver.

The intent of this group of questions was to determine both motorist understanding and DPS interpretation of the legal issues involved with passing someone that is driving on the shoulder. The percentages of positive responses are illustrated in Table 9. Both the general public and the law enforcement officers felt certain it was legal to pass someone that was driving on the shoulder without crossing the center line of the highway.

When comparing the responses from the motorists to those from the DPS officers, significant differences existed for scenarios numbers 1, 2, 4 and 5.

Table 9. Laboratory Responses for Legality Questions*.

	General Public			Law Enforcement Officers		
	Female Drivers	Male Drivers	All Drivers	≤ 5 Yrs. Experience	> 5 Yrs. Experience	All Law Officers
LEGAL TO PASS SOMEONE DRIVING ON SHOULDER WITHOUT CROSSING CENTER LINE						
1. Contrast - Edge Line	86%	87%	86%[a]	94%	100%	98%[a]
2. Contrast - No Edge Line	88%	87%	88%[a]	91%	98%	95%[a]
3. No Contrast - Edge Line	93%	91%	92%[a]	97%	98%	98%[a]
4. No Contrast - No Edge Line	79%	91%	85%[a]	97%	98%	98%[a]
5. School Bus	79%	91%	85%[a]	97%	98%	97%[a]
6. Truck	95%	89%	92%[a]	97%	100%	98%[a]
LEGAL FOR SOMEONE TO DRIVE ON SHOULDER						
1. Contrast - Edge Line	37%	60%	50%[b]	76%	89%	85%[a]
2. Contrast - No Edge Line	58%	66%	63%	68%	84%	79%[a]
3. No Contrast - Edge Line	53%	66%	60%[b]	71%	86%	79%[a]
4. No Contrast - No Edge Line	49%	66%	58%[b]	79%	88%	86%[a]
5. School Bus	53%	53%	53%[b]	82%	84%	84%[a]
6. Truck	49%	64%	57%[b]	76%	88%	84%[a]
IS IT A LEGAL REQUIREMENT TO PULL ONTO SHOULDER TO LET A VEHICLE PASS?						
1. Contrast - Edge Line	37%	38%	38%[b]	24%	25%	24%
2. Contrast - No Edge Line	35%	40%	38%[b]	26%	21%	25%
3. No Contrast - Edge Line	35%	32%	33%	26%	25%	26%
4. No Contrast - No Edge Line	51%	45%	48%[b]	29%	32%	30%
5. School Bus	40%	38%	39%[b]	24%	27%	26%
6. Truck	35%	38%	36%	18%	26%	23%[a]

*Percent yes answers; [a]Certain answers; [b]Uncertain answers.

A significantly smaller number of motorists felt that it was legal to pass someone that was driving on the shoulder without crossing the center line of the highway. Four combinations of pavement contrast and edge line markings, elicited no discernible differences in the perceived legality of this maneuver by either the motorists or the DPS officers. When comparing different vehicles on the shoulder - school bus and truck - neither the motorists nor the DPS officers indicated a difference in the legality of the maneuver.

Group 5. LEGAL FOR SOMEONE TO DRIVE ON SHOULDER

- The general public is uncertain whether it is legal for someone to drive on the shoulder; however, DPS patrolmen feel certain that this driving maneuver is legal.

The intent of this group of questions was to determine motorist understanding of the legal issues involved with driving on the shoulder. The percentages of positive responses are illustrated in Table 9. The general public is uncertain whether it is legal for someone to drive on the shoulder; however, law enforcement officers feel certain that this driving maneuver is legal.

When the responses by the public were compared to those by the DPS officers, a significantly smaller group of motorists felt that is was legal for someone to drive on the shoulder. As the general public was uncertain whether or not the driving maneuver was legal, this result was anticipated. Neither the motorists nor the DPS officers indicated a difference in the legality of the maneuver for the four combinations of pavement contrast and edge line markings. Likewise, neither group indicated a difference in response for either a school bus or a truck.

Group 6. IS IT A LEGAL REQUIREMENT TO PULL ONTO THE SHOULDER TO LET A FASTER VEHICLE PASS?

- The general public is uncertain whether it is a legal requirement to pull onto the shoulder to let a faster vehicle pass.
- A significantly larger number of motorists than law enforcement officers feel it is legally a requirement to pull onto the shoulder to let a faster vehicle pass.

The intent of this group of questions was to determine motorists understanding of the legal issues involved with pulling onto the shoulder to let a faster vehicle pass. The percentages of positive responses are illustrated in Table 9. For scenario numbers 1, 2, 4 and 5, motorists are uncertain whether it is a legal requirement to pull onto the shoulder to let a faster vehicle pass. Responses by the law enforcement officers could not statistically be classified as either certain or uncertain.

When the responses of the public were compared to those by the DPS officers, a larger number of motorists felt it was legally a requirement to pull onto the shoulder in order to let a faster vehicle pass. This difference was significant for scenario numbers 1, 4 and 6. When comparing the response to this question for the four combinations of pavement contrast and edge line markings, neither the motorists nor the DPS officers indicated a difference in the legality of this requirement for any of the various situations. As before, neither group indicated a difference in response when a school bus was compared to a truck.

Group 7. IS PASSING ON THE RIGHT LEGAL?

- The general public is uncertain whether it is legal to use the shoulder to pass a vehicle turning left at a driveway; however, DPS patrolmen seem certain that this driving maneuver is legal.

- When comparing the general public to the DPS patrolmen, a significantly smaller number of motorists feel it is legal to use the shoulder to pass a vehicle that is turning left at either a driveway or an intersection.

The intent of this group of questions was to determine driver understanding of the legal issues involved with passing on the right. The percentages of positive responses are shown in Table 10. The general public felt certain the two pass-in-right-lane maneuvers were legal; however, they were uncertain about the pass-on-shoulder-at-a-driveway situation. The DPS patrolmen appeared certain that all of the maneuvers that were described were legal.

When the responses of the public were compared to those of the DPS officers, several differences were noted. A significantly smaller number of motorists felt it was legal to use the right lane to pass a vehicle on a four-lane highway. When comparing passing on the right at intersections and driveways, neither the motorists nor the DPS officers indicated any difference in the response as to the perceived legality of the maneuver. When comparing the two pass-in-right-lane situations, neither group indicated a difference in response.

Group 8. USE SHOULDER TO PASS A VEHICLE ON RIGHT?

- The general public is certain that to use the shoulder to pass a vehicle on the right is dangerous, not legal and should not be legal; however, they are uncertain whether or not it is currently legal.

The intent of this group of questions was to determine driver familiarity with using the shoulder to pass a vehicle on the right. The percentages of positive responses are shown in Table 10. The general public seemed certain that to use the shoulder to pass a vehicle on the right was dangerous, not

Table 10. Laboratory Responses to Miscellaneous Questions*.

	General Public			Law Enforcement Officers		
	Female Drivers	Male Drivers	All Drivers	≤ 5 Yrs. Experience	> 5 Yrs. Experience	All Law Officers
IS PASSING ON THE RIGHT LEGAL?						
1. Pass on Shoulder a Vehicle Turning Left at a Driveway	63%	45%	53%[b]	79%	89%	86%[a]
2. Pass in Right Lane a Vehicle Turning Left at an Intersection	95%	98%	97%[a]	94%	98%	97%[a]
3. Pass on Shoulder a Vehicle Turning Left at an Intersection	72%	57%	64%	82%	84%	84%[a]
4. Pass in Right-Lane a Vehicle on a Four-Lane Highway	95%	89%	92%[a]	97%	100%	99%[a]
USE SHOULDER TO PASS A VEHICLE ON THE RIGHT?						
1. Have You Seen?	14%	33%	25%	79%	98%	90%[a]
2. Is It Dangerous?	81%	94%	89%[a]	94%	81%	86%[a]
3. Is It Legal?	16%	11%	14%[a]	35%	63%	53%[b]
4. Should It Be Legal?	16%	13%	15%[a]	12%	18%	16%[a]
WHICH IS SAFER?						
1. Level Section						
- Pass Vehicle in Main Lane to Left of Center Line	51%	38%	44%[b]	32%	25%	28%
- Pass Vehicle on Shoulder Without Crossing Center Line	49%	62%	56%[b]	68%	75%	72%
2. Long Upgrade						
- Pass Vehicle in Main Lane to Left of Center Line	42%	30%	35%	26%	18%	21%[a]
- Pass Vehicle on Shoulder Without Crossing Center Line	58%	70%	65%	74%	82%	79%[a]
3. High Volume Highway						
- Pass Vehicle in Main Lane Left of Center Line	84%	87%	85%[a]	82%	73%	77%[a]
- Pass Vehicle in Main Lane Using Shoulder on the Right	16%	13%	15%[a]	18%	27%	23%[a]

*Percent yes answers; [a]Certain answers; [b]Uncertain answers.

legal and should not be legal. The DPS patrolmen agree that it is dangerous and should not be legal; however, they were uncertain whether or not it is currently legal. When the responses of the general public were compared to those of the DPS patrolmen, a significantly smaller number of motorists had seen the maneuver and thought it to be legal. When comparing "Is It Legal?" to "Should It Be Legal?" there was no apparent difference in the response by the motorists; however, there was a significant difference in the response by the DPS officers. A significantly smaller number of patrolmen felt it should be a legal maneuver. Interestingly, there is no apparent difference in response to the "should" question when the motorists answers are compared to those by the DPS officers.

Group 9. WHICH IS SAFER?

- On a high volume highway, both the general public and the law enforcement officers seem certain it is safer for the overtaking vehicle to cross the center line and pass on the left than it is to use the shoulder and pass on the right.

The intent of this group of questions was to determine the relative safety between pairs of alternative passing situations. The percentages of positive responses are shown in Table 10. On a level section, motorists are uncertain whether it is safer for the overtaking vehicle to pass a vehicle in the main lane to the left of a center line or to pass a vehicle on the shoulder without crossing the center line. The response by the DPS patrolmen can not be considered certain or uncertain. On a long upgrade, the law enforcement officers seem certain it is safer for the overtaking vehicle to pass a vehicle on the shoulder without crossing the center line than it is to pass a vehicle in the main lane to the left of the center line. In this case, the answers given by the motorists were statistically neither sure nor unsure. On a high volume highway, both groups of respondents seem certain it is safer for the overtaking vehicle to cross the center line and pass on the left than it is to use the shoulder and pass on the right.

Conclusions and Recommendations

Texas drivers perceive a difference between using a paved shoulder to pass vehicles turning left into an intersection and turning left into a driveway. Results of this study indicate that motorists are more likely, have more experience and feel more secure when performing the intersection pass. In addition, drivers are uncertain about the legality of the shoulder pass. On the other hand, DPS officers did not indicate a difference between the two driving situations in any of the study areas - preference, experience, safety or legality. If, in fact, there is no difference, it may be appropriate to add the words "at either an intersection or a driveway" to Section 55. (a) 1. of the Texas Motor Vehicle Laws.

Both the general public and the DPS patrolmen seem certain it is legal to pass someone that is driving on the shoulder without crossing the center line of the highway. However, the motorists are uncertain whether it is legal for someone to simply drive on a paved shoulder or whether it is a legal requirement to pull onto the paved shoulder to let a faster vehicle pass. Shoulder contrast, edge line markings or type of vehicle made no difference in the response to these questions. As it is a legal requirement for vehicles proceeding at less than the normal speed of traffic to give way to the right and be driven as close as practical to the right-hand edge of the roadway, an interesting paradox exists: Is the paved shoulder a part of the roadway? Results from this study indicate confusion; therefore, the following recommendations have been made:

1. A paved shoulder should not be considered a part of the roadway.
2. It should be legal for motorists to drive on a paved shoulder

unless signs or markings prohibit such a maneuver or it is unsafe to do so.

3. It should be legal to pass, without crossing the center line of the highway, someone that is driving on a paved shoulder.
4. It should be legal for a motorist traveling at less than the normal speed of traffic to pull onto the paved shoulder in order to let faster vehicles pass; however, it should not be a requirement.

Texas drivers seem certain that to use the shoulder to pass a non-turning vehicle on the right is dangerous, not legal and should not be legal. DPS officers agree that it is dangerous and should not be legal; however, they are uncertain whether or not it is currently legal. Again, this confusion is probably related to whether the paved shoulder is a part of the roadway. Based upon the results of this study, it is recommended that using the shoulder to pass a non-turning vehicle on the right should not be legal and that the Texas Motor Vehicle Laws be amended so as to reflect this point.

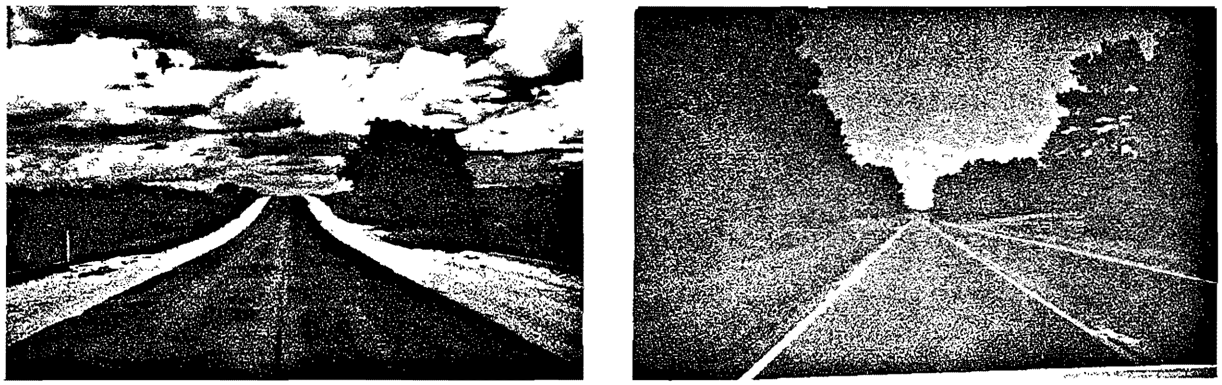
CHAPTER III. SAFETY EFFECTS OF PAVED SHOULDER USAGE

Introduction

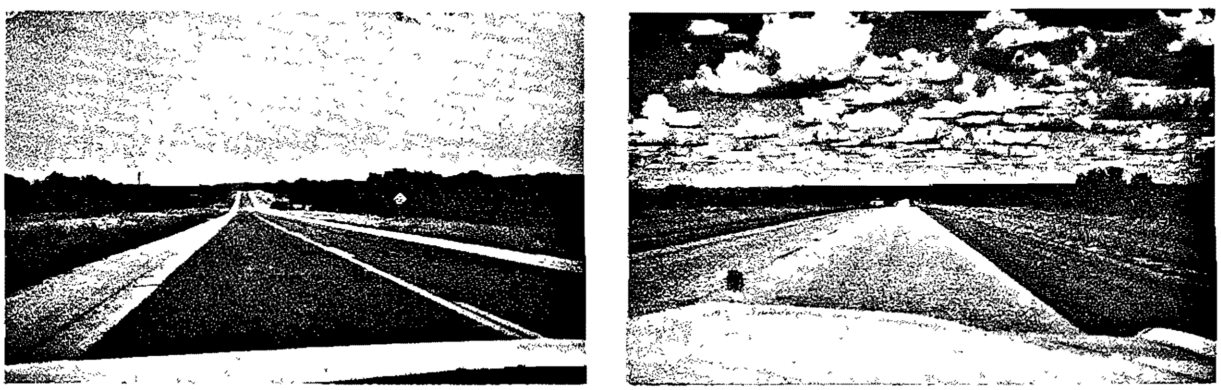
The level of safety performance is one of the major characteristics of a particular roadway. Traffic engineers routinely perform a variety of accident analyses to determine these characteristics. Although there are many types of analyses, the most common purposes for such studies are to identify hazardous locations, to examine the aptness of proposed corrective measures or to evaluate the effectiveness of previous improvements. In addition, comparatative studies are often performed to identify roadway sections with good and poor safety practices.

The SDHPT does not have a documented data base for establishing design policies and practices concerning the upgrading of two-lane highways without paved shoulders to two-lane highways with paved shoulders, or for upgrading two-lane highways with paved shoulders to "poor-boy" highways. One of the purposes of this study was to establish the accident effects related to the presence or absence of a paved shoulder. The Transportation Planning Division of the SDHPT considers any paved shoulders less than six feet wide as "none or inadequate" and codes the State's computerized geometric files in that manner. The same definition for shoulder was adopted for this study. The study was limited to rural Texas highways of the types shown in Figure 3.

Two separate accident investigations were conducted as a portion of this project. Their objective was to determine the safety effects of paved shoulders on Texas highways. The initial investigation was an analysis of accident rates, patterns and characteristics on roadways with and without paved shoulders. The second was a before-and-after study to determine the change in safety characteristics caused by the addition of paved shoulders to a two-lane road, or by the conversion of paved shoulders to additional travel lanes ("poor-boy" treatment).



Two-Lane Roadways with Unpaved Shoulders



Two-Lane Roadways with Paved Shoulders

Four-Lane Roadways with Unpaved Shoulders

Figure 3 Typical Examples for Three Different Classes of Highways.

Background

Previous safety research on shoulders and shoulder width can be divided into three general groups: those finding adverse effects of wider shoulders, those finding unclear or null effects of wider shoulders and those finding favorable effects for wider shoulders. It appears as though different conclusions have been reached in every study on the subject. This diversity of opinion can be explained in part by examining the scope and data constraints in each individual study. This chapter will attempt to shed some light upon the exact relationships between shoulder characteristics and accident experience.

Shoulder Width. Early studies in California by Belmont (9,10) concluded that accident rates increased with increasing shoulder widths. In his first study (9), three ranges of paved shoulder width - less than six feet, six feet and greater than six feet - were tested against total accident frequency. Among his findings he concluded that for traffic volumes over 5000 vehicles per day, accident rates were significantly lower on sections with six-foot shoulders than they were on sections with wider shoulders. In a later study (10), he developed a relationship between shoulder widths and injury accident rates. This relationship indicated accidents increase as volumes increase and for volumes greater than 1300 vehicles per day, accidents increase as shoulder widths increase. An Oregon study by Blensey and Head (11) supports Belmont's hypothesis. For the range of traffic volumes studied, they reported that accident frequencies increased as the shoulder width increased. A major weakness in each of the three studies was the use of tangent sections of highway only. Shoulders are more likely to be used for vehicle recovery on curved sections of roadway; therefore, the use of only tangent sections will not represent the full benefits that paved shoulders provide for typical rural highways. In addition, none of the studies gave consideration to specific shoulder-related accident types. Because some accident types are not necessarily related to shoulder improvements, their inclusion may detract from the actual safety benefits that shoulders provide.

Several studies (12,13,14) either found mixed results or concluded that no relationship existed between shoulder widths and accident rates. Raff (12) used data from 15 states in attempting to find such a relationship. Although he found nothing significant on rural two-lane highways in general, he did find that wide shoulders helped to reduce the accident rate on curved highway sections. Perkins (13) found no consistent accident trends from Connecticut data. He concluded that no significant relationship exists between accident rates and shoulder widths. Woo (14) studied the two-lane Indiana Rural State Highway System and found shoulder width to possess little correlation with accident rates. While these studies did make use of curved sections of highway, they failed to examine the effects of specific related accident types. In addition, the data used for these studies appears to be strongly correlated to traffic volumes and this relationship was not examined. No doubt, these could be reasons that meaningful results were not obtained.

The majority of past studies support the concept of reduced accident rates on roadway sections with wide shoulders. Stohner (15) studied rural two-lane highways in New York State. His results showed that accident rates decreased as the shoulder width increased, particularly the rates for property damage accidents. In a later study, Billion and Stohner (16) found five- to seven-foot shoulders to be safer than three- to four-foot shoulders under all conditions of vertical and horizontal alignment, and eight-foot shoulders had lower accident indices than narrow or medium width shoulders on poor alignment. An Australian review of road safety (14) also found that increasing the width of the shoulder will decrease the accident rate provided the use of the shoulder by vehicular traffic is controlled. Jorgenson (18) developed the accident rate adjustment factors shown in Table 11 from a Maryland-Washington data base. Reductions are constant for both tangent and horizontally curved sections. These studies included substantial sample sizes and good classification schemes for grouping similar highway types for analysis purposes. Unfortunately, none of the studies include an analysis of specific shoulder-related accident types.

Table 11. Accident Rate Adjustment Factors For Rural Two-Lane Highways (18).

Shoulder Width (Feet)	Pavement Widths (Feet)			
	18	20	22	24
0 - 2	1.85	1.64	1.57	1.57
3 - 4	1.51	1.34	1.29	1.29
5 - 6	1.34	1.18	1.14	1.14
7 - 8	1.20	1.06	1.02	1.02
9 - 10	1.18	1.04	1.00	1.00

One of the more prominent studies on the effect of shoulder width on accidents was conducted by Rinde in 1977 (19). He used a before and after technique to evaluate shoulder widening projects on rural two-lane roads in California. Accident rates were reduced by 16 percent for additional shoulder widths of from 2 to 4 feet (under 3,000 vehicles per day), by 35 percent for additional widths of from 4 to 7 feet (under 5,000 vehicles per day) and by

29 percent for additional widths of from 7 to 10 feet (over 5,000 vehicles per day). Reductions for the latter two categories were statistically significant at the 95 percent confidence level. Head-on accidents decreased by about 50 percent and fixed-object accidents decreased by about 25 percent. The total accident rates were greater for the wider shoulder roadways because of the higher volume on these facilities. This study would appear to present a very good analysis of the effect of shoulder width on safety.

Shoulder Presence. A recent study (20) compared accident rates on homogeneous highway sections with paved shoulders to those on identical highway sections without shoulders. Using North Carolina data, Heimbach found a significantly lower accident experience and accident severity index associated with various types of two-lane highways which had three- to four-foot paved shoulders when compared with their counterpart sections which had unpaved shoulders. A sample of 3,000 rural highway sections which carried from 2,000 to 10,000 vehicles per day was used in this analysis.

Economic Analysis. The cost-effectiveness of shoulder widening projects depends on the improvement costs and the safety benefits that will result. Obviously, if shoulder widening has no effect on safety, there are no expected benefits. Therefore, the only studies which might be expected to include a meaningful economic analyses are those where shoulder widening was found to improve safety. Several more of the more important studies of this type are discussed below.

Heimbach (20) found three- and four-foot paved shoulders to generally be cost-effective for two-lane roads but not for four-lane roads. North Carolina accident data was used to estimate accident costs for two-lane roads which carried from 2,000 to 10,000 vehicles per day. Reasonable assumptions were made concerning paving costs, service lives, economic rates of return and traffic volumes in the 3,000 to 4,000 vehicle per day range. The minimum cost-effectiveness occurred in the 2,000 to 3,000 vehicle per day range.

Shannon (21) undertook an economic analysis to compare long term monetary effects associated with several pavement width options. Traffic accident data from Idaho and Washington were used to estimate annual accident costs for several pavement widths under various assumptions about traffic growth, interest rate and the cost of an individual accident. Construction and maintenance costs were estimated using Idaho and Nevada data. Overall economic comparisons were made among various widths for six different volume ranges. Results of this analysis were used to determine reasonable minimum pavement widths as shown in Table 12. The suggested widths were lower than existing standards and, in most cases, their adoption could be expected to result in a slight

Table 12. Reasonable Minimum Pavement Widths For Various Volume Ranges (21).

Average Daily Traffic	Minimum Paved Width, Ft.	Probable Shoulder Width, Ft.
0 - 249	20	-
250 - 399	20	-
400 - 749	24	-
750 - 999	28	2
1000 - 1999	34	5
2000 - 2999	40	8

Note: Lane widths are assumed to be either 10 or 12 feet.

increase in both maintenance cost and traffic accident frequency. However, the cumulative economic effect of these increases over a thirty year period would not offset the construction cost saving unless a pronounced increase occurs in average accident cost or major shifts occur in accident trends.

Davis (22) developed a procedure for determining optimum shoulder widths based on the relationship between shoulder design and highway safety. This approach uses traffic volume as a measure of exposure, traffic speed as a measure of risk and 1975 dollars as a common economic factor to measure costs, benefits and net worth of shoulder improvements. Optimum shoulder widths for two traffic speeds and a range of traffic volumes are shown in Figure 4. This figure indicates that for 30 mile per hour traffic the optimum shoulder width is two feet for up to 1,000 vehicles per day, six feet for 1,000 to 5,000 vehicles per day, eight feet for 5,000 to 6,000 vehicles per day, and 10 feet for over 6,000 vehicles per day. For 60 mile per hour traffic, the optimum width is ten feet for highways which carry over 3,000 vehicles per day. Improved data, particularly for low volume roads, could eliminate some of the assumptions that are used in this procedure.

An economic analysis study relating to shoulder widening projects in Kentucky was conducted by Zeeger (23). Costs for shoulder widening were based on statewide construction costs and adjusted to 1976 dollars. Benefits for such improvements were a function of the annual number of related accidents that would be prevented. Plots of benefit-cost ratios for various shoulder widening projects and accident frequencies were presented. It should be noted that no project would be cost-effective unless the annual number of related accidents before the improvement was greater than six accidents per mile.

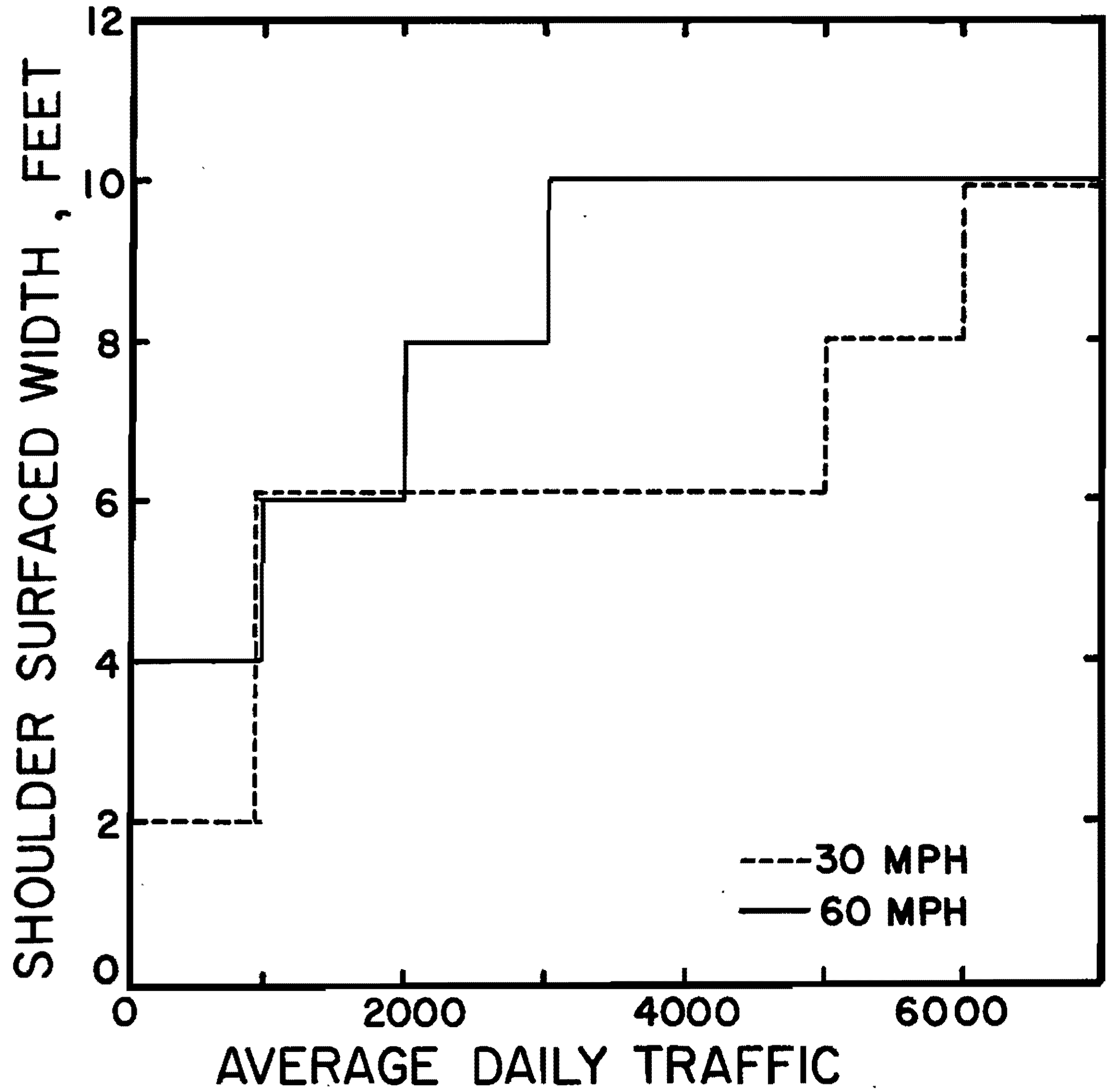


Figure 4. Optimum Shoulder Widths for Various Traffic Volumes and Travel Speeds (22).

Texas Roads: Lengths and Usage

An analysis was conducted to determine the lengths and usage for the types of roads in the study. As shown in Table 13, less than one fourth of the two-lane roads in Texas have paved shoulders, and there are 100 times more two-lane roads than four-lane no shoulder roads in the state. Figures 5 and 6 clearly indicate the extremely large amount of low volume two-lane highways. Of the roads studied, 66 percent of the mileage and 75 percent of the vehicular travel are for two-lane no shoulder highways with ADT's less than 1000 vehicles per day. At extremely low volume levels, the two-lane no shoulder is the dominant type of highway. As volume increases, the use of

Table 13. Summary of Texas Highway Lengths and Vehicular Travel (1977).

	TWO-LANE NO SHOULDER		TWO-LANE WITH SHOULDER		FOUR-LANE NO SHOULDER	
Average Daily Traffic (x1000)	Length (Miles)	Million Veh-Miles of Travel	Length (Miles)	Million Veh-Miles of Travel	Length (Miles)	Million Veh-Miles of Travel
Less than 1	37367.30	45321.61	3351.07	767.38	25.82	6.71
1 to 2	4073.21	2040.60	4627.29	2528.87	44.12	25.71
2 to 3	1131.46	1002.47	2474.06	2212.57	142.81	125.92
3 to 4	414.02	520.72	1269.99	1604.30	149.89	192.92
4 to 5	168.97	272.25	614.95	998.42	72.67	119.33
5 to 6	84.85	168.56	311.65	623.16	31.17	62.55
6 to 7	50.83	120.75	204.87	481.94	16.65	40.13
7 to 8	30.52	83.85	67.96	184.26	16.03	42.90
8 to 9	17.77	54.56	63.66	195.37	16.71	53.04
9 to 10	17.26	59.73	13.17	45.32	8.49	28.78
over 10	25.11	118.98	38.67	180.57	35.65	206.64
Total	43381.30	49764.08	13037.34	9822.16	560.01	944.63

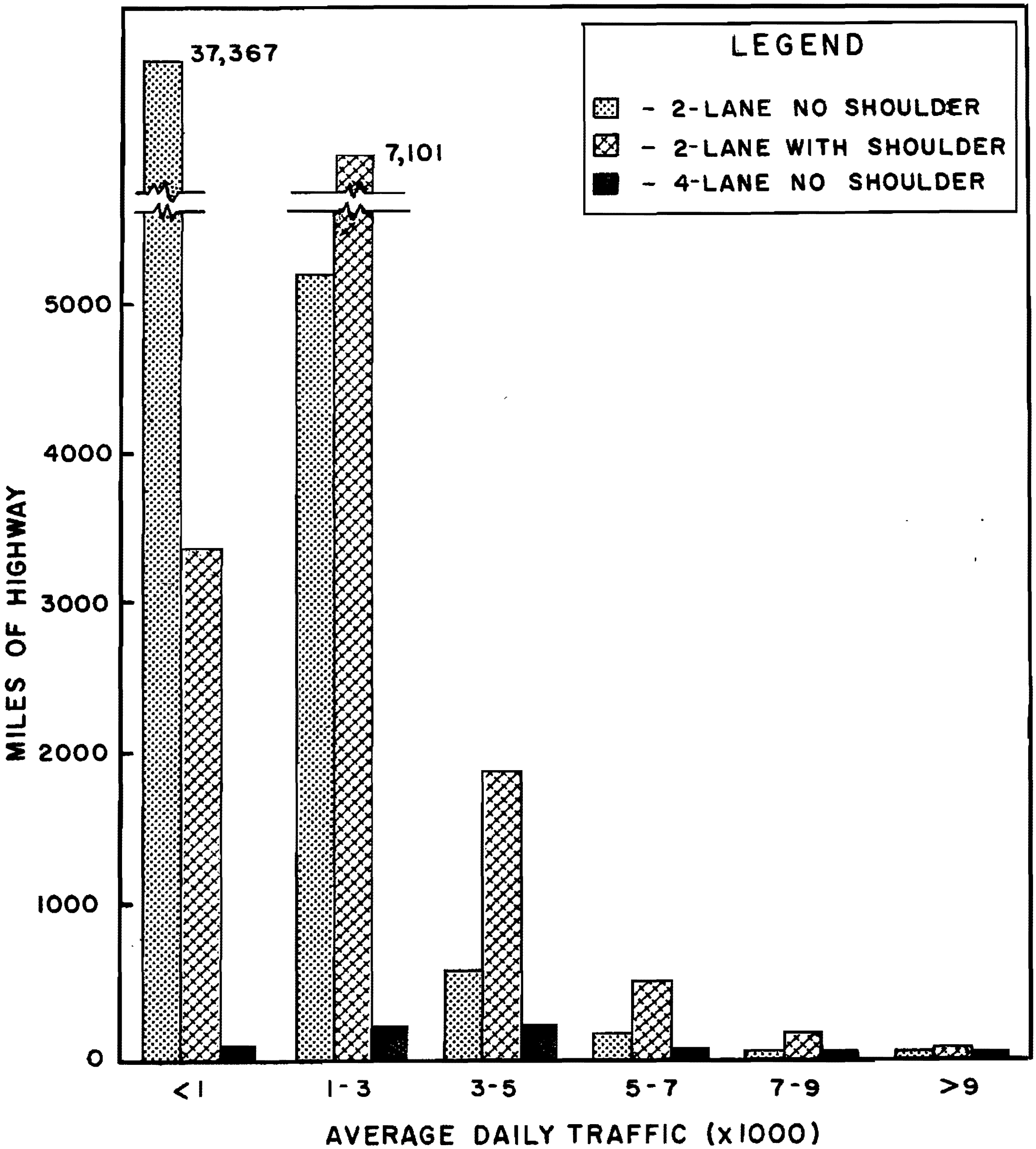


Figure 5. Total Mileage in Texas for Different Classes of Highways (1977).

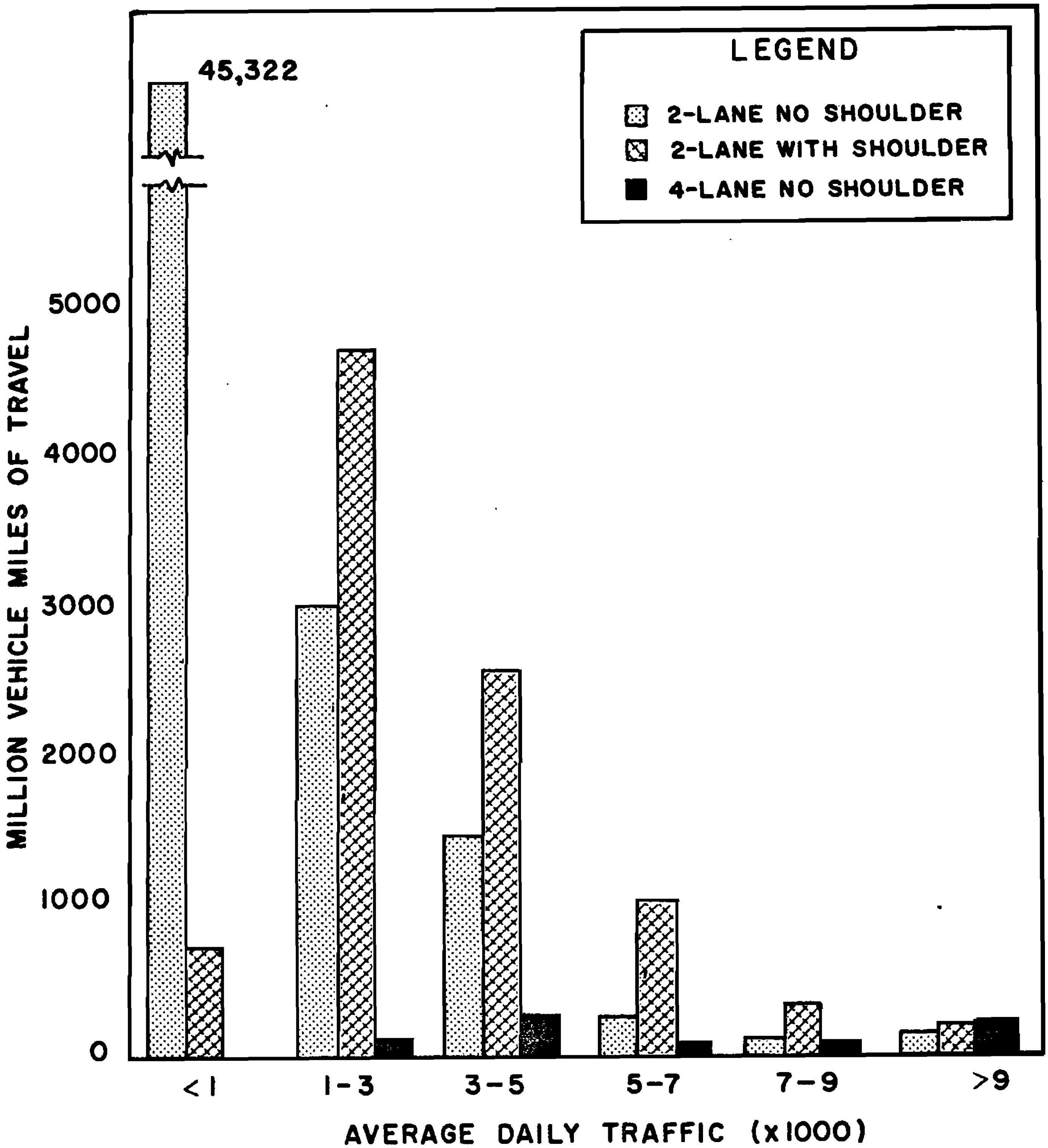


Figure 6. Total Vehicle-Miles of Travel in Texas For Different Classes of Highways (1977).

this type of roadway decreases rapidly. Ninety-eight percent of these roads carry less than 3000 vehicles per day while less than one-half of one percent carry over 5000 vehicles per day.

As ADT passes 1000 vehicles per day, the two-lane with shoulder becomes the dominant roadway type. About one-half of these highways fall into the 1000 to 3000 vehicles per day category. The use of this class of highway also decreases rapidly with increasing volume. Less than two percent carry over 7000 vehicles per day. The limited amount of four-lane no shoulder roadway in Texas is illustrated in Figures 5 and 6. About one percent of the rural roads in the state fit this classification. Most of them carry from 1000 to 5000 vehicles per day (73 percent), with decreasing use as volume rises. Approximately one-fourth of these roads carry more than 5000 vehicles per day.

The overall pattern for these types of highways is dominant use of two-lane no shoulder roads below 1000 vehicles per day and dominant use of two-lane with shoulder road above that figure. Four-lane with no shoulder never dominates; however, it achieves near equivalency at extremely high volume levels. As volume increases, the usage of all three types of roads decrease.

Two-lane roadways are scattered throughout the state. At low-volume ranges, there is about ten times as much roadway without shoulders as with shoulders. As volumes increase, the trend is to have more two-lane roads with shoulders than without. This trend is fairly consistent over the state with the exception of the Panhandle, the Rio Grande Valley and portions of far West Texas. For example in District 6, there is almost as much paved shoulder mileage as unpaved shoulder mileage for two-lane roads with ADT's under 1000 vehicles per day.

A brief review was conducted to determine the geographical distribution of the three types of roadways. Highways having four lanes but no shoulders were found to be heavily concentrated in only a few areas. One-half of the state's mileage is located in District 14, seventeen percent is found in District 19, ten percent is located in District 11, nine percent is located in District 12, and the remainder is scattered throughout the state. Thus 86 percent of this type roadway can be found in only 4 of the state's 25 districts. The vast majority is located in the eastern half of the state, in a region characterized by rolling topography and high traffic volumes.

Accident Study: Comparative Analysis

Overall the characteristic patterns of traffic accidents exhibit only slight changes from year to year (24). As long as roadway geometrics and traffic volumes remain relatively uniform, accident patterns should display the same general trends; however, this may not always be true. Even though the general pattern may remain fairly constant, it is possible to gather localized point data which does not support the trend. Accidents are assumed to be random occurrences that can be described by statistical theory and are thus quite sensitive to sample size and bias of the observer. Jorgensen's landmark report on accident analysis procedures (25) points out that small sample sizes and random variations in non-roadway characteristics may seriously bias the results of the study. Jorgensen also states that the data must cover a sufficient period of time to give a statistically valid sample.

To ensure that there was a sound statistical basis for site selection and that the sample would be representative of Texas highways, three years of accident data were gathered for a series of carefully selected locations. Gwynn's work (26) has shown that using more than three years of data does not significantly improve the statistical accuracy of such results. The next portion of this report details the steps that were followed to select sites for the accident investigation.

Site Selection. A matrix of desired characteristics was created to stratify the sites by traffic volume, shoulder type and number of lanes. Table 14 contains the nine classifications created to allow a comparative analysis of the effects of these variables on accident rates and characteristics. To ensure a large and representative data sample, it was desired to study ten sites in each class, with each site containing five or more miles of geometrically consistent roadway.

Table 14. Site Classification for Comparative Accident Study.

Classification Number	Type of Highway	Type of Shoulder	A.D.T. Range
100	two-lane	unpaved	1000-3000
200			3000-5000
300			5000-7000
400	two-lane	paved	1000-3000
500			3000-5000
600			5000-7000
1000	four-lane	unpaved	1000-3000
700			3000-5000
800			5000-7000
900			7000-9000

Once the general site criteria had been defined, all roadways in Texas were screened as potential sites through a computer listing of the roadway geometric file, commonly referred to as the RI-2-TLOG. The file was carefully reviewed to obtain a list of potential rural sites which fit the requirements outlined in Table 14. The initial screening was a substantial undertaking involving an evaluation of over 29,000 roadways segments. Table 15 illustrates the number of segments of Texas roadway in each study classification.

Table 15. Site Selection Process for Comparative Accident Study.

Classification Number	Candidate RI-2-TLOG Segments	Length Miles	Potential Sites	Selected Sites	Length Miles
100	10,029	5204.7	152	10	113.5
200	1,441	583.0	32	10	59.3
300	440	135.7	11	8	42.4
400	10,515	7101.4	260	10	136.3
500	3,969	1884.9	51	10	120.0
600	1,346	516.5	32	10	101.0
1000	453	186.9	15	10	92.5
700	554	223.0	19	9	74.1
800	253	47.8	6	4	19.5
900	150	32.7	7	4	21.1
Total	29,149	15,916.6	598	85	777.1

As shown, there was not a uniform distribution of segments among the classes. For instance, more than seventy-seven percent of the total eligible mileage was found to fall in Classes 1 and 4 (two-lane, without/with shoulder, ADT of 1000-3000). Thus, the majority of candidate sites could be termed as low-volume, two-lane and rural. On the other hand, only three percent of the total mileage was "poor-boy" highways (Classes 7, 8, 9, and 10).

During this portion of the study it became apparent that ten study sites could not be obtained for some classifications. In fact, only eight sites were found that met the qualifications of Class 3, nine sites for Class 7, and four sites each for Classes 8 and 9. Classes 7, 8 and 9 were restricted due to the limited quantity of "poor-boy" mileage in the state. At this time it was decided to add a tenth category to the study (Class 10: Four-lane, unpaved shoulder, 1000-3000 ADT) to handle low volume "poor-boy" roadways. The addition of this category allowed direct comparison of accident rates at low traffic volumes for the three types of highways in the study.

A great deal of effort was expended in checking the eligible sites to ensure that they were typical of their respective categories. For example, ADT was reviewed for each location to verify that no major changes had occurred during the three year study period. Pavement widths and shoulder types were scrutinized for uniformity both for each site and in each class. Divided roadways were deleted from the investigation. Careful reviews were conducted using county, highway district and state maps to isolate and remove sites which contained major intersections, towns, or other factors which might bias the results of the study.

The selection process is summarized in Table 15. The 85 selected sites were taken from an original group of over 29,000 segments contained on the RI-2-TLOG tape. The table clearly shows several stages of refinement in achieving a representative sample of rural highways spread over a wide geographic area. The abundance of low-volume two-lane roadways (Classes 1 and 4) produced over 400 potential sites, and the research staff was able to choose roadways of considerable length with an optimal geographic distribution. On the other hand, the limited amount of "poor-boy" mileage (Classes 7 through 10) caused a corresponding reduction in the number of sites available for study. Figure 7 indicates the general locations of the study sites. A quick glance at this figure shows that all of the state's geographic regions are represented.

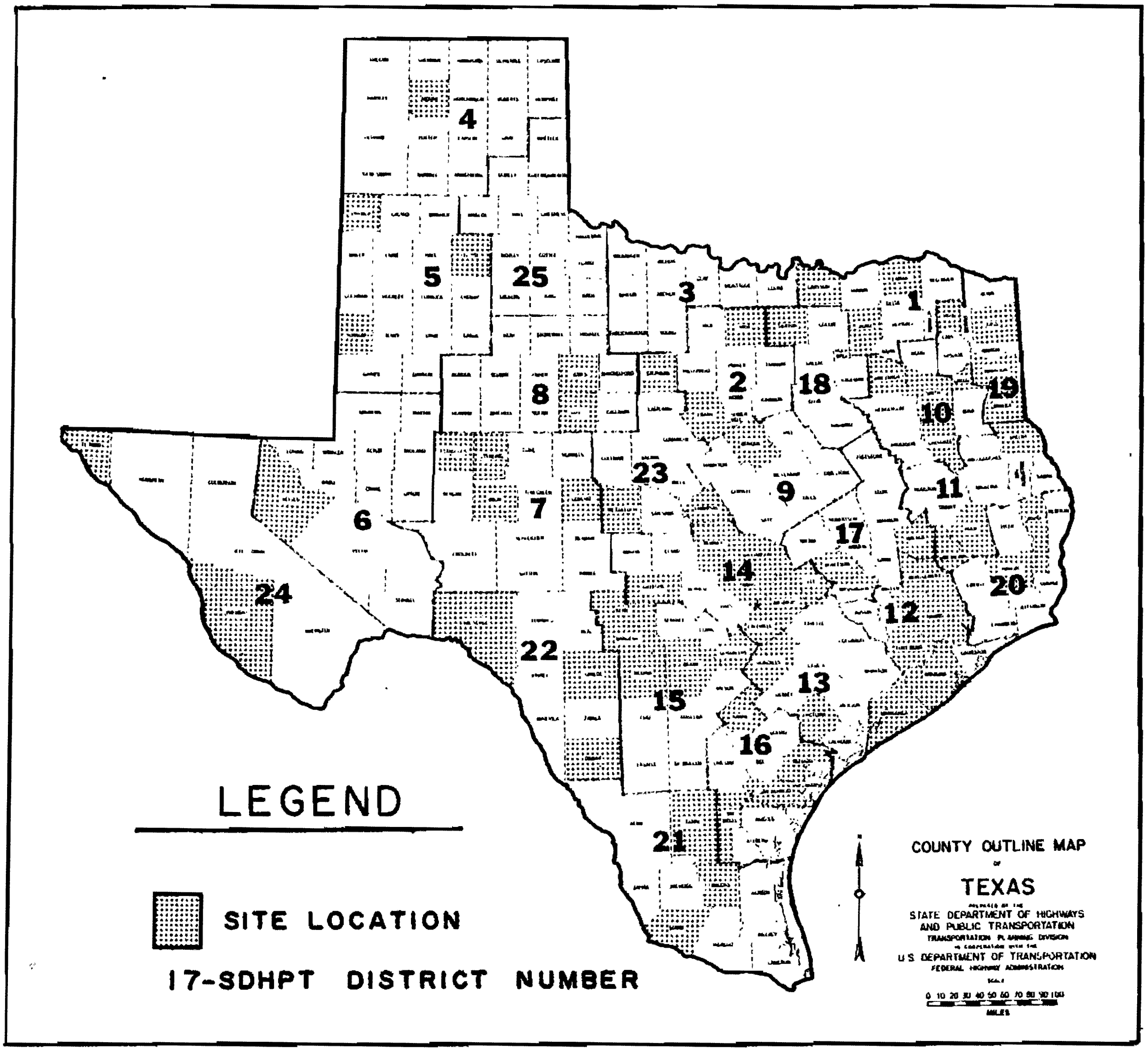


Figure 7. Location of the Sites for the Accident Study.

Data Collection. Once the sites had been finalized, accident data were gathered for the three most recent years available (1975, 1976, and 1977). The SDHPT's computerized accident files were scanned for all accidents occurring on the 85 sites during the three year period. A total of 16,334 accidents were included in the study's data base. Each comprehensive accident record contained 393 characters of information about the collision and the roadway upon which it occurred. The accident detail allowed a very thorough examination and cross classification of the data base. Records were reviewed and sections with unusual conditions were removed. For example, construction zones, traffic signals and railroad crossings were found to be major contributors to the accident rate at various locations. In each case the study site was shortened to remove the atypical situation.

Geometric data were taken from the RI-2-TLOG to calculate the vehicular miles of travel for each site. These figures were combined with the number of accidents on each roadway to yield accident rates. Since the number of intersections varied from site to site, a separate analysis was performed on non-intersection accidents to isolate and remove the disproportionate effects such collisions might cause among sites in the various classifications. The data base without intersection accidents contained 8815 accidents. The two data sets will be referred to as the all-accident group and the non-intersection accident group for the remainder of this report.

Findings: Accident Rates

Figures 8 and 9 illustrate the results of the accident rate investigation for all-accidents and for non-intersection accidents data sets, respectively. The two figures are similar, with the non-intersection curves

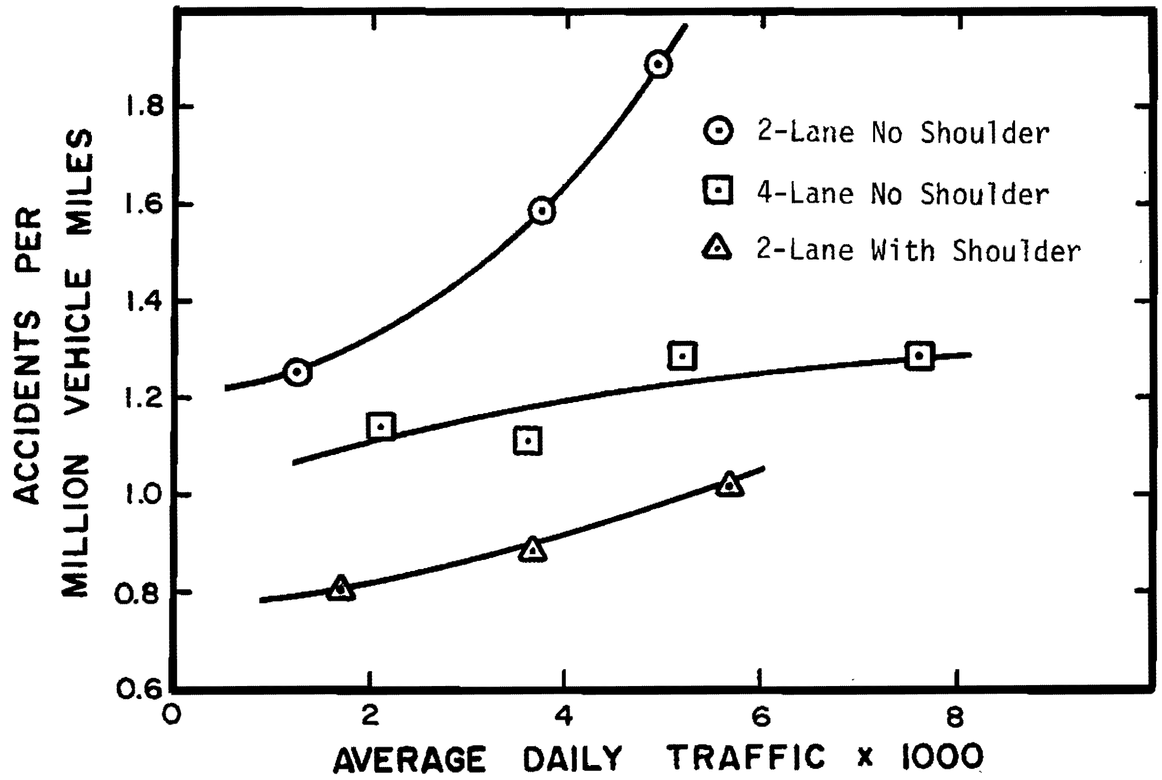


Figure 8. All-Accident Data, Accident Rates for Different Classes of Highways (1975-1977).

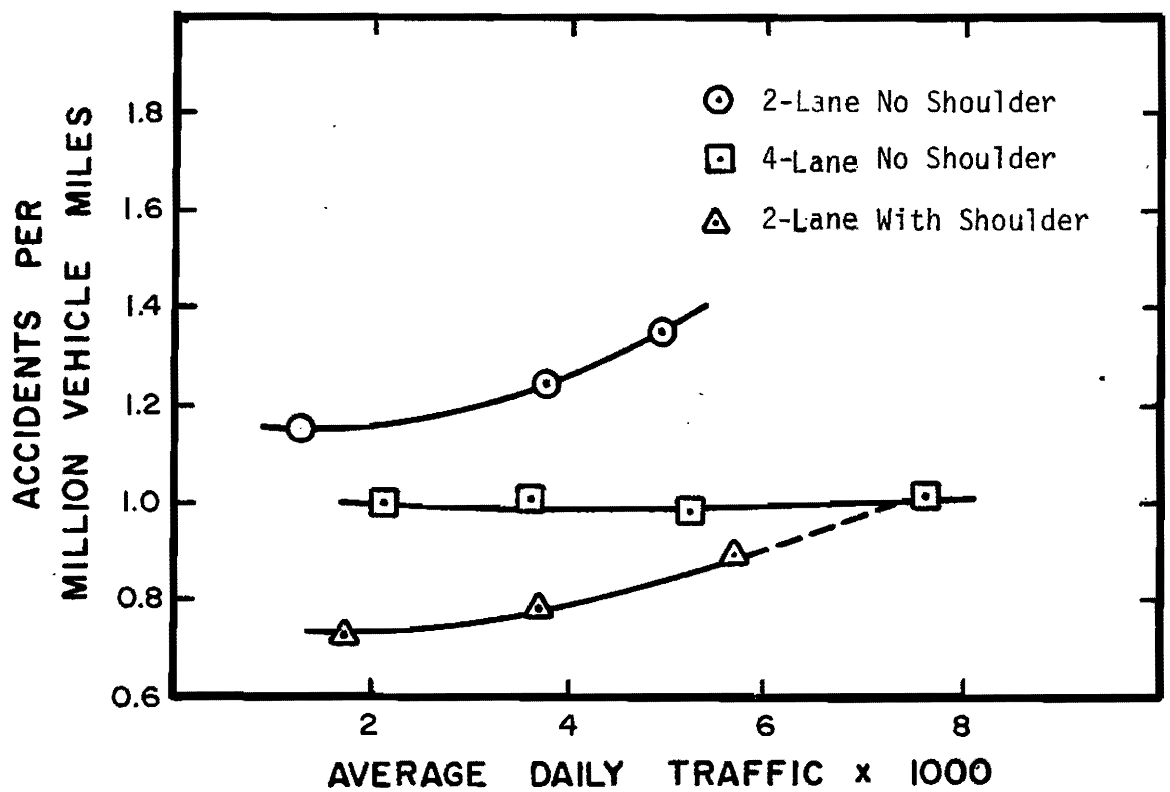


Figure 9. Non-Intersection Data, Accident Rates for Different Classes of Highways (1975-1977).

generally at lower values and flatter slopes than the all-accident curves. Implications of the two figures will be discussed in the following paragraphs.

All-Accidents. The most obvious feature of Figure 8 is that the accident rate tends to increase as the average daily traffic (ADT) increases for all three types of roads in the study. The highest accident rate is associated with two-lane roads without shoulders. In addition, this type of roadway has the curve with the steepest slope. Thus, it is the most sensitive to increases in traffic volume. The parabolic curve becomes very steep and approximates a straight line at volumes above 4000 vehicles per day. In this region, the two-lane no shoulder roads have a distinctly higher accident rate than either of the other two roadway classes.

It is important to note that the lowest accident rates were associated with two-lane roadways having paved shoulders. This was true for all volume levels studied. Its curve has a gentle slope and is slightly parabolic in nature. The curve for the third type of roadway in the study ("poor-boy") falls in between those for the other two, being safer than two-lane without shoulder roadways and not as safe as two-lane with shoulder roadways.

It would seem that all four-lane roadways should be safer than all two-lane roadways, yet Figure 8 clearly indicates otherwise. The presence of paved shoulders on two-lane roads makes them safer than four-lane roadways without shoulders ("poor-boys"). The benefit of that paved shoulders provide is indicated on Figure 8 by sharply reduced accident rates. There are several logical reasons for these safety benefits. Paved shoulders provide recovery areas for vehicles accidently leaving the roadway, provide a refuge for stalled vehicles, provide acceleration and deceleration lanes for right-turning vehicles, and instill a feeling of comfort for drivers. Conversely, there are reasons why "poor-boys" have relatively higher accident rates. When the paved shoulders are converted to travel lanes, the immediate recovery zone is removed for vehicles that accidently exit the travel lanes. The clear zone adjacent to the pavement is not extended outward, leaving fixed objects nearer the recovery area. For this reason, the recovery maneuver becomes more difficult and consequently leads to more accidents of the run-off-road and hit-fixed-object varieties. In addition, the paved four-lane roadway encourages higher speeds at lower traffic volumes. The foregoing is a partial list of reasons why two-lane roadways with shoulders might be safer than either of the other two types of roadways in the study.

In summary, there are two major conclusions that can be drawn from Figure 8. The first is that accident rate increases with ADT for all three types of roads in the study. The second finding is the relative position of the accident rate curves. In descending order of accident rate they are two-lane without shoulder, four-lane without shoulder and two-lane with shoulder roadways.

Non-Intersection Accidents. The non-intersection accident data were summarized and the results are presented as Figure 9. Highways in study classes 1 through 3 (two-lane without shoulder) again displayed the highest accident rates. The figure shows that up to 5000 vehicles per day, the accident rate increases in a parabolic manner. The curve for two-lane roadways with shoulders (Classes 4 through 6) also has a parabolic shape and is generally parallel to the no shoulder curve; however, the roads with shoulders have only two-thirds as many accidents as roads without shoulders. The presence of shoulders on two-lane highways offers definite safety benefits by decreasing non-intersection accidents rates.

Once again the "poor-boy" accident rates fell in between those of the other two types of roads. The curve has a greatly ascending slope with a distinctly lower rate of increase than two-lane roads. In fact, the "poor-boy" curve is nearly horizontal, implying that the accident rate is fairly uniform over the range of traffic volumes included in this study.

The curves for "poor-boy" and two-lane with shoulder roadways appear to converge at higher volume levels. The lines were extended and the "theoretical point" of intersection of the two curves was found to be slightly less than 7500 vehicles per day. The dashed extension of the lowest curve in Figure 9 indicates the location of this theortical point of intersection. The data indicates that two-lane roads without shoulders are safer than "poor-boys" at all volumes below that level. Based on this data, consideration should be given to using "poor-boy" highways for ADT's above 7500 and two-lane roadways with shoulders below that volume if safety is the major or only consideration for upgrading a facility.

Comparison of All-Accidents and Non-Intersection Accidents. The removal of intersection accidents caused the curves of Figure 9 to generally move downward and to the right. This implies a lower accident rate as would be expected. However, the different types of roads do not all experience the same amount of change. For example, two-lane no shoulder roads undergo a very noticeable alteration. The curve for non-intersection accidents is significantly displaced to the right and has a much flatter slope. This implies that such roadways are apparently very sensitive to intersection accidents, especially as volume rises. At 2000 vehicles per day, there is only about 10 percent difference in the two curves. This difference reaches 50 percent at 6000 vehicles per day. This indicates that the construction of paved shoulders at rural intersections may be an effective treatment to reduce the accident rate on high traffic volume roadways.

The same intersection accident trend is also present for "poor-boy" roadways. The curve for non-intersection accidents has a much flatter slope than the curve for all accidents. At low volume levels the curves are very close to the same value, but as volume increases the curves diverge. When the volume reaches 8000 vehicles per day, intersections add 30 percent to the accident rate. This again points to increased intersection accident sensitivity as volume increases.

The least amount of change is experienced by two-lane roads with shoulders. The curves for all-accidents and non-intersection accidents are virtually parallel, indicating that volume has very little effect upon intersection accident rate. It may thus be concluded that the presence of shoulders may have a beneficial effect on reducing intersection accidents since the two types of roads without shoulders experienced large changes in accident rates between the two data sets, whereas roads with shoulders experienced only minor changes between data sets.

Findings: Accident Characteristics

The types of accidents occurring on a specific roadway or at a specific site often yield clues to the nature of safety related problems. Corrective procedures are often formulated based upon analyses of accident characteristics. The pertinent findings of the accident characteristic investigation will be summarized in the next few paragraphs.

Severity Analysis. Traffic accidents are usually placed into one of three severity classifications: fatal, injury, or property damage only collisions. Accident rate curves, shown in Figures 8 and 9, can be considered to represent all three types of accidents. Injury and fatal accident rate curves for the non-intersection data set have been plotted in Figure 10. The solid lines

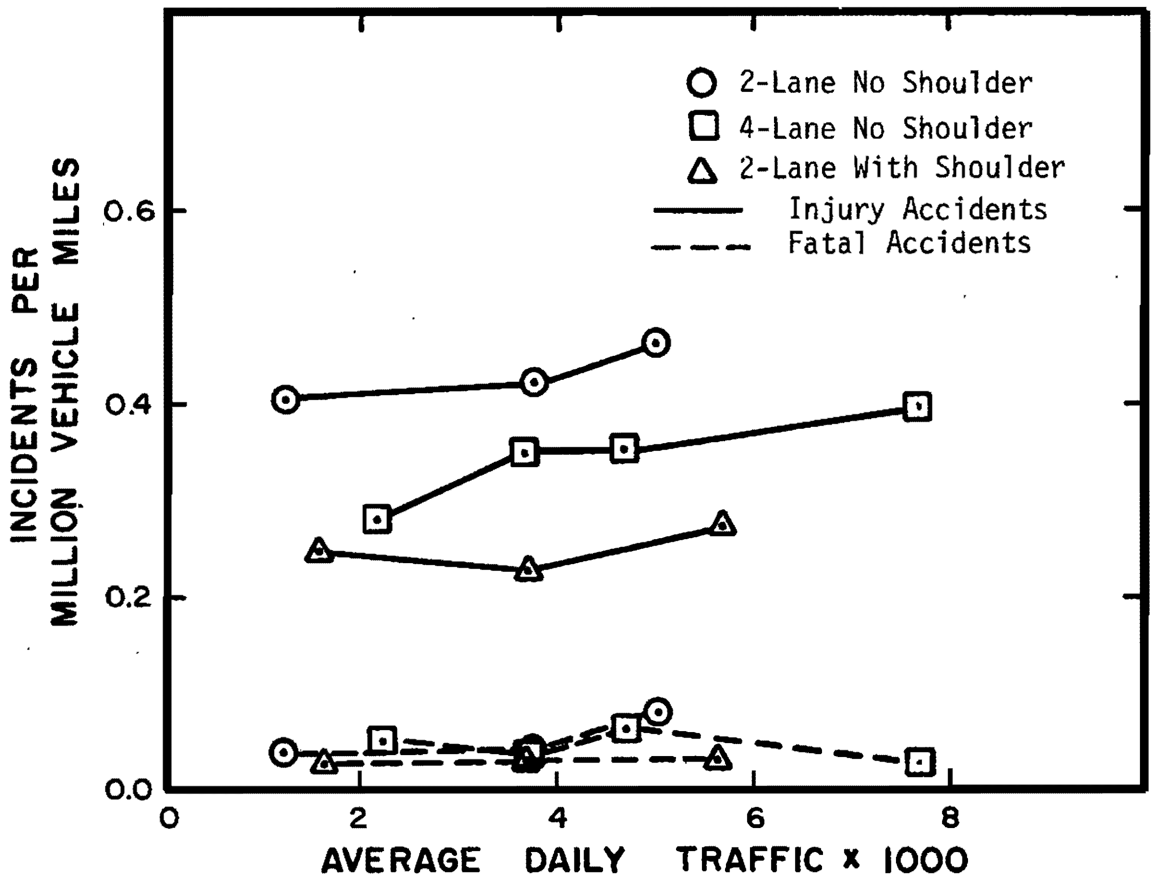


Figure 10. Severity Rates of Non-Intersection Accidents on Different Classes of Highways (1975-1977).

depict injury accident rates and fall into a familiar pattern. As before, accident rates increase as volume increases. The highest rates are associated with two-lane highways without shoulders and the lowest rates are for two-lane highways with shoulders. The curves for two-lane highways are approximately parallel, and both are parabolic in nature. The "poor-boy" curve remains between the two two-lane curves. The high degree of similarity between the total accident curves and the injury accident curves indicates that there are no unusual changes in the injury pattern as volume increases, and that analysis of total accident trends will suffice for an analysis of injury accident trends within the scope of this study.

Fatal accident rates are shown by the dashed lines in Figure 10. The data points all fall in close proximity to one another and there is not a great distinction between the curves for the three types of roads. The slopes are almost flat, indicating that the fatal accident rate is fairly constant for volumes between 1000 and 8000 vehicles per day. For the two-lane roads without shoulders there is a slight diversion from this trend in the area of 5000 vehicles per day. The implications of this diversion are not clear, but it could well be that these roadways have passed a critical volume level and have become slightly more susceptible to high severity accidents. The lowest rates are for two-lane roads with shoulders, where the curve remains constant at approximately 0.06 fatal accidents per million vehicle miles of travel.

It is difficult to draw conclusions from the fatal accident plot due to the low rates and data convergence. Perhaps the most significant conclusion would be the uniformity of the fatal accident rate. Since these rates remain constant over a wide range while the other types of accidents increase, it implies that the additional accidents at high volume levels are confined to low severity type collisions.

Figure 11 shows the relationship between the three accident severity rates for a single class of road (two-lane with shoulder, non-intersection accident data). Similar relationships exist for the other types of roadways in the study. The relative position of the curves in Figure 11 indicates the relationships of total, injury and fatal accident rates. The fatal accident rate is 12 to 15 times lower than the total accident rate, and the injury accident rate is approximately three times lower than the total accident rate. The change in slope for the three lines indicates their sensitivity to volume levels. The most sensitive (steepest sloped) curve is for total accidents, the next most sensitive is for injury accidents, and the least sensitive is for fatal accidents. This reinforces the previous observation that additional accidents at high traffic volumes are not high severity type accidents.

Run-Off-Road Accidents. The lack of a suitable recovery area for vehicles leaving the travel lanes should cause an increase in run-off-road type accidents. This premise is supported by Figure 12, which indicates that two-lane roads with shoulders have the lowest occurrence level for such accidents. As shown, the incident level is quite uniform over a wide range of traffic volumes. On the other hand, both types of roadways without shoulders exhibit higher and more erratic run-off-road accident rates. The fluctuation of these curves may be explained in terms of traffic volume and driver workload. At low volume levels, driving is an easy task requiring few decisions and drivers are likely to become inattentive. As volume increases, drivers are forced to make more frequent decisions as they meet additional oncoming traffic and handle various driving situations. Thus, they are forced to become more attentive. At high volume levels, the driver workload becomes very heavy, requiring almost constant evaluation of vehicle position, speed and similar

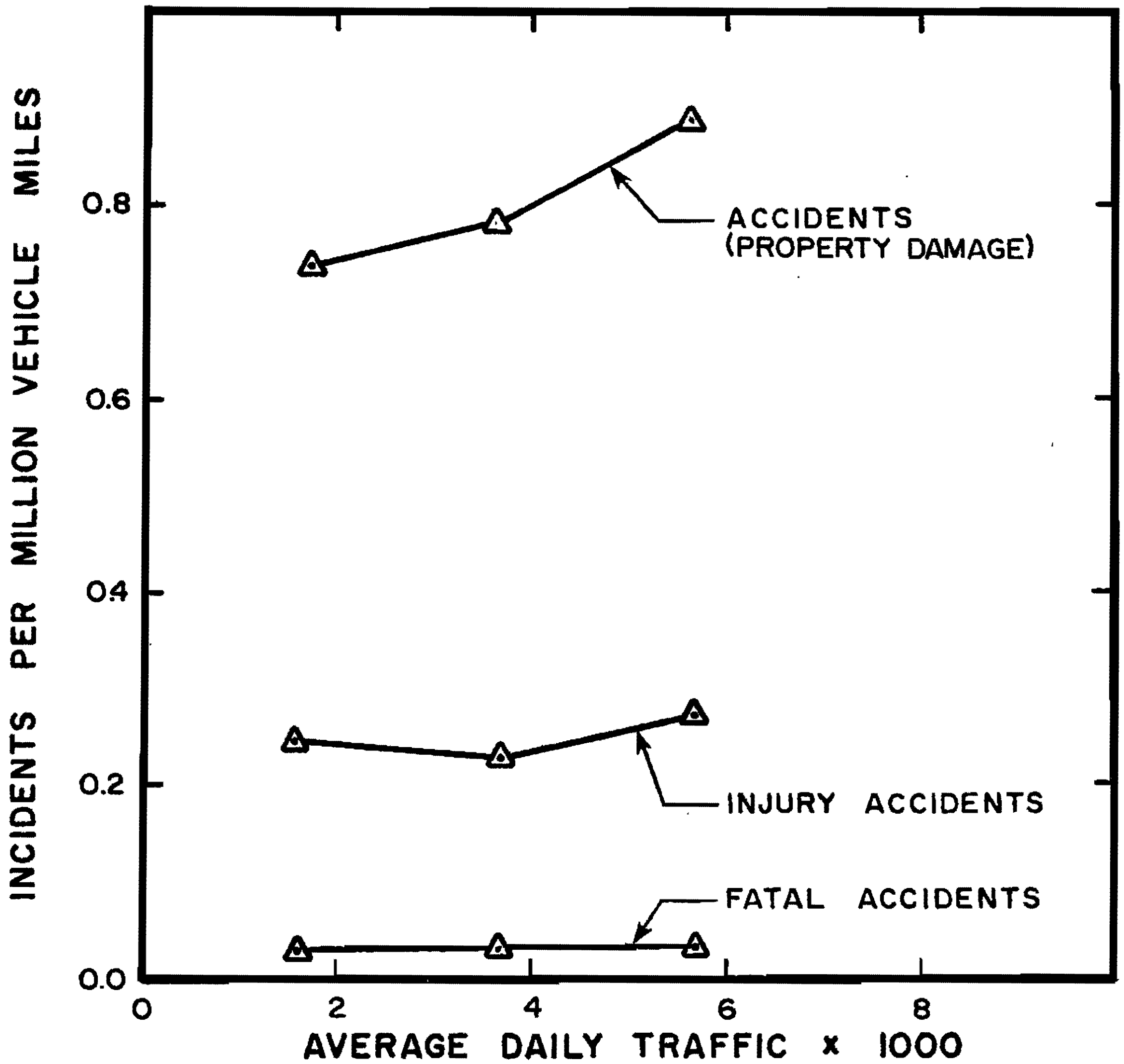


Figure 11. Accident Severity Relationships for Two-Lane Roadways With Shoulders, Non-Intersection Data Group (1975-1977).

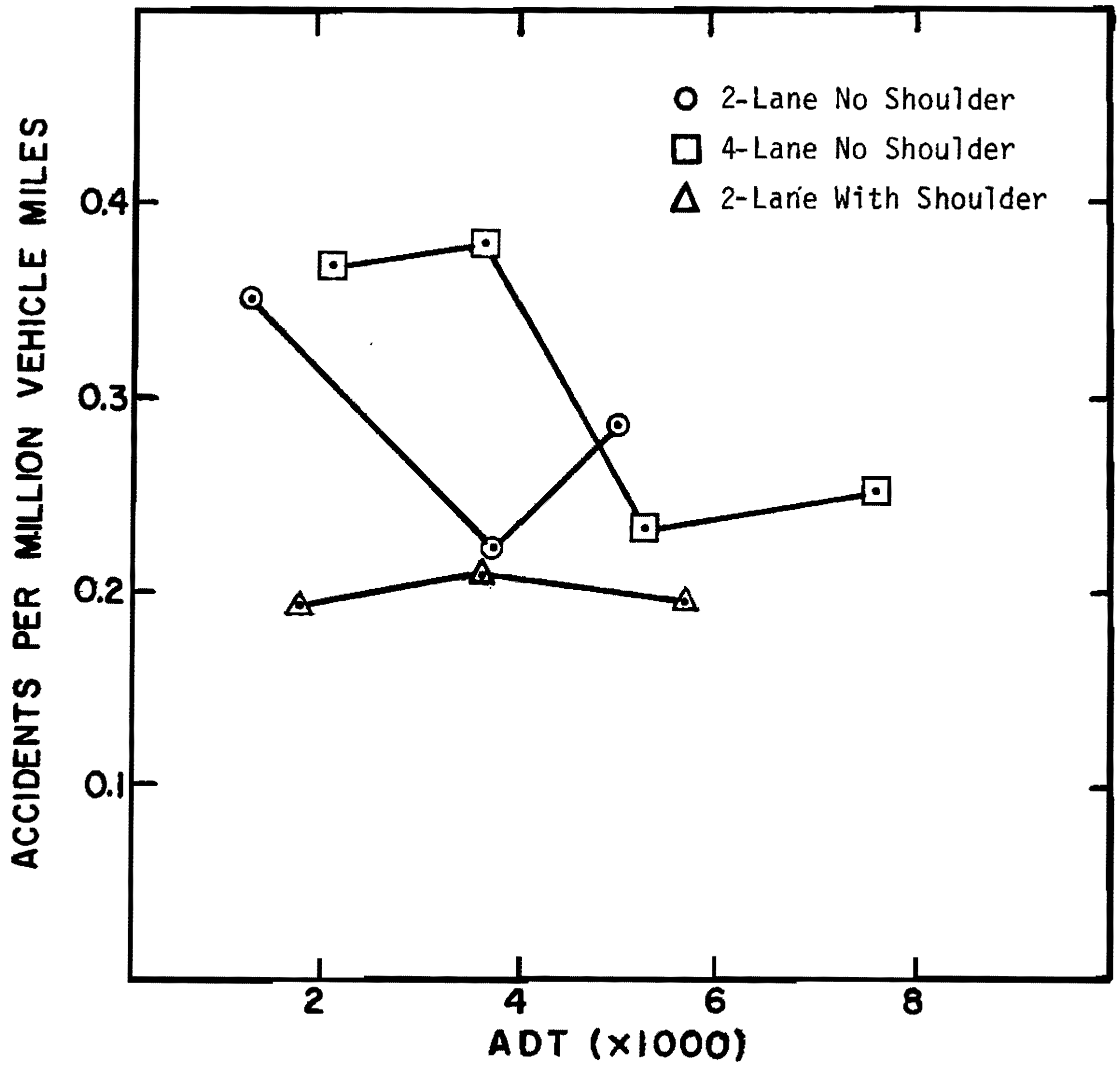


Figure 12. Run-Off-Road Accident Rates for Non-Intersection Data Group (1975-1977).

items. The driver is more apt to become fatigued or to miss important stimuli that might warn of approaching danger.

Driver inattentiveness at low traffic volumes probably accounts for the high run-off-road accident rate shown in Figure 12. As volume and driver attentiveness increase, the accident rate drops for both types of highways without shoulders. For two-lane roads this drop occurs in the 1000 to 3000 vehicles per day range. The additional paved lane on the four-lane roads allows drivers additional lateral freedom and decreases their workload. Thus, the attentiveness increase does not occur until the volume level reaches 4000 to 5000 vehicles per day. Both types of roads have lower accident rates for mid-volume ranges. As the two-lane road reaches relatively high volume levels, the run-off-road accident rate begins to increase, probably due to driver work overload and high volume accident situations which force the driver to make emergency maneuvers away from the normal travel lane. This is indicated by the rising accident rate around 5000 vehicles per day. For "poor-boy" roads, this point has not been reached at the volume levels shown on Figure 12; however, the "poor-boy" curve is beginning to climb (at 8000 vehicles per day) indicating that the run-off-road accident rate is beginning to increase with increasing volume. It could well be that the "poor-boy" curve peaks at high volumes in the same manner that two-lane no shoulder roads peaked at 5000 vehicles per day.

Type of Collision. Another meaningful accident characteristic is the first harmful event in a collision sequence. Figure 13 indicates the number of times that hitting another car was the first harmful event. A number of conclusions may be drawn from this figure. First, the increasing slopes of the lines indicate that the chances of hitting another vehicle increase as traffic volumes

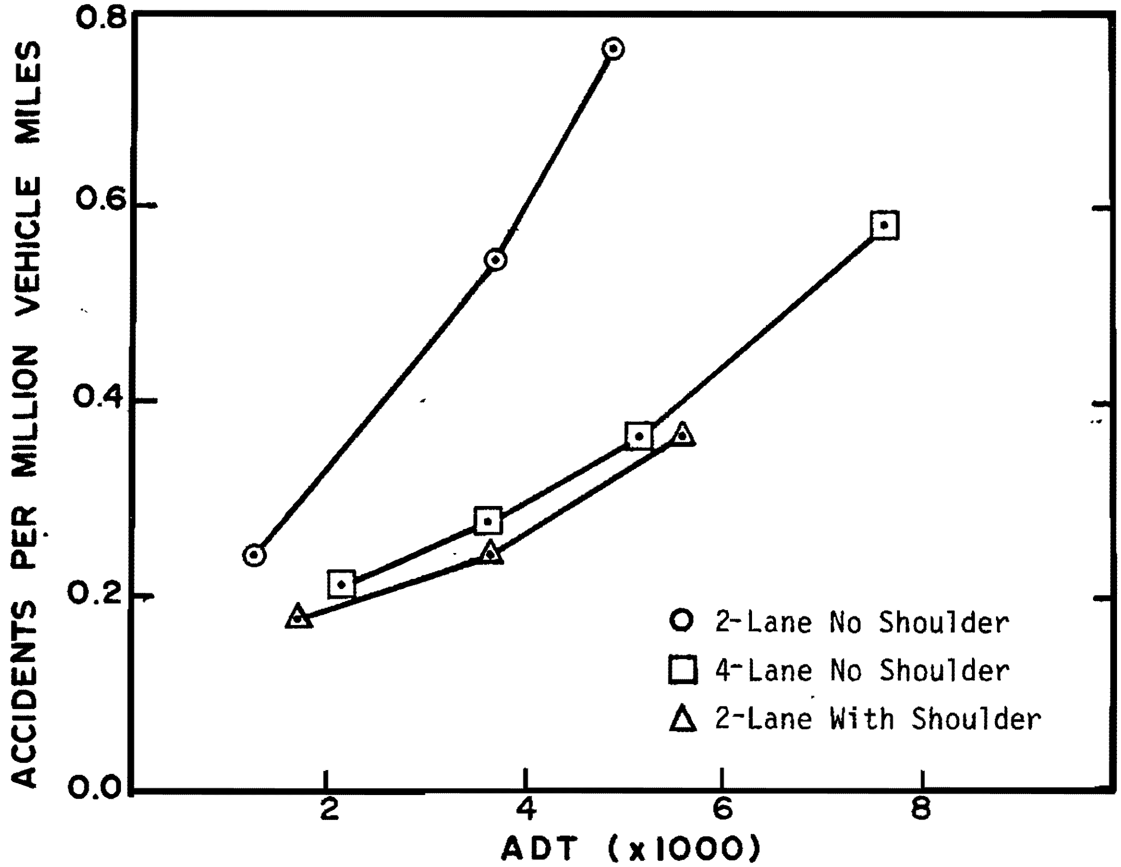


Figure 13. Hit-Other-Car Accident Rates for Non-Intersection Data Group (1975-1977).

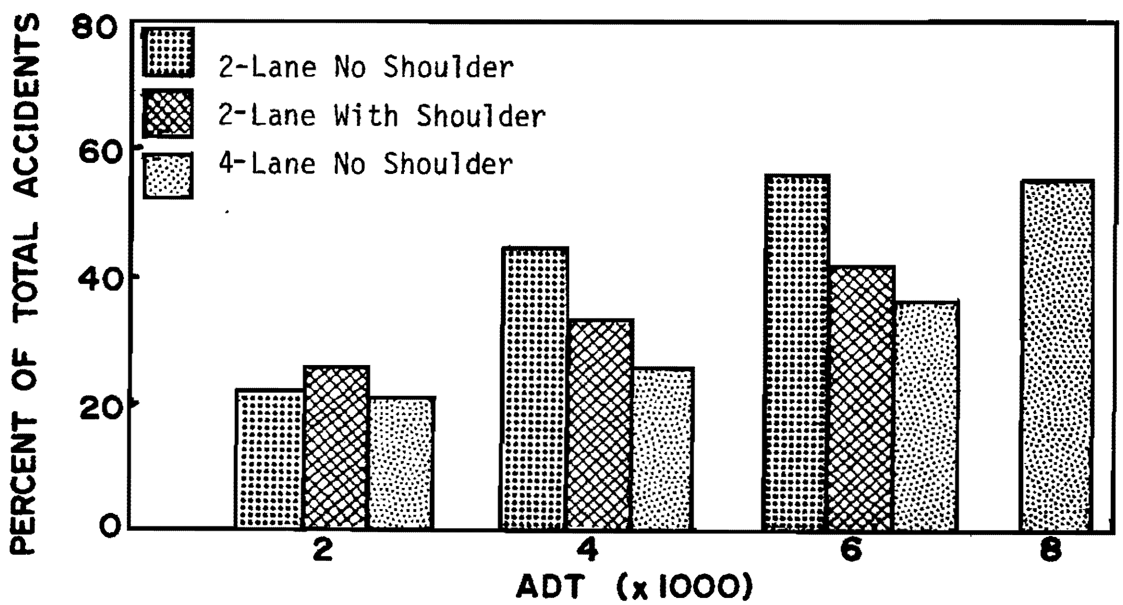


Figure 14. Hit-Other-Car Accident Frequencies by Class of Road (1975-1977).

increase. Such is to be expected, since there are more vehicles on the highway as the volume increases. At low volumes, more vehicles are running off the road than are hitting other vehicles. A comparison of the "poor-boy" accident rate curves in Figures 12 and 13 shows that approximately twice as many vehicles run off the road as hit other cars at a volume level of 2000 vehicles per day. At volumes less than 4000 vehicles per day, the run-off-road accident is dominant.

Perhaps the most important conclusion that can be drawn from Figure 13 is the almost identical curves for two-lane roadways with shoulders and the "poor-boy" roadways. The curves are parallel and lie almost on top of one another. This indicates that both roadways exhibit the same behavior for hit-other-car type accidents. It is highly probable that the paved shoulders and extra paved travel lanes both serve the function of providing additional maneuvering room for vehicles during the collision sequence.

Figure 14 emphasizes the increase in hit-other-car accidents as volume increases. The percentage of accidents which involved hitting another vehicle climbs steadily as traffic volume increases. As shown, the same trend exists for all three types of roads in this study. Both the percentage and the rate of hit-other-car accidents increased at about the same rate.

Hit-Fixed-Object Accidents. A hit-fixed-object incident is often found in the chain of harmful events in a collision sequence. These types of accidents were examined and found to closely resemble the run-off-road accident pattern, especially for "poor-boy" and two-lane with shoulder highways. At low volume levels, the "poor-boy" roadway exhibited a high rate of fixed-object collisions. The rate began to decrease as the volume rose above 4000 vehicles per day in the same manner noted earlier for run-off-road accidents. At 8000 vehicles per day, the fixed-object rate had dropped by fifty percent. This echoes the previous premise that accidents on low volume "poor-boy" roadways are usually not the multiple vehicle type, but rather result from driver inattentiveness and lack of paved recovery area.

Non-Daylight Accidents. Figure 15 illustrates non-daylight accident rate as a function of total vehicular travel (both daylight and non-daylight). The three curves hold their familiar position. The most dangerous is two-lane without shoulders. The curves are fairly flat, indicating uniform accident rates for all road types regardless of traffic volume. It is noteworthy that a disproportionate number of the accidents occurred at night. This is especially true for "poor-boy" roads. For example, by cpmparing accident rates on Figures 9 and 15, it may be noted that approximately 60 percent of all "poor-boy" accidents occurred during non-daylight hours. The vast majority of rural traffic occurs during the day, which means that 60 percent of the accidents result from the small percentage of the total traffic that occurs at night, and that "poor-boy" highways are significantly more dangerous at night than during the day.

Conclusions: Comparative Analysis

Based upon the findings of this analysis, several conclusions may be drawn. They involve both accident rates and accident characteristics for three types of rural Texas highways, and are discussed in the following paragraphs.

Accident Rate. When all accidents which occurred at the study sites were considered, the accident rate for each roadway type increased as the traffic volume increased. Two-lane highways without paved shoulders had the highest accident rates and were the most sensitive to changes in traffic volume. Two-lane highways with paved shoulders had the lowest accident rates for the volume levels investigated in this study (1000 to 7000 vehicles per day). The third

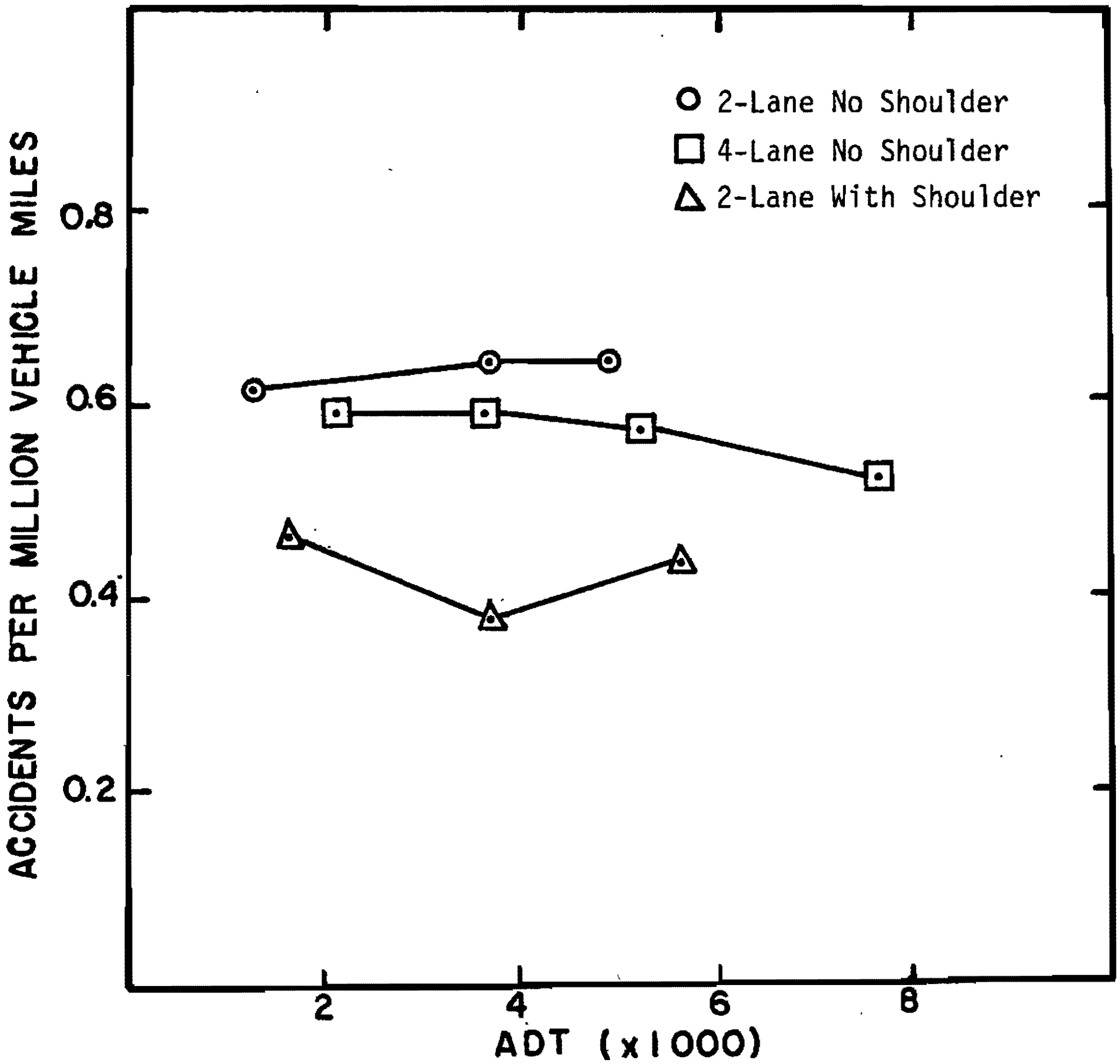


Figure 15. Non-Daylight Accident Rate for Non-Intersection Accident Group (1975-1977).

type of roadway investigated, "poor-boy" roadways, was the least sensitive to volume level and had an accident rate in between the other two types of roads. Thus, the presence of paved shoulders had a noticeable effect in reducing the accident rate on rural Texas highways.

When intersection accidents were removed from the data set, the roadway types retained the same rank - two-lane without shoulder roadways being the most dangerous and two-lane with shoulder roadways being the least dangerous. "Poor-boy" roadways were found to have a fairly uniform accident rate regardless of the volume level, while the accident rate curves for the other two roadways were parallel parabolas. Full-width paved shoulders were again shown to have positive effects in reducing accident rates. An extension of the data indicated that two-lane paved shoulder highways had lower accident rates than "poor-boy" highways at volume levels below 7500 vehicles per day.

A comparison of the non-intersection accident data group with the all-accident data group indicated that two-lane highways without paved shoulders are very sensitive to intersection accidents, especially at high volume levels. "Poor-boy" roadways are somewhat sensitive and two-lane paved shoulder roadways are relatively insensitive to such accidents. Thus, it appears that the construction of full-width paved shoulders at rural intersections may be effective in reducing the number of accidents on high volume two-lane roadways.

Accident Characteristics. The severity analysis revealed that injury accident rate curves are approximately parallel to total accident rate curves, while fatality accident rate curves are very low and fairly uniform for the range of traffic volumes studied. This trend was similar for all three types of roadways. The lowest fatality rate was 0.06 fatal accidents per million vehicle miles of travel for two-lane paved shoulder highways.

The absence of full-width paved shoulders increased the run-off-road accident rate, especially at low volume levels. The two-lane with paved shoulder roads had a fairly uniform run-off-road accident rate, while the rates for the other two roads were of a higher level and varied considerably with volume. The most probable reason for the variations and the high run-off-road rates at low volume is driver inattentiveness and lack of a paved recovery zone for vehicles accidently exiting the travel lane.

Hit-other-car accidents tended to increase drastically with increasing volumes, with two-lane no shoulder highways having more of these accidents than the other two highway types. The "poor-boy" and two-lane highways with shoulders have virtually identical hit-other-car accident rate curves. At lower volumes, other types of collisions were more frequent. For example, on "poor-boy" highways, the run-off-road accident is the most frequent type of accident at all volumes below 4000 vehicles per day. Hit-fixed-object accident rates were found to closely resemble the rates for run-off-road accidents on roadways without shoulders. Again, this reflects the lack of a paved recovery area and the presence of fixed objects in the clear zone adjacent to the roadway.

Driveways and Minor Intersections

As documented previously and shown on Figures 8 and 9, intersections have a pronounced effect on accident rates for a particular roadway. A secondary investigation was conducted to determine if driveways and minor intersections exerted the same type of influence on accident rates.

Data for the study was gathered from the 1979 District Control-Section and County General Highway maps from the SDHPT. For each of the sites used in the comparative accident study, the number of driveways and minor intersections was determined by a physical inspection of the SDHPT maps. The highest number of driveways at any one site was 33, while the lowest was 2 and the average was 9.4. The number of driveways was compared to the accident rate at each site using two techniques. First, the data were plotted and examined for the presence of patterns. Second, a correlation analysis was performed to statistically check the relationship between accident rate and the number of driveways and minor intersections.

Several different groupings were used in an effort to isolate and identify any pattern that might exist. Analyses were performed using both the number of intersections and the rate of occurrence (intersections per mile) for all sites. No specific relationship could be identified between the accident rate and the presence of intersections. Figure 16 is typical of these findings and has been included in this report for illustrative purposes. The data displayed a high degree of scatter and the statistical test for correlation indicated no significant relationship between accidents and number of driveways and minor intersections.

These findings were contradictory to those anticipated. It would seem that numerous driveways would cause a definite increase in accident rates. This was not the case. Perhaps the study procedure was not rigorous enough to correctly evaluate the existing situation. The accuracy of data obtained from maps was not as desirable as field observations; however, a more detailed analysis was beyond the scope of this study.

Edge Lines and Shoulder Contrast

The presence of edge lines normally helps reduce the roadway accident rate, especially at night, at horizontal curves or restricted width structures. Shoulders constructed of materials which contrast in color with the

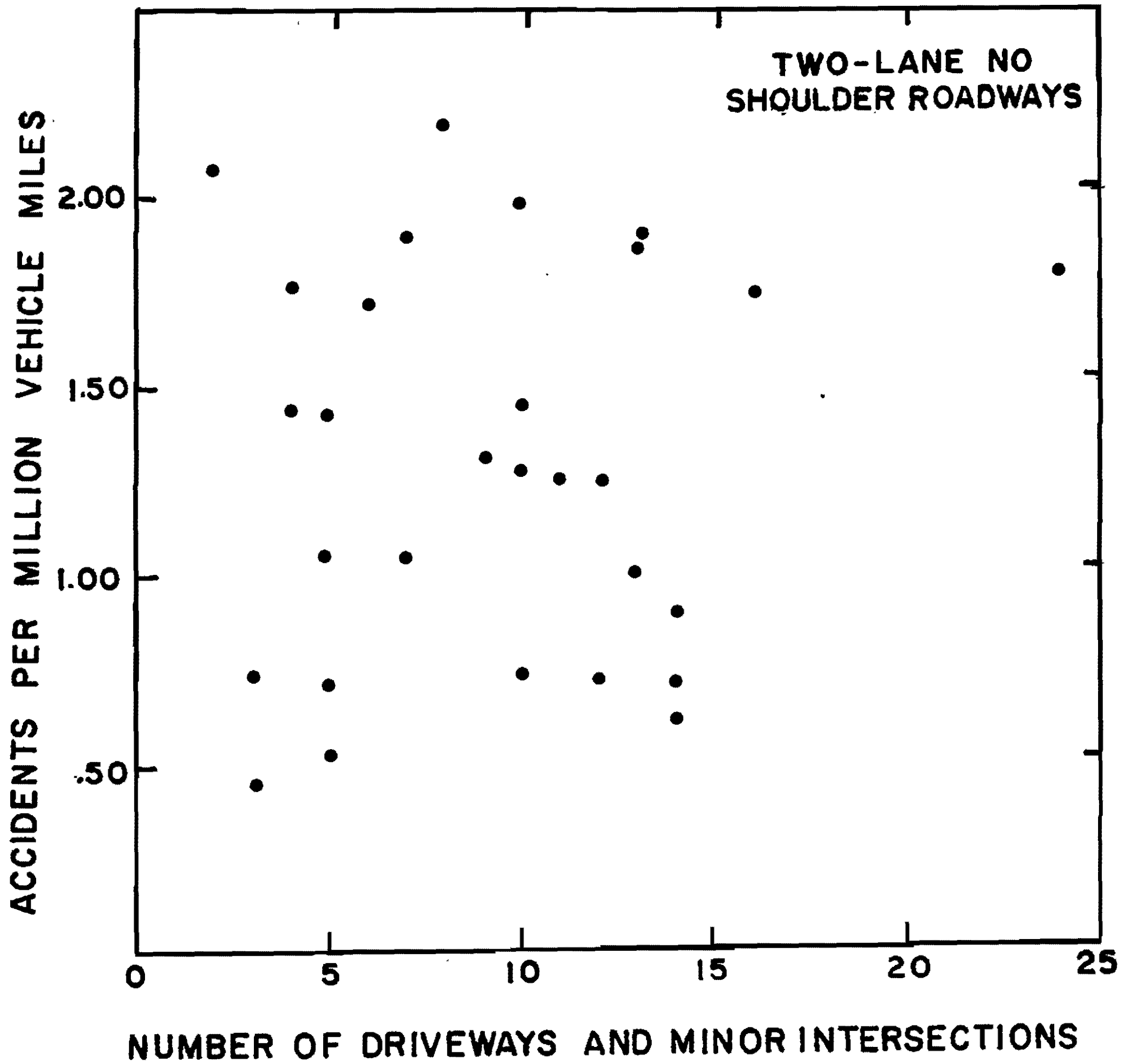


Figure 16. Influence of Driveways on Accident Rates of the Non-Intersection Data Group.

travel lane should accomplish the same purpose. A brief investigation was conducted to ascertain the safety effects of edge lines and shoulder contrast on the study sites. Almost half of these sites had been photographed during the operational characteristics portion of this research (35mm slides, 8 mm movies and video tapes). These photos were used as the data base for this analysis.

Table 16 contains the numerical codes used to evaluate the 43 locations which had been photographed. A rating was established for both contrast and marking at each site. Although the ratings were somewhat subjective in nature, every effort was made to produce consistent evaluations. Accident rates were compared to contrast/marking ratings for all ten roadway classes used in the comparative accident study. The same type of analysis was performed for grouped data, i.e., two-lane roads without shoulders, two-lane roads with shoulders, and four-lane roads without shoulders.

Table 16. Rating Chart for Edge Lines/Shoulder Contrast.

Rating	Edge Lines	Contrast
0	None	None
1	Faded	Construction Joint Only
2	Fair	Some
3	Good	Different Materials/Colors
4	Exceptional	Exceptional

No significant correlation was found for accidents, when compared to ratings for edge marking, shoulder contrast, or a combination of the two. Testing the data in separate classes or in groups did not improve the results.

Figure 17 is typical of the many data plots drawn for this study. The figure is for two-lane roads and the non-intersection accident data group. The reason for the poor statistical correlation is obvious in light of the "shotgun" scatter of the plotted data.

There are several possible reasons for the poor correlation. For instance, accident data were taken from a three-year period, and changes surely occurred in pavement marking at the various locations during that time. The markings in use at the time of observation were not necessarily those in place during the entire study period. A second reason might be the variability of shoulder contrast/marking within a study site. For the correlation study, the average value was used. It is reasonable to assume that one very hazardous section with poor markings could experience a large number of accidents. This section would not lower the average shoulder rating, but would certainly raise the accident rate. Another and perhaps more important reason is that other factors may be more important than shoulder contrast and edge lines in determining the accident rate at a given site. In summary, it appears that neither shoulder contrast nor edge lines had a significant effect on the accident rate for sites in this study.

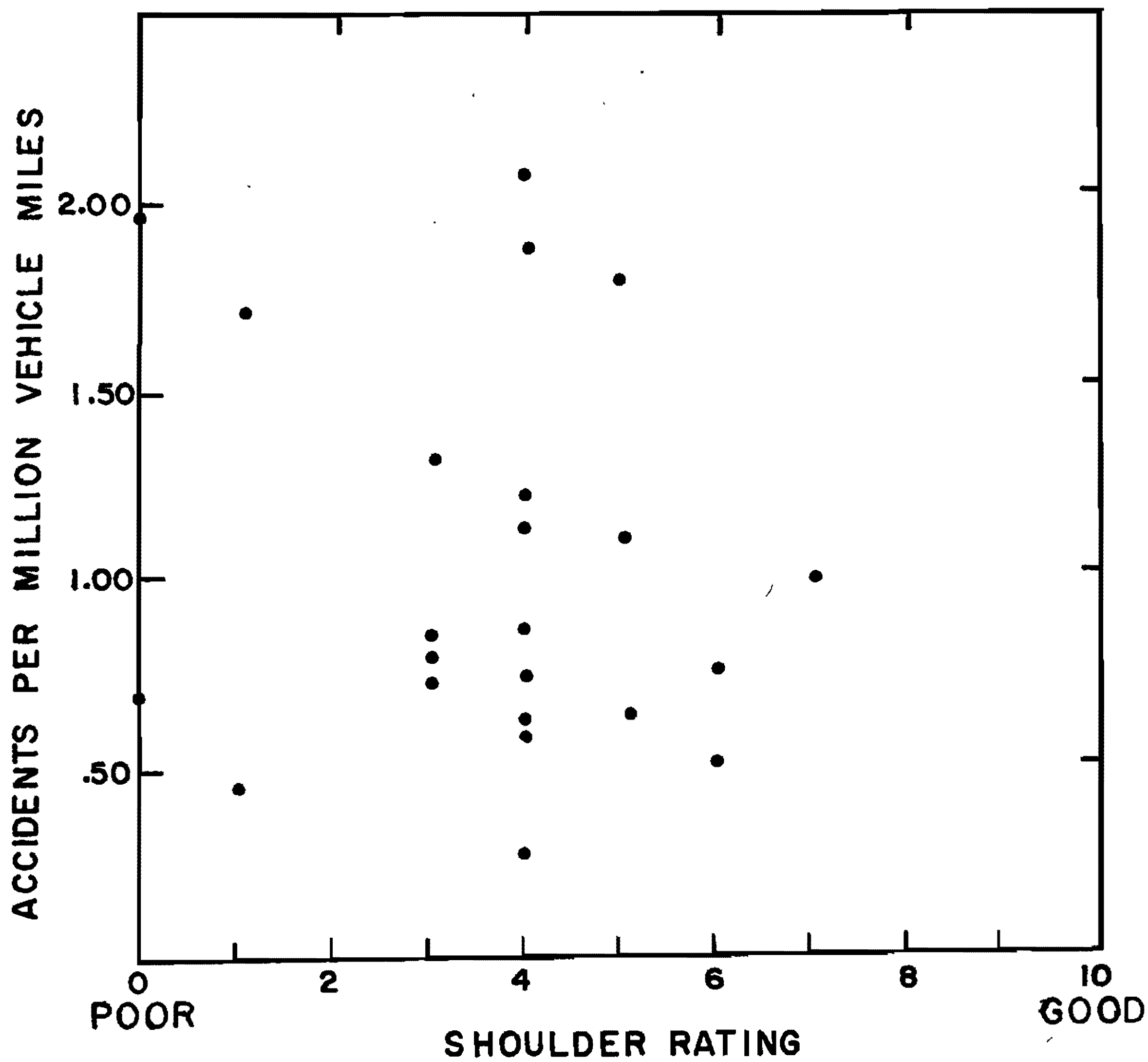


Figure 17. Effects of Shoulder Marking and Contrast on the Accident Rates of Two-Lane Roads.

Accident Study: Before-After Analysis

The Texas State Department of Highways and Public Transportation (TSDHPT) has tried several techniques to improve the operating conditions on their rural two-lane highways. The most common of these treatments has been the addition of paved shoulders to roadways without them. An innovative treatment that provides additional capacity at a minimum cost has been the conversion of two-lane roadways with full-width paved shoulders into undivided four-lane roadways without shoulders. This treatment results in what is commonly known as a "poor-boy" highway and entails resurfacing and restriping, or restriping the existing pavement. Increased capacity is obtained without incurring expenses for earthwork, drainage, intersections and structures. Although both treatments improve traffic operations, their effect on safety has not heretofore been quantified. Therefore, a study was designed to evaluate these effects.

The purpose of this analysis was to establish the consequences related to safety whenever full-width paved shoulders are added to a two-lane roadway or a two-lane highway with full width paved shoulders is converted to a four-lane "poor-boy" roadway. A previous section of this report has described the accident effects related to the presence or absence of paved shoulders. The following section presents an accident frequency comparison between the before and after improvement time periods.

Site Selection. A stratification matrix of roadway characteristics was developed delineating traffic volume, type of improvement and number of lanes. Table 17 details the six classifications used in the before-after analysis. To ensure a statistically valid and representative data sample, it was desired to have a minimum of ten sites in each classification, with each site containing five or more miles of geometrically consistent roadway.

Table 17. Site Classification for Before-After Accident Study.

Classification Number	Modification Conditions	A.D.T. Range
100	Add paved shoulders to two-lane highway	1,000-3,000
200	Add paved shoulders to two-lane highway	3,000-5,000
300	Add paved shoulders to two-lane highway	5,000-7,000
400	Convert two-lane with shoulders to four-lane without paved shoulders	1,000-3,000
500	Convert two-lane with shoulders to four-lane without paved shoulders	3,000-5,000
600	Convert two-lane with shoulders to four-lane without paved shoulders	5,000-7,000

The SDHPT's roadway geometric computer files, RI-2-TLOG's, were used to screen all rural roadways in the state as potential sites. As this process involved more than 29,000 roadway segments and ten years of data, it was a substantial undertaking. For each segment, key geometric features on the 1977 file were checked against the same features on the 1968 file. This comparison was used to determine if during that time period, the roadway had been either reconstructed from a two-lane without shoulder to a two-lane with shoulder roadway or converted from a two-lane with shoulder to an undivided four-lane without shoulder roadway. Manual examination of the two files found 390 segments (77 different sites) that had been so modified. After these roadways had been identified, their geometric files for the other eight years (1969-1976) were checked in order to determine when the modification took place. For a site to be selected, it had to have a two-year period both before and after the modification without any additional changes. In addition, candidate sites were checked for uniform cross-sections, consistent traffic volumes, and standard geometric features. Roadways not meeting these criteria were discarded.

Results from this initial screening process were similar to those from the comparative accident study in that there was not a uniform distribution of candidate sites among the different roadway classes. There were more than enough Class 1 roadways (shoulders added to a low-volume two-lane highway) suitable for this study. The number of Class 2 roadways (shoulders added to a mid-volume two-lane highway) were sufficient to choose sites that met most of the selection criteria. Class 3 roadways (shoulders added to a high-volume two-lane highway) were virtually nonexistent as only three possibilities were found. Sites suitable for evaluating the conversion from a two-lane with shoulder roadway to an undivided four-lane without shoulder roadway were limited by two conditions. Either the conversion took place less than three years after a shoulder had been added or it was direct from a two-lane without shoulder roadway. Several additional sites were dropped from the sample because the change took place after 1975, i.e., two years of accident data after the conversion were not available. In addition, several sites were less than five miles in length. Because these problems caused the sample size to be small, no additional sites were discarded. The process by which the study sites were selected is summarized in Table 18.

In summary, an adequate number of low-volume (Class 1 and Class 4) roadways were found that either met or exceeded the minimum selection criteria. The number of moderate-volume (Class 2 and Class 5) roadways was expanded to a desirable size by including several roadway segments that were less than five miles in length. The number of high volume (Class 3 and Class 6) roadways was inadequate and both samples encompass a broad range of conditions. An initial finding of this study is that even with a large number of candidate roadway segments, the selection criteria restricted the number of sites eligible for study to a relatively small number. However, even with this shortcoming, the sample size was larger and more uniform than those used in previous before-after accident studies. A listing of the sites that were selected for this study is contained in Appendix C.

Table 18. Site Selection Process for Before-After Accident Study.

Class	Candidate RI-2-TLOG Segments	Length Miles	Potential Sites	Eligible Sites	Selected Sites	Length Miles
1	10,515	7,101	260	18	16	135
2	3,969	1,885	51	18	11	68
3	1,346	516	32	3	3	11
4	453	187	15	15	13	78
5	554	223	19	17	11	68
6	403	80	13	6	6	34
Total	27,240	9,992	390	77	60	394

Data Collection. For each study location, the SDHPT's accident files were used to obtain the accident histories for each site during the two years before and the two years after the modification took place. At this time, checks for both milepoint compatibility and construction related accidents were made. This insured that data was collected for the same section of roadway and also that the modification was completed within a one year time period. During this process, several adjustments to the data set were required to account for extended construction activity. In some cases, this necessitated the use of up to six years of accident data.

Compilation of the accident data was another labor intensive task. Each accident record had to be manually transcribed from a microfiche card reader to a coding form before it could be placed in a computer data file. Each record contained more than 30 variables. To compound the problem, minor changes in both format and variable descriptions occurred from time to time. Conversion to a compatible data base was done manually. Although each item of data was coded, only the information that was relevant to this type of study was analyzed. All of the variables that were analyzed are listed in Table 19. Finally, it should be noted that accidents not necessarily related to roadway type were excluded from the data set.

Table 19. Accident Frequency Analysis Variables.

Accident Type	Severity Measures
Angle	(PI+F)* Accident
Head-On	Fatality Accident
Right-Turn	Number of Injuries
Left-Turn	Number of Fatalities
Rear-End	Time of Day
Same Direction	Daytime
Fixed-Object	Nighttime
Run-Off-Road	Total
Animal	Location
Other	All
Total Number	Non-Intersection

* PI+F - Personal Injury and Fatality

The accident data was used to create a computerized data file. For comparative purposes, a frequency analysis was run for each site on a yearly basis - two years before and two years after modification. Accident frequencies for the after conditions were adjusted to account for changes in the average daily traffic. Appendix C contains summarized data for each of the six roadway classes. Separate tables are provided for total accident frequencies and non-intersection accident frequencies. Findings from this analysis are discussed in the following paragraphs.

Findings: Frequency Analysis

All Accidents. Summarized results of the frequency analysis for the all-accident data set are presented in Tables 20 and 21. Although nine types of accidents were studied, they have been grouped into three broad categories for this discussion - multi-vehicle accidents, run-off-road and hit-fixed-object single vehicle accidents and other single vehicle accidents. A more detailed breakdown is not necessary as both categorization schemes support the same conclusions. Major findings from this study are discussed below.

When full-width paved shoulders were added to a two-lane roadway (Table 20), total accidents decreased in number. This was true for all volume levels studied. In the low-volume category (1000 to 3000 vehicles per day), there were a total of 16 sites. The average volume on these roadways was 1450 vehicles per day in the before condition and 1580 vehicles per day in the after condition. While the number of total accidents decreased, only single vehicle run-off-road and hit-fixed-object accidents contributed to this reduction. There were 11 sites included in the moderate volume category (3000 to 5000 vehicles per day). The average volume on these roadways was 2550 vehicles per day in the before condition and 2730 vehicles per day in the after condition. Several of the sites were less than five miles in length. Although the total number of accidents

Table 20. Safety Benefits From Adding Shoulders to a Two-Lane Roadway, All Accidents.

Volume Range	Type of Accident	No. of Accidents		Percent Change
		Before	After[c]	
1000-3000	Multi-Vehicle	69	69.5	+ 0.7
	Single Vehicle[a]	74	34.2	-53.8
	Other[b]	29	31.7	+ 9.3
	Total	172	135.4	-21.3
3000-5000	Multi-Vehicle	92	82.3	-10.5
	Single Vehicle[a]	77	62.7	-18.6
	Other[b]	31	39.1	+26.1
	Total	200	184.1	- 8.0
5000-7000	Multi-Vehicle	44	33.9	-23.0
	Single Vehicle[a]	17	14.9	-12.4
	Other[b]	7	8.2	+17.1
	Total	68	57.1	-16.0

[a]Run-off-road and hit-fixed-object accidents.
[b]Other single vehicle accidents.
[c]Adjusted for changes in average daily traffic.

Table 21. Safety Benefits from Converting to a Four-Lane "Poor-Boy" Highway, All Accidents.

Volume Range	Type of Accident	No. of Accidents		Percent Change
		Before	After[c]	
1000-3000	Multi-Vehicle	61	68.2	+11.8
	Single Vehicle[a]	90	75.3	-16.3
	Other[b]	33	45.3	+37.3
	Total	184	188.7	+ 2.6
3000-5000	Multi-Vehicle	104	77.0	-26.0
	Single Vehicle[a]	83	71.6	-13.7
	Other[b]	42	35.4	-15.7
	Total	229	184.0	-19.7
5000-7000	Multi-Vehicle	80	72.7	- 9.1
	Single Vehicle[a]	57	35.8	-37.2
	Other[b]	26	24.4	- 6.2
	Total	163	132.9	-18.5

[a]Run-off-road and hit-fixed-object accidents.
[b]Other single vehicle accidents.
[c]Adjusted for changes in average daily traffic.

again decreased, both multi-vehicle and single vehicle run-off-road and hit-fixed-object accidents contributed to this reduction. There were only three sites in the high volume category (5000 - 7000 vehicles per day). The average volume on these roadways ranged from 3840 vehicles per day in the before condition to 4880 vehicles per day in the after condition. All three sites were less than five miles in length. As before, the number of total accidents decreased. However, in this situation, multi-vehicle accidents were the primary contributor to this reduction.

When a two-lane with paved shoulder roadway was converted to an undivided four-lane without shoulder roadway (Table 21), total accidents decreased only for volume levels greater than 3000 vehicles per day. The low volume category (1000 to 3000 vehicles per day) included 12 sites. The average volume on these roadways was 2000 vehicles per day in the before condition and 2200 vehicles per day in the after condition. Although the number of single vehicle run-off-road and hit-fixed-object accidents decreased, there was a small increase (+3 percent) in the total number of accidents. In the moderate volume category (3000 to 5000 vehicles per day), there were 11 sites. The average volume on these roadways changed from 2910 vehicles per day in the before condition to 3310 vehicles per day in the after condition. In this category, all three types of accidents decreased in number. There were only six sites in the high volume category (5000 to 7000 vehicles per day). The average volume on these roadways was 4100 vehicles per day in the before condition and 5130 vehicles per day in the after condition. As in the previous category, all three types of accidents decreased in number. The reasons for this behavior are discussed in the following section of this report.

Non-Intersection Accidents. Summarized results of the frequency analysis for the non-intersection data set are presented in Tables 22 and 23. As their title suggest, intersection related accidents have been deleted. Categories for accident types and the sample of study sites are the same as those in the previous discussion. For this reason, their descriptions will not be repeated. Results from the analyses of the two data sets are remarkably similar. The following paragraphs describe the probable causes of these trends.

When full width paved shoulders are added to a two-lane highway (Table 22), the number of total accidents can be expected to decrease in number. This was true for all volume levels studied. Both the magnitude of the reduction and the types of accidents contributing to it changed with increasing volume. Percentagewise, the biggest savings occur during low volumes (1000 to 3000 vehicles per day); however, single vehicle accidents were the only types of accidents that decreased in number. As they constitute almost 70 percent of the total accidents in the "before" condition, these results are not surprising. Accidents which occur at these volume levels are often the result of inattentiveness brought on by a low driver workload. Typically, these incidents involve drivers that for some reason lose control of their car and run off the road. Adding paved shoulders to the roadway provides more surface area for motorists to recover from this type of mistake. This results in a decrease in the expected number of single vehicle accidents.

At moderate volumes (3000 to 5000 vehicles per day), accident reductions are less than half those of the lower volume category. In this case, both single and multi-vehicle accidents decreased in number. The percentage of single vehicle accidents in the "before" condition has decreased to about 60 percent of the total. The additional traffic has raised the driver's workload and made them more attentive, but at the same time, it has increased their

Table 22. Safety Benefits From Adding Shoulders to a Two-Lane Roadway, Non-Intersection Accidents.

Volume Range	Type of Accident	No. of Accidents		Percent Change
		Before	After[c]	
1000-3000	Multi-Vehicle	35	36.4	+ 4.0
	Single Vehicle[a]	58	26.1	-55.0
	Other[b]	27	25.1	- 7.0
	Total	120	87.6	-27.0
3000-5000	Multi-Vehicle	68	53.9	-14.7
	Single Vehicle[a]	67	52.9	-21.4
	Other[b]	29	36.7	+26.6
	Total	164	143.5	-12.5
5000-7000	Multi-Vehicle	27	16.9	-37.4
	Single Vehicle[a]	12	12.0	-0-
	Other[b]	6	8.2	+36.6
	Total	45	37.1	-17.6

[a]Run-off-road and hit-fixed-object accidents.
[b]Other single vehicle accidents.
[c]Adjusted for changes in average daily traffic.

Table 23. Safety Benefits from Converting to a Four-Lane "Poor-Boy" Highway, Non-Intersection Accidents.

Volume Range	Type of Accident	No. of Accidents		Percent Change
		Before	After[c]	
1000-3000	Multi-Vehicle	35	44.8	+28.0
	Single Vehicle[a]	72	69.4	- 3.6
	Other[b]	33	43.4	+31.5
	Total	140	157.6	+12.6
3000-5000	Multi-Vehicle	73	44.0	-39.8
	Single Vehicle[a]	72	68.7	- 4.6
	Other[b]	40	37.1	- 7.3
	Total	185	149.8	-19.0
5000-7000	Multi-Vehicle	53	39.6	-25.3
	Single Vehicle[a]	55	28.8	-47.6
	Other[b]	29	30.3	+ 4.5
	Total	137	98.7	-28.0

[a]Run-off-road and hit-fixed-object accidents.
[b]Other single vehicle accidents.
[c]Adjusted for changes in average daily traffic.

probability of hitting another car. Although paved shoulders still provide recovery area, they are now being used for accident avoidance maneuvers. Thus, the decrease in the expected number of both accident types. At high volumes (5000 to 7000 vehicles per day), accident reductions are between those for the other two volume categories. Interestingly, only multi-vehicle accidents contributed to the reduction. The percentage of single vehicle accidents in the "before" condition has decreased to 40 percent of the total. Heavy traffic volumes have caused the driver's workload to become extremely high. As a result, accidents caused by inattention are infrequent. Most incidents involve more than one vehicle; therefore, the majority of safety benefits resulting from the addition of paved shoulders come from a reduction in the number of multi-vehicle accidents.

When a two-lane with paved shoulder roadway is converted to an undivided four-lane without shoulder roadway (Table 23), total accidents can be expected to decrease in number whenever the roads carry more than 3000 vehicles per day. If the volume is less than this value, accident frequencies will probably increase. At these low volumes (1000 to 3000 vehicles per day), both single and multi-vehicle accidents can be expected to increase in number. As described previously, accidents which occur at these volume levels are often the result of inattentiveness brought on by a low driver workload. Conversion of the shoulder to a travel lane adds to this false feeling of security and reduces the area available for vehicle recovery. Therefore, it is not surprising accident rates increased after the modification. This type of improvement does reduce accidents at higher volume levels. This saving increases with increasing volumes. It is interesting to note that the number of single vehicle accidents did not decrease until the volume reached 5000 vehicles per day. This indicates the point at which the workload on a four-lane highway becomes great enough to capture the driver's attention.

Findings: Paired T-Test Comparisons

To supplement the previous analysis, a paired t-test was used to compare the accident frequencies between the two years before and the two years after the modification. The data were examined for significant changes in either accident type or their accident severity on a class by class basis. A two-tailed t-test at the 90 percent confidence level was used to test for these differences. Findings from this analysis are discussed in the following paragraphs.

All Accidents. Significant differences in before-after accident frequencies for the all-accident data set are shown in Table 24. When paved shoulders were added to a two-lane roadway, the total number of accidents decreased. This difference was significant in both the high and low volume categories. Few changes in the frequency of occurrence for specific types of accidents were noted. The data does indicate that paved shoulders will decrease accident severity on low and moderate volume roadways; however, they appear to increase accident severity on high-volume roads. The reasons for this can best be described in the following manner. As documented in Chapter IV, the average speed on two-lane roadways is not affected by the presence or absence of a paved shoulder until the volume on the facility reaches 5000 vehicles per day. Above this point, the average speed on a with shoulder roadway is at least 10 percent greater than it is on a similar section without shoulders. Previous research (27) has shown that higher speeds are normally associated with increased accident severity. Thus, the benefits resulting from a reduction in total accident frequency and a savings in travel time are being partially offset by an increase in the severity of those accidents that do occur.

When a two-lane with paved shoulder roadway was converted to an undivided four-lane without shoulder roadway, the number of total accidents decreased for

Table 24. Statistically Significant Differences in Accident Types, All Accidents.

Type of Conversion	Type of Accident	ADT Range		
		Low-Volume (1000-3000)	Moderate-Volume (3000-5000)	High-Volume (5000-7000)
Add Paved Shoulders to Two-Lane Roadway	Angle	Increased(N)	-	-
	Head-On	-	-	-
	Right-Turn	-	-	-
	Left-Turn	-	-	Decreased(D,T)
	Rear-End	-	Decreased(D,T)	-
	Same Direction	-	-	Decreased(T)
	Fixed-Object	-	Decreased(N,T)	-
	Run-Off-Road	Decreased(D,N,T)*	-	-
	Animal	-	-	-
	Other	-	-	-
	Total Number	Decreased(D,T)	-	Decreased(T)
	PI+F Accident	-	Decreased(N,T)	-
	Fatal Accident	-	Decreased(N,T)	-
	Injuries	Decreased(D,T)	-	Increased(D,T)
	Fatalities	-	Decreased(N,T)	Increased(N,T)
Convert Two-Lane with Shoulder to Four-Lane without Shoulder	Angle	-	-	-
	Head-On	-	Decreased(D,T)	Decreased(D)
	Right-Turn	-	-	Increased(N)
	Left-Turn	Decreased(D,T)	Decreased(D,T)	-
	Rear-End	-	-	Decreased(D)
	Same Direction	-	-	-
	Fixed-Object	Decreased(D,T)	-	-
	Run-Off-Road	-	Decreased(T)	Decreased(D,T)
	Animal	-	Decreased(N,T)	Decreased(N,T)
	Other	Increased(D)	-	Increased(T)
	Total Number	-	Decreased(D,T)	-
	PI+F Accident	Increased(N) Decreased(D)	Increased(N) Decreased(D)	Decreased(D,T)
	Fatal Accident	-	-	-
	Injuries	Increased(N) Decreased(D)	Increased(N) Decreased(D)	-
	Fatalities	-	-	Decreased(D)

* D-Daytime, N-Nighttime, T-Total

roadways with volumes greater than 3000 vehicles per day. However, this difference was significant in the moderate-volume category only. In contrast to the other type of improvement, many changes were noted in the frequency of occurrence for specific types of accidents. As shown in Table 24 these differences were more common in the moderate and high-volume categories. Conversion to a "poorboy" roadway appears to have an inconsistent effect on accident severity. The frequency with which injury accidents occur increased during the night and decreased during the day. The reasons for these changes are unclear at best; however, results from the comparative analysis study revealed that 60 percent of the total accidents on this type of road occur at night. This indicates that darkness may be eliminating visual cues that alert the driver to the closeness of the edge of the roadway.

Non-Intersection Accidents. Significant differences in before-after accident frequencies for the non-intersection accident data set are shown in Table 25. The addition of paved shoulders caused the total number of accidents to decrease. This difference was significant in all three volume categories. At low-volumes, the frequency of several types of single vehicle accidents decreased. At moderate and high volumes, the frequency of several types of multi-vehicle accidents decreased. This reinforces the premise that shoulders are effective in reducing the occurrence of different types of accidents at different volume levels. This data also indicates an overall decrease in accident severity when shoulders were added to two-lane roads; however, the number of fatalities did increase in the high-volume category. Again, this increase is probably the result of higher speeds after the modification.

The conversion of a two-lane with paved shoulder roadway to an undivided four-lane without paved shoulder roadways resulted in an increase in the total

Table 25. Statistically Significant Differences in Accident Types, Non-Intersection Accidents.

Type of Conversion	Type of Accident	ADT Range		
		Low-Volume (1000-3000)	Moderate-Volume (3000-5000)	High-Volume (5000-7000)
Add Paved Shoulders to Two-Lane Roadway	Angle	-	-	-
	Head-On	-	-	-
	Right-Turn	-	-	-
	Left-Turn	-	Decreased(D,T)	Decreased(D,T)
	Rear-End	-	Decreased(D,T)	Decreased(T)
	Same Direction	-	-	Decreased(T)
	Fixed-Object	Decreased(D)	-	-
	Run-Off-Road	Decreased(D,N,T)*	-	-
	Animal	Decreased(T)	Increased(N,T)	-
	Other	-	-	Increased(T)
	Total Number	Decreased(D,N,T)	Increased(N) Decreased(D,T)	Decreased(T)
	PI+F Accident	-	Decreased(T)	-
	Fatal Accident	-	Decreased(N,T)	-
	Injuries	Decreased(T)	-	Decreased(D)
	Fatalities	-	Decreased(N,T)	Increased(N,T)
Convert Two-Lane with Shoulder to Four-Lane without Shoulder	Angle	-	-	-
	Head-On	-	Decreased(D,T)	-
	Right-Turn		-	-
	Left-Turn	Decreased(D,T)	Decreased(D,T)	-
	Rear-End	-	Decreased(D,T)	Decreased(N,T)
	Same Direction	Increased(T)	-	-
	Fixed-Object		-	Decreased(D)
	Run-Off-Road	-	-	Decreased(D,T)
	Animal	-	Decreased(N,T)	Decreased(N,T)
	Other	Increased(D,T)	Increased(N,T)	Increased(T)
	Total Number	Increased(T)	Decreased(D,T)	Decreased(D,T)
	PI+F Accident	-	-	Decreased(D,T)
	Fatal Accident	-	-	-
	Injuries	Increased(N)	-	Decreased(D)
	Fatalities	-	-	-

* D-Daytime, N-Nighttime, T-Total

number of accidents at low-volumes and a decrease at moderate and high-volumes. The frequency of occurrence for the various accident types exhibits similar characteristics. The number of injury accidents increased at low-volumes and decreased at high-volumes. It is interesting to note that the increase occurred at night and the decrease occurred during the daytime. Again this observation points to a potential nighttime safety problem.

Conclusions: Before-After Analysis

Based upon the findings from this analysis, several conclusions may be drawn. These involve changes in both accident frequency and accident type after modification of two types of rural Texas highways, and are discussed in the following paragraphs.

Shoulder Addition. The addition of full-width paved shoulders to a two-lane roadway was effective in reducing the total number of accidents that occurred. The magnitude of the reduction and characteristics of the accidents varied with the traffic volume. These changes were similar for both the all-accident and the non-intersection accident data bases. At low-volumes, shoulder additions resulted in fewer single vehicle accidents (run-off-road and hit-fixed-object). Thus, the shoulder provides additional paved recovery area for drivers inadvertently exiting from the travel way. These results should be expected as the potential is low for multi-vehicle accidents and high for driver boredom. At moderate volumes, shoulder additions reduced the total number of accidents and the severity of those that did occur. Both single and multi-vehicle accidents decreased in number. This indicates that shoulders are being used for accident avoidance as well as recovery maneuvers. On high-volume roadways, these improvements resulted in fewer total accidents; however, they increased the overall severity of those that did occur. This increase is attributed to increased operating speeds after the shoulder was added to roadways in this volume category.

"Poor-Boy" Roadways. When two-lane with paved shoulder roadways were converted to undivided four-lane without shoulder roadways, the results varied with the volume level. At low-volumes, the total accident frequency actually increased after the conversion. At moderate and high-volume locations, "poor-boy" roadways resulted in fewer total accidents. The magnitude of the reduction increased with increasing volumes. This type of modification appears to have an inconsistent effect on accident severity. The frequency with which injury accidents occur increases during the night and decreases during the day. These results indicate that darkness may be eliminating visual cues that alert the driver to the hazards associated with this type of roadway.

CHAPTER IV. OPERATIONAL EFFECTS OF PAVED SHOULDER USAGE

Introduction

Paved shoulders are used by many motorists for making a large variety of traffic maneuvers and satisfying numerous driving task demands. Some common uses include to bypass left-turners at driveways or non-channelized intersections and as acceleration/deceleration lanes on high-speed high volume highways. In addition, they are sometimes used as an auxiliary lane by slow moving vehicles. As a courteous gesture to let faster vehicles pass, Texas drivers commonly pull onto the paved shoulders of rural two-lane highways. Many operational benefits result from these maneuvers being made on paved shoulders. Most of them are apparent to drivers since the voluntarily use the shoulder. Traffic congestion and delays are reduced and fuel is saved. However, there is little documentation as to the types and frequency of shoulder usage and the impacts and conditions under which they occur. In order to quantify these variables, several field studies were planned.

Site Selection

The roadway classification matrix developed for the comparative accident study (Table 14) was used to stratify sites for the field studies. Desirably, the sample should be representative of statewide operating conditions; therefore, the following site selection procedure was adopted. For each of the ten highway classes, the accident study sites were ranked by their accident rate. The two extremes (highest and lowest rates) from each category were tentatively selected for further study. As neither extremely short nor widely separated segments lend themselves to maximizing the data collection effort, section lengths and geographic locations were checked. Sites that did not meet these criteria were discarded and replaced by the next ranked site in the category. Figure 18

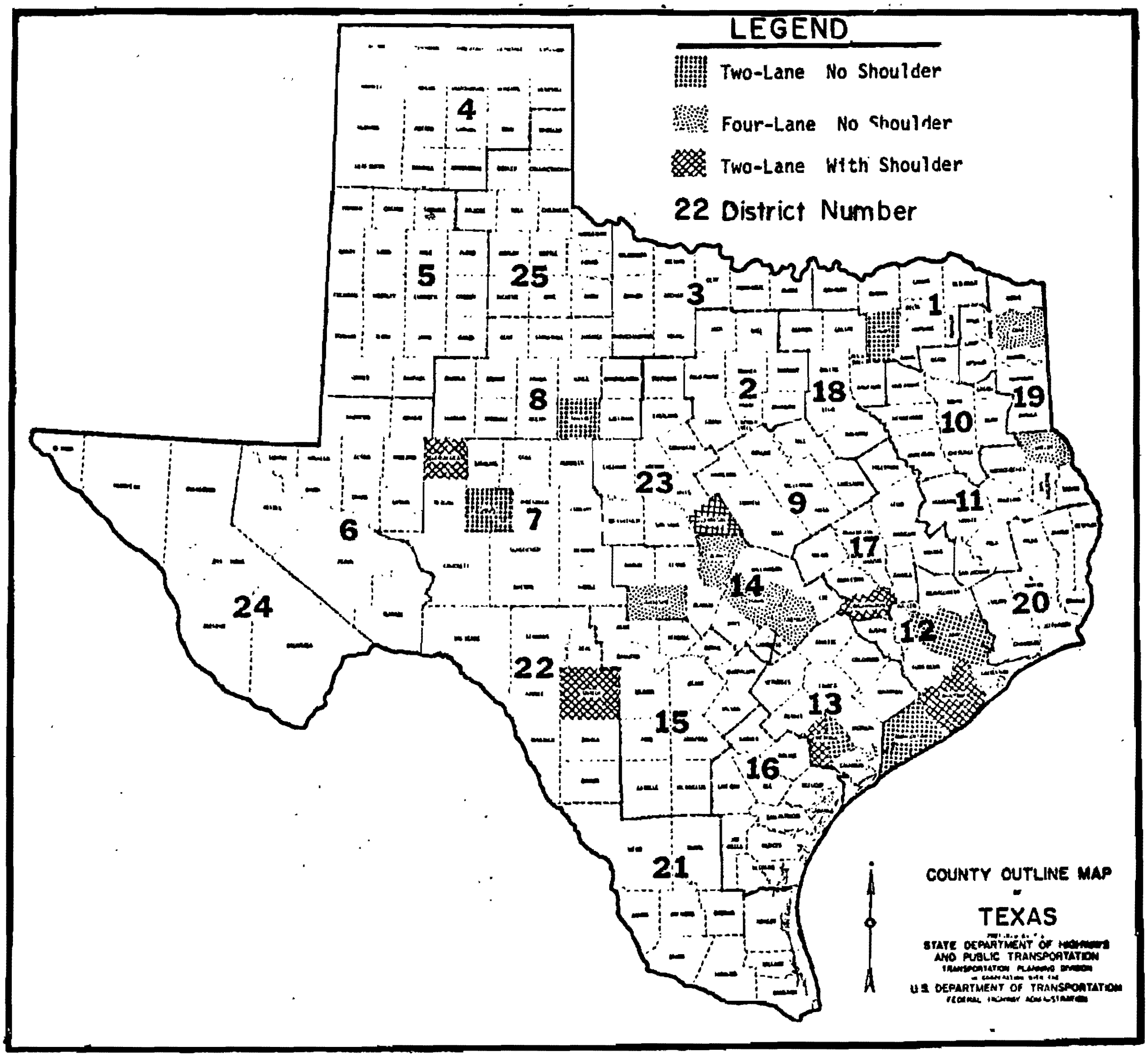


Figure 18. Field Operational Study Site Locations.

indicates the general location of the field study sites. As shown, most of the state's geographic regions are represented in the sample. Verbal descriptions of each site are contained in Table 26. A more detailed description of the study sites is included in Appendix D.

Table 26. Location and Description of Field Study Sites.

Type of Highway	Site Number	Highway Number	County Name	Type of Curvature Horizontal[a]	Type of Curvature Vertical[b]
Two-Lane No Shoulder	101	US 67	Irion	Mild	Moderate
	108	US 277	Taylor	Moderate	Moderate
	205	US 276	Hunt	Moderate	Moderate
	208	Texas 35	Matagorda	Mild	Mild
	303	FM 2100	Harris	Mild	Mild
	308	US 87	Victoria	Mild	Mild
Two-Lane With Shoulder	408	Texas 105	Washington	Moderate	Moderate
	409	Texas 158	Glasscock	Mild	Mild
	501	US 90	Uvalde	Mild	Mild
	508	US 190	Lampassas	Moderate	Moderate
	604	Texas 35	Brazoria	None	None
	606	US 77	Victoria-Refugio	Mild	Mild
Four-Lane No Shoulder	1002	Texas 21	Burleson-Lee	Moderate	Moderate
	1009	US 290	Gillespie	Severe	Moderate
	703	US 290	Bastrop	Mild	Moderate
	705	Texas 29	Burnet	Severe	Moderate
	803	US 183	Travis	Mild	Mild
	906	US 59	Cass	None	Moderate

[a]Less than 3 degrees - mild; 3 to 6 degrees - moderate; greater than 6 degrees - severe.

[b]Rolling terrain and unrestricted sight distance (PSD >1200 ft.) - mild; rolling terrain and restricted sight distance (PSD <1200 ft.) - moderate.

Study Methodology

The procedure developed to collect operational data was constrained by practical considerations of mobility, accuracy, economy and minimum distraction to motorists. Primarily, it was designed to collect five types of traffic data - traffic composition, traffic volume, vehicle speeds, lateral placement and queued vehicles. Roadway geometrics and other pertinent information also were recorded. The specifics of this procedure are discussed in the following paragraphs.

At each site, a study vehicle and two members of the research team were required to collect the field data. The vehicle was equipped with an on-board moving radar gun, a distance measuring instrument, a CB radio and several cameras. As shown in Figure 19, most of the equipment used was mounted on the dash of the car. The vehicle operator was responsible for driving the car, classifying vehicles and calling out their speeds. The responsibilities of the study coordinator included photography, reading longitudinal distances and recording all of the data.

Upon arrival at a site, features that could be easily referenced (intersections, bridges, county lines, etc.) were selected as the ends of the study section. Several "drive-throughs" of the site were made to select several intermediate reference points within the section. An additional drive-through was used to videotape the site and to take 35mm slides of the general roadway appearance. Data were collected for a six-hour period. During this time, the study vehicle was driven in a continuous circuit from one end of the section to the other. Channel 19 on the CB radio was monitored to determine if the radar had been either detected or observed. Although a few high-speed vehicles noticed the radar and in some instances slowed down, the overall effect on

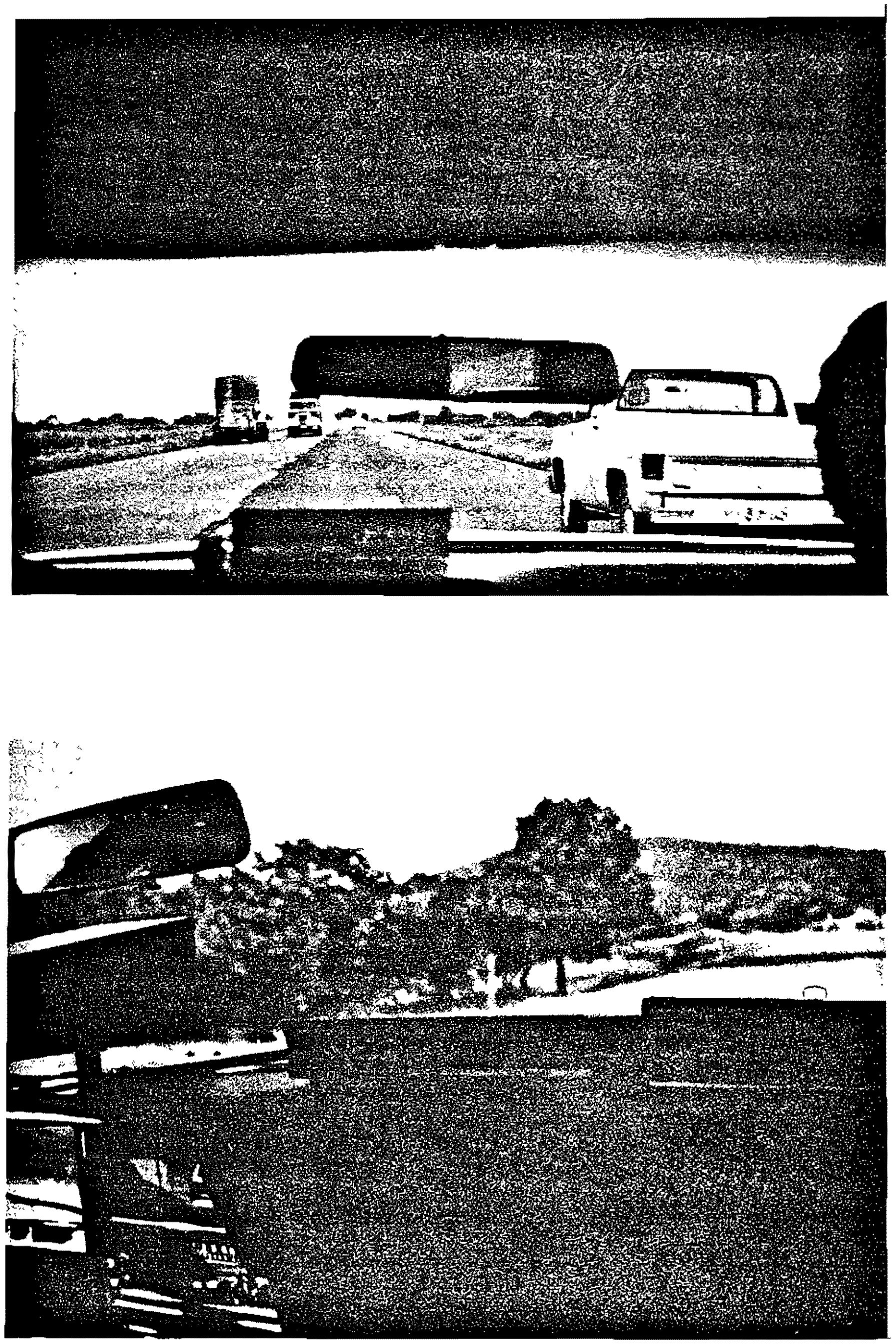


Figure 19. Study Vehicle Equipment Setup.

average speed was negligible. At the conclusion of the study, lane and shoulder widths were measured and recorded.

For each vehicle met by the study team, its type, speed, lane position and longitudinal placement were manually recorded. For platoons of vehicles, the lead vehicle's speed and longitudinal position were recorded along with the number and composition of vehicles in the platoon. Vehicle classifications used in this study include passenger cars, pick-ups, recreational vehicles, farm vehicles, trucks and motorcycles. Lane position referred to whether the vehicle was driving on the shoulder of the two-lane sections or the outside lane of the four-lane sections. Longitudinal placement was used to identify locations where shoulder usage occurred.

Study Summary

Field data were collected at a total of 18 different sites from around the state. Three types of highway were studied - two-lane highways without paved shoulders, two-lane highways with paved shoulders and undivided four-lane highways without paved shoulders. The sample included two sites from each roadway classification except for Class 8 and 9. Operational characteristics of over 21,000 vehicles were observed and recorded. For each study site, the data was reduced, compiled and summarized for each direction. This information has been included in Appendix D. During the conduct of the field studies, many different types of shoulder usage were observed. Some of these are illustrated in Figure 20.

Study Results

Vehicle Speeds. Average speeds for all vehicles as well as those for trucks only are presented in Table 27 and illustrated in Figure 21. From these data, several interesting trends can be observed. Even though speeds varied between sites, they fell into a range of 52 to 63 miles per hour. Truck

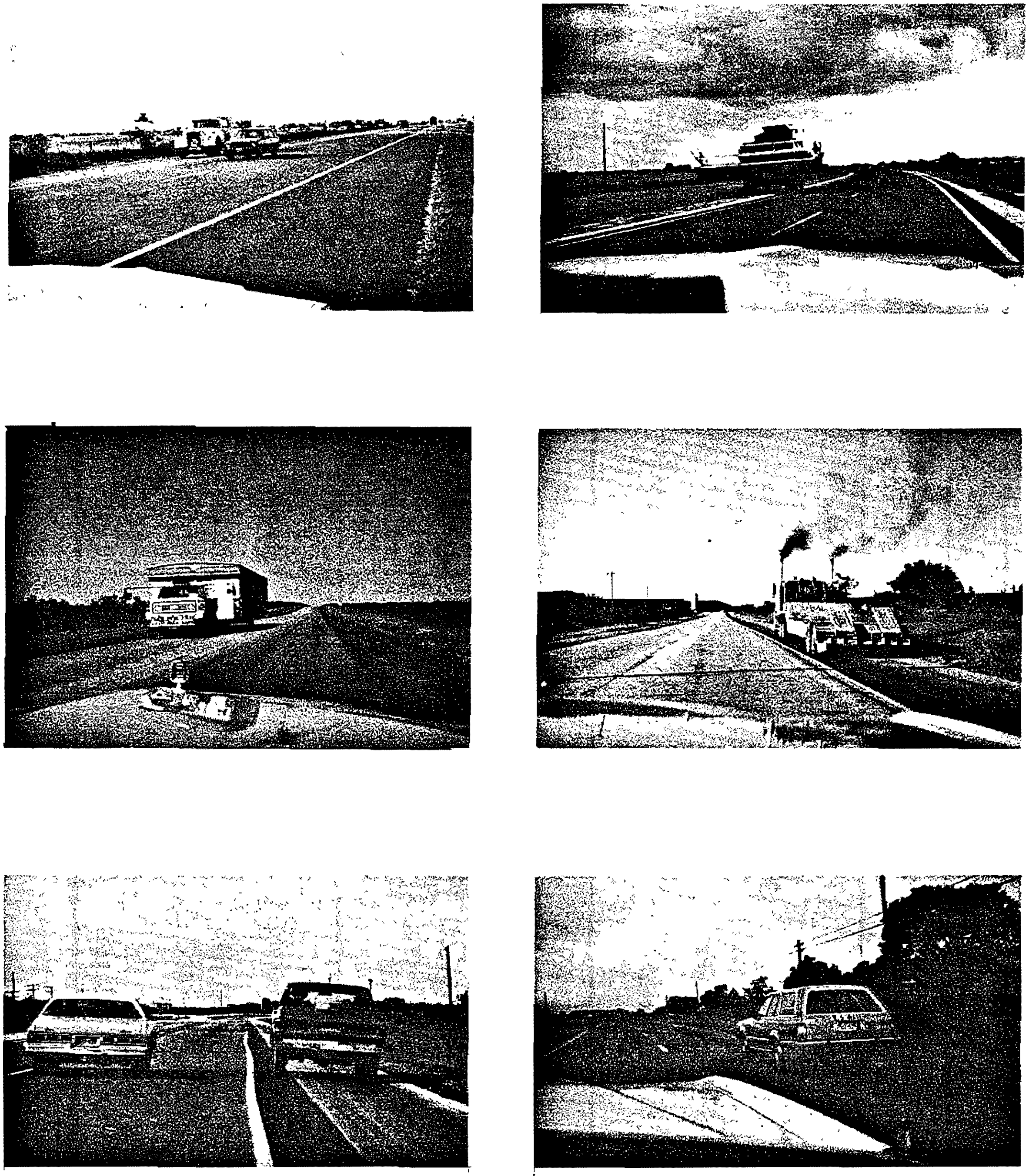


Figure 20. Observed Shoulder Usage.

Table 27. Results from the Operational Field Studies.

Site Number	Direction "A"				Direction "B"			
	Total Vehicles	Average Speed*	Percent Trucks	Truck Speed*	Total Vehicles	Average Speed*	Percent Trucks	Truck Speed*
101	217	62.39	10.14	58.55	174	61.71	13.22	57.96
108	230	60.70	19.10	57.80	219	61.20	16.00	59.50
208	472	57.24	20.34	56.32	465	56.72	22.58	56.32
205	253	54.20	10.30	51.80	257	53.40	9.30	54.00
308	637	54.53	7.22	54.14	563	53.30	5.68	51.75
303	828	51.80	13.16	49.90	738	53.00	10.03	57.40
409	382	62.20	25.00	60.10	316	63.40	20.00	61.60
408	319	57.99	14.32	56.59	413	60.79	17.19	57.29
501	470	58.37	22.13	57.46	518	60.56	23.75	59.74
508	650	54.73	12.00	51.05	629	54.48	13.51	55.27
604	1204	55.91	10.47	54.96	1039	56.58	12.32	54.52
606	1656	58.24	22.83	58.96	1465	56.97	22.80	56.36
1002	348	59.29	12.93	55.82	376	58.51	20.74	56.31
1009	107	60.96	7.48	62.38	138	58.70	13.77	61.00
703	757	60.14	15.46	59.41	674	61.32	12.61	59.01
705	674	52.80	8.90	52.60	727	54.60	10.50	54.50
803	676	57.01	12.13	54.92	643	58.32	11.20	56.32
906	1235	58.18	19.27	56.95	1143	59.58	21.61	58.59

* Average Speed is in miles per hour.

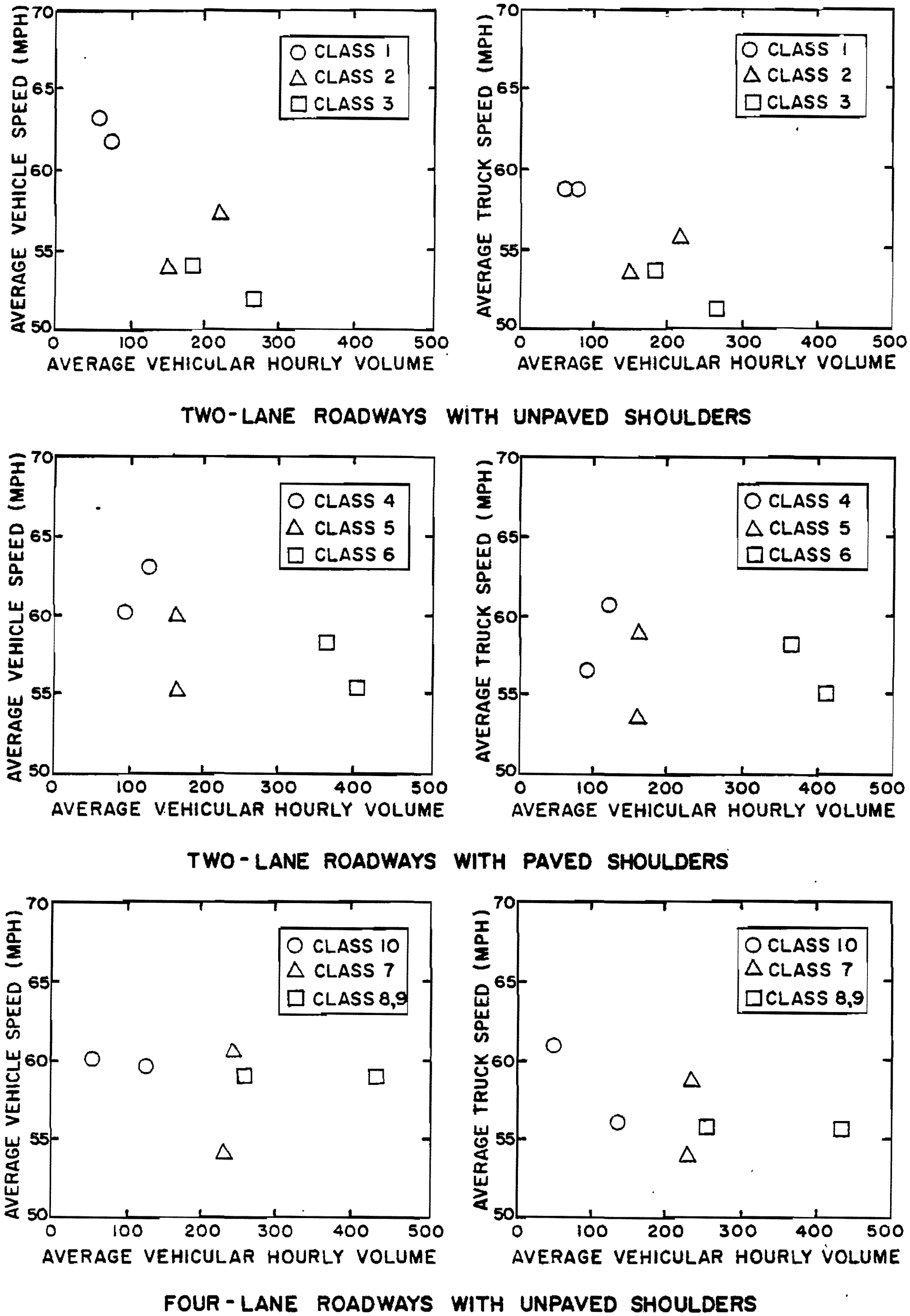


Figure 21. Average Vehicular Speeds on Three Types of Texas Highways.

speeds ranged from 50 to 62 miles per hour. For the most part, they are less than or about the same as the average speed on the roadway. Only at Site No. 1009 was this not the case. The reason for this divergence is not clear; however, this particular roadway carried less traffic than any other site even though it was a four-lane highway. The percentage of trucks at each site ranged from 5 to 25 percent. Although these numbers seem high, it should be noted that they include single-unit as well as tractor trailer trucks.

For two-lane roads without shoulders, the average speed drops from 62 miles per hour at low-volumes to 52 miles per hour at high-volumes (Top of Figure 21). Although less pronounced, the average truck speed exhibits a similar reduction. This suggests that increasing the volume on this type of highway will have less effect on truck speeds than it will on the speeds of other vehicles. For two-lane roads with paved shoulders, the average speed drops from 63 miles per hour at low-volumes to 56 miles per hour at high-volumes (Middle of Figure 21). Again, the average truck speed exhibits a similar but less pronounced reduction. It should be pointed out increasing the volume on this type of highway seems to have less effect on average speeds than it does on two-lane roads without shoulders. For the undivded four-lane roadway without shoulders, the average speed dropped from 59 miles per hour at low volumes to 57 miles per hour at high-volumes (Bottom of Figure 21). In this case, the reduction in average truck speed is the same. This suggests that increasing the volume on this type of highway has little effect on average vehicular speeds.

A direct comparison of the average speeds on the three types of highways is presented at the top of Figure 22. Increasing volumes have the most impact on two-lane roads without shoulders. Speeds also decreased on two-lane roads with paved shoulders, but only until the volume reached about

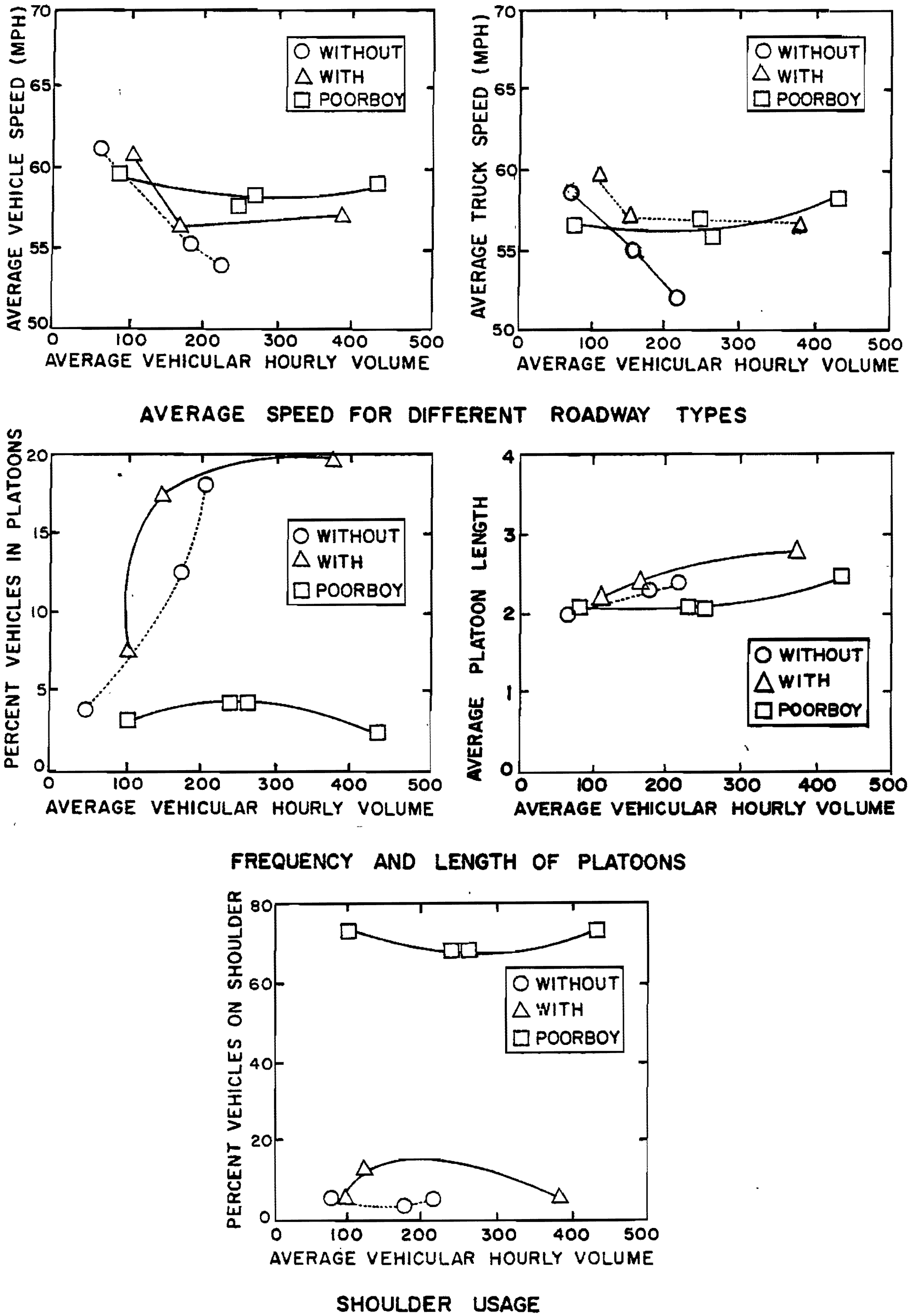


Figure 22. Operational Characteristics on Three Types of Texas Highways.

150 vehicles per hour. Further reductions did not occur. Above volumes of 200 vehicles per hour, the average speed on the roadways with shoulders is about 10 percent higher than it is on comparable roadways without shoulders. For the four-lane roadways without shoulders, speed did not decrease with an increase in volume. Conversion of the paved shoulder to an additional travel lane appears to increase the average speed by about 5 percent at volumes above 150 vehicles per hour.

Based upon these observations, the following premises have been formulated. First, the addition of full-width paved shoulders to two-lane roadways carrying more than 200 vehicles per hour will increase the average speed by at least 10 percent. Second, the conversion of a full-width paved shoulder to an additional travel lane will increase the average speed by about 5 percent on roadways carrying more than 150 vehicles per hour.

Platoon Characteristics. Motorists whose speeds are impeded by slower vehicles in front of them are actually being delayed; therefore, a roadway's platooning characteristics are an important indicator of its operational efficiency. Data from the field study was used to quantify two of these parameters - average percent of the vehicles in a platoon and average length of the platoon. A direct comparison of these variables for the three types of study highways is presented in the middle of Figure 22.

As shown in the drawing on the left-hand side of the page, increasing volumes have the most impact on the platoon characteristics of two-lane roadways. At low-volumes (1000 to 3000 vehicles per day), the number of vehicles in a platoon ranged from 2 to 7 percent. At moderate-volumes (3000 to 5000 vehciles per day), the range was from 12 to 17 percent and at high-volumes (5000 to 7000 vehicles per day), more than 18 percent of the vehicles were in a platoon. At this point, the value of this parameter on two-lane with shoulder roadways began to stabilize at about 20 percent even though it was still increasing on the two-lane without shoulder roadways. This reinforces the premise that operational benefits on two-lane with shoulder roadways are not noticeable until the volume reaches 200 vehicles per hour.

The average length of each platoon on the three types of roadways is shown in the drawing on the right-hand side of the page. As expected, the average length increased with increasing volume. Comparatively, this increase was slight on the four-lane roads and much greater on the two-lane roads. The data indicates parallel trends for both two-lane roadway types. Surprisingly, the longest platoons occurred on the with shoulder roadways. This observation was probably the result more of traffic volume than of roadway type. For this reason the average platoon length may not be a good measure for assessing the operational efficiency of the roadway. A more representative measure might be the percent change in platoon length.

Shoulder Usage. Although shoulder usage on rural highways is probably greater in Texas than in any other state, its frequency of occurrence has heretofore never been determined. Therefore, one of the primary objectives of this entire study was to quantify this variable for the three roadway types. The bottom drawing in Figure 22 illustrates the results of this effort. On the two-lane without shoulder roadways, shoulder usage consisted primarily of vehicles stopped alongside the paved surface. As shown by the lower curve, about 2 to 4 percent of the vehicles "use the shoulder" on this type of road. On the two-lane with shoulder roadways, the shoulder is used by between 5 and 13 percent of the vehicles. This rate appears to be about twice that of the without shoulder roadways. On the undivided four-lane without shoulder roadways, vehicles driving in the outside lane were considered to be using the shoulder. As shown by the upper curve, between 65 and 75 percent of the vehicles use this part of the roadway. The implications of these results are discussed in the following paragraphs.

Driving patterns on two-lane with shoulder roadways and undivided four-lane without shoulder roadways are surprisingly different. Counter to some viewpoints, the data indicates that Texas motorists do not continually drive on the shoulder, but only use it in a passing situation. In fact, at a given location, only about 5 percent of the traffic use the shoulder at all. If these same roadways are converted to four-lane roadways, the motorist will drive to the right, in the outside or "shoulder" lane. Oftentimes, this modification consists of simply restriping the roadway. If the original shoulder is not constructed to the same standard as the main lanes, the riding quality of the "outside" lane may be worse than the riding quality of the "inside" lane. Even with these conditions, Texas drivers still retain their "trained" behavior of driving in the outside lane.

Thus, motorists drive diametrically different on the two types of roadways. Only in a passing and overtaking situation, or during a slow vehicle movement do the roadways operate in the same manner. On two-lane with shoulder roadways, 95 percent of the drivers position themselves in the travel lane except when they pull onto the shoulder to let a faster vehicle "through" or to pass a left-turning vehicle. This leaves the paved shoulder available for a recovery area. On the undivided four-lane without paved shoulder roadway, more than two-thirds of the drivers position their vehicles in the outside (shoulder) lane and only leave it to pass vehicles that are in that lane. For all practical purposes, the recovery area no longer exists. These two different driving patterns are the result of prior experience and legal understanding.

Conclusions

Field measurements were made to quantify the operational characteristics on three different rural highway types - two-lane without shoulder roads, two-lane with shoulder roads and undivided four-lane without shoulder roads. Results from these studies support several conclusions concerning the operational benefits attributable to the presence or absence of a paved shoulder. Significant findings are discussed below.

As traffic volume increases, the operational benefits derived from a full-width paved shoulder increase. Although these benefits are minimal at low and moderate volumes, they are significant at volumes greater than about 200 vehicles per hour. At this point, paved shoulders appear to raise the average speed on the roadway by at least 10 percent and limit the number of vehicles that are in platoons to less than 20 percent. Surprisingly, only about 5 percent of the total traffic actually uses the shoulder at any one location.

Conversion of the shoulder to an additional travel lane offers <u>no</u> apparent operational benefits until the volume reaches about 150 vehicles per hour. On higher volume roads, this modification could be expected to increase the average speed by about 5 percent and limit the number of vehicles that are in a platoon to less than 5 percent. Significantly, this conversion results in more than two-thirds of the traffic using the outside or "shoulder" lane.

CHAPTER V. CONCLUSIONS AND RECOMMENDATIONS

Paved shoulders in Texas apparently are used by many motorists for making a large variety of traffic maneuvers and satisfying numerous driving task demands. Texas motorists commonly pull onto the paved shoulders of rural two-lane highways at relatively high speeds as a courteous gesture to let faster vehicles pass them. Paved shoulders may also be used by through traffic to bypass left-turners at driveways or non-channelized intersections. Furthermore, they are sometimes used as an auxiliary lane by some road users. While motorists are apparently benefiting from these maneuvers, there has been little documentation as to the types and frequency of shoulder usage and the impacts and conditions under which they occur. The goal of this study was to quantify benefits and/or disbenefits associated with shoulder usage in the state of Texas. Significant findings of this research are presented in the following paragraphs.

SDHPT Questionnaire. In order to gain additional insight and credible information regarding field experience with driving on full-width paved shoulders, the SDHPT district offices were surveyed by a combination questionnaire and personal interview technique. Highway design, traffic operations and roadway maintenance personnel, from 23 of the districts, provided shoulder usage information on intended functions, operational and safety problems, field experience and relative benefits. Although much useful data were obtained, there was a wide range of answers for many of the questions. The most common responses are as follows:

- Intended Function - Accommodation for emergency stops.
- Operational Problems - Shoulder usage as a passing lane (passing on right).

- Safety Problems - Shoulder usage near narrow bridges.
- Field Experience - Most drivers will use a paved shoulder.

Laboratory Study. It was anticipated that Texas motorists were not aware of the legal aspects involved with driving on paved shoulders. As a result, a laboratory study was designed to test their understanding of these issues. In addition, the study investigated driver preferences for and experiences with shoulder usage. The same basic study was used to ascertain DPS patrolmen's interpretation of the legal issues involved and their observations of shoulder usage throughout the state. Ninety-six "average" drivers and ninety-one law enforcement officers participated in the study. The most significant findings are as follows:

- Texas drivers perceive a difference between using a paved shoulder to pass vehicles turning left into a driveway and using the same shoulder to pass vehicles turning left at an intersection.
- Both the general public and the DPS patrolmen seem certain it is legal to pass someone that is driving on the shoulder; however, the motorists are uncertain whether it is legal for someone to simply drive on the paved shoulder or whether it is a legal requirement to pull onto the paved shoulder to let a faster vehicle pass.
- Texas drivers and DPS patrolmen seem certain that to use the shoulder to pass non-turning vehicles on the right is dangerous and should not be legal.

Safety Effects. Two separate accident investigations were conducted as a portion of this research. Their objective was to determine the safety effects of paved shoulders on three types of rural Texas highways. The initial investigation was an analysis of accident rates, patterns and characteristics on roadways with and without paved shoulders. The second was a before and after study to determine the change in safety characteristics caused by the addition of paved shoulders to a two-lane road, or by the conversion of paved shoulders to additional travel lanes. The most significant results from these analyses are as follows:

- The accident rate for each roadway type increases as the volume increases.

- Two-lane highways without paved shoulders have the highest accident rates and are most sensitive to changes in traffic volume.

- Two-lane highways with paved shoulders have the lowest accident rates for the volumes in this study (1000 to 7000 vehicles per day).

- "Poor-boy" roadways have an accident rate in between the other two types of roads and are the least sensitive to volume.

- An extension of the data points indicates that two-lane highways with paved shoulders have lower accident rates than poor-boy highways at all volume levels below 7500 vehicles per day.

- Construction of full-width paved shoulders at rural intersections may be effective in reducing the number of accidents on high-volume roadways.

- The addition of full-width paved shoulders to a two-lane roadway is effective in reducing the total number of accidents that occur.

- Conversion of a shoulder to an additional travel lane results in fewer total accidents only if the volume is greater than 3000 vehicles per day.

- "Poor-boy" roadways have an unusually high nighttime accident rate.

Operational Effects. Field measurements were made to quantify the operational characteristics on three types of rural Texas highways - two-lane without shoulder roads, two-lane with shoulder roads and undivided four-lane without shoulder roads. Data were collected and analyzed for over 21,000 vehicles. Results from these studies support several conclusions concerning the operational benefits attributable to the presence or absence of a paved shoulder. Significant findings are as follows:

- The operational benefits derived from a full-width paved shoulder increase as the volume increases.

- These benefits are minimal at low and moderate volumes; however, at volumes greater than 200 vehicles per hour, a paved shoulder will increase the speed on the roadway by at least 10 percent.

- At any one location, only about 5 percent of the traffic actually use the shoulder.

- Conversion of the shoulder to an additional travel lane offers no apparent operational benefits until the volume reaches about 150 vehicles per hour.

- Such a conversion will result in more than two-thirds of the traffic using the outside or "shoulder" lane.

Recommendations. The results from this study can be used to make several policy and procedure recommendations concerning shoulder usage in the State of Texas. In addition several potential problem areas were identified. Specific recommendations are as follows:

- A paved shoulder should not be considered a part of the roadway.

- It should be legal for motorists to drive on a paved shoulder unless signs or markings prohibit such a maneuver or it is unsafe to do so.

- It should be legal to pass someone that is driving on the shoulder.

- It should be legal for a motorist to pull onto the paved shoulder in order to let faster vehicles pass; however, it should not be a requirement.

- It should not be legal to use the shoulder to pass a non-turning vehicle on the right.

- Paved shoulders should probably be added to all two-lane roads with traffic volumes in excess of 200 vehicles per hour.

- The conversion of a paved shoulder to an additional travel lane probably should not be considered unless the volume on the roadway exceeds 3000 vehicles per day.

- Evaluate the potential safety improvements resulting from the addition of full-width paved shoulders at major intersections on two-lane roads without shoulders.

- Evaluate the potential nighttime safety improvements resulting from improved edge line delineation systems on "poor-boy" highways.

ACKNOWLEDGEMENTS

The research reported herein was performed within the research project "Operational Effects of Driving on Paved Shoulders" by the Texas Transportation Institute and sponsored by the Texas State Department of Highways and Public Transportation in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

The authors wish to thank Mr. Ernest W. Kanak of D-18T, Mr. John F. Nixon of D-10R and Mr. Harold D. Cooner of D-8 of the Texas State Department of Highways and Public Transportation and Mr. Ted Miller of the Federal Highway Administration for their technical inputs and constructive suggestions throughout the duration of this project. A special thanks is extended to Inspector Glenn E. Simmons and Captain Dudley M. Thomas of the Texas Department of Public Safety. The assistance of Messrs. Carroll J. Messer, Thomas E. Kessler, Steven R. Bartlett, David M. Petty and the secretarial staff of the Traffic Operations Program of the Texas Transportation Institute is also gratefully acknowledged.

REFERENCES

1. A Policy on Geometric Design of Rural Highways. American Association of State Highway Officials, Washington, D.C., 1965.

2. Rowan, N.J. "A Survey on Shoulder Design and Operation Practices." Highway Research Circular No. 142, April, 1973, pp. 1-2.

3. Portigo, J.M. "State-of-the-Art Review of Paved Shoulders." Transportation Research Record 594, 1976, pp. 57-64.

4. "Design and Use of Highway Shoulders." National Cooperative Highway Research Program - Synthesis of Highway Practice 63, August, 1979.

5. Gordon, D.A. "Studies of the Road Marking Code." Federal Highway Administration - FHWA-RD-76-59, April, 1976.

6. Manual on Uniform Traffic Control Devices for Streets and Highways - 1978. Federal Highway Administration, Washington, D.C., 1978.

7. "Texas Motor Vehicle Laws: 1977-1978." Texas Department of Public Safety, Austin, Texas, 1977.

8. Uniform Vehicle Code and Model Traffic Ordinance: Revised - 1968. National Committee on Uniform Traffic Laws and Ordinances, Washington, D.C., 1968.

9. Belmont, D.M., "Effects of Shoulder Width on Accidents on Two-Lane Tangents." Highway Research Board Bulletin 91, 1954, pp. 29-32.

10. Belmont, D.M., "Accidents Versus Width of Paved Shoulders on California Two-Lane Tangents - 1951 and 1952." Highway Research Board Bulleting 117, 1956, pp. 1-16.

11. Blensy, R.C. and Head, J.A., "Statistical Determination of Effect of Paved Shoulder Width on Traffic Accident Frequency." Highway Research Board Proceedings - Volume 36, 1957.

12. Raff, M.S., "Interstate-Highway Accident Study," Highway Research Board Bulletin 74, 1953, pp. 18-45.

13. Perkins, E.T., "Relationship of Accident Rate to Highway Shoulder Width," Highway Research Board Bulletin 151, 1957, pp. 13-14.

14. Woo, J.C.H., "Correlation of Accident Rates and Roadway Factors." Joint Highway Research Project C-36-59C. Purdue University, Lafayette, Indiana, July, 1957.

15. Stohner, W.R., "Relations of Highway Accidents to Shoulder Width on Two-Lane Rural Highway in New York State." Highway Research Board Proceedings - Volume 35, 1956.

16. Billion, C.E. and Stohner, W.R., "A Detailed Study of Accidents as Related to Highway Shoulders in New York State," Highway Research Board Proceedings - Volume 36, 1957.

17. Sinclair, Wright and Partners, Ltd., "A Review of Road Design in Relation to Road Safety," Australian Department of Transport Report #NR/11, October 1971.

18. Jorgenson, R.E. and Associates, "Cost and Safety Effectiveness of Highway Design Elements." National Cooperative Highway Research Program Report 197, Washington, DC, 1978.

19. Rinde, E.A., "Accident Rates Vs. Shoulder Widths." California Department of Transportation Report CA-DOT-TR-3147-1-77-01, September, 1977.

20. Heimbach, C.L., Hunter, W.W., and Chao, G.C., "Paved Highway Shoulders and Accident Experience." Transportation Engineering Journal of ASCE, Vol. 100, No. TE4, November 1974, pp. 889-908.

21. Shannon, P. and Stanley, A., "Pavement Width Standards for Rural Two-Lane Highways," Idaho Transportaion Department, Research Project 80, December 1976.

22. Davis, D.I., "Shoulder Improvements on Two-Lane Roads," Transportation Research Record 737, 1979, pp. 59-60.

23. Zegeer, C.V. and Mayes, J.G., "Cost-Effectiveness of Lane and Shoulder Widening on Rural, Two-Lane Roads in Kentucky," Department of Transportation, Commonwealth of Kentucky, Research Report 999, 1979.

24. Pignataro, L.J., "Traffic Engineering: Theory and Practice," Prentice-Hall, Inc., Englewood Cliffs, N.J. 1973. p. 281.

25. Jorgensen, Roy and Assoc., "Evaluation of Criteria for Safety Improvements on the Highway," 1966.

26. Gwynn, D.W., "Accident Rates and Control of Access." Traffic Engineering, November, 1966.

27. Solomon, D., "Accidents on Main Rural Highways Related to Speed, Driver, and Vehicle," Bureau of Public Roads, U.S. Department of Commerce, 1964.

APPENDIX A

SDHPT Questionnaire

Cover Letter and Survey Form

TEXAS A&M UNIVERSITY
TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION TEXAS 77843

Transportation Systems Division

May 25, 1979

Dear Sir:

The Texas Transportation Institute in cooperation with the State Department of Highways and Public Transportation is conducting research to study the effects (both good and bad) of motorists driving on paved shoulders. Texas driving practices with regard to paved shoulder usage are relatively unique. The general courteous driving habits of Texas motorists have promoted the idea that a slower driver should pull over to allow faster vehicles to pass. Extensive high-type rural highway design standards using 8-10 foot paved shoulders have provided a wide pavement surface for this maneuver. As road users are apparently benefitting from this type of operation, there has been little research on how, when, where and why Texas motorists should be allowed to drive on the paved shoulders of rural highways.

In order to provide additional insight and credible information regarding field experience with shoulder usage, the research staff has prepared a short survey form for each district to fill out and return to us. The survey addresses design, operations and maintenance issues. All results will be summarized on a statewide, rather than a district-by-district basis. Your assistance in providing us with this information is appreciated.

As a follow-up to this survey, we will interview several districts either by personal visit or telephone, primarily to locate field sites suitable for further study. It would be helpful if you would indicate the appropriate person in your district to contact for this interview.

In addition, we will be visiting Department of Public Safety field offices to ascertain additional information concerning shoulder usage, safety problems and enforcement practices.

Should any questions arise, please feel free to contact me by phone at (713) 845-1717 or 857-1717 (TEXAN). Thanks for your time and cooperation.

Sincerely,

Dan Fambro

Daniel B. Fambro
Engineering Research Associate

DBF/kk

Enclosure

A SURVEY ON THE EFFECTS OF
DRIVING ON PAVED SHOULDERS

1. In your district, what are the intended functions of a full width (8-10 ft.) paved shoulder on rural two-lane highways? Check (✓) one.

Intended Function	Observed Usage: Never	Sometimes	Frequently
a. Accomodations for emergency stops;	____	____	____
b. Parking of disabled vehicles;	____	____	____
c. Climbing lane on hills;	____	____	____
d. Travel lane for school buses;	____	____	____
e. Travel lane for mail carriers;	____	____	____
f. Travel lane for farm vehicles;	____	____	____
g. Travel lane for bicycles and/or hikers;	____	____	____
h. Extra lane for added capacity;	____	____	____
i. Temporary use during maintenance, construction or emergencies;	____	____	____
j. Room for slower vehicles to permit passing manuevers;	____	____	____
k. Other. Please explain.	____	____	____

2. What, if any, operational problems result with full width paved shoulders on two-lane rural highways in your district?

3. How are the paved shoulders on rural two-lane highways in your district delineated from the main lanes?

	Never	Sometimes	Frequently
a. No distinction;	____	____	____
b. Contrasting color;	____	____	____
c. Edge lines;	____	____	____
d. Different textures;	____	____	____
e. Raised pavement markings;	____	____	____
f. Jiggle bars;	____	____	____

g. Other. Please list.

4. Based on your experience, indicate whether the following drivers would pull onto a full width paved shoulder on a two-lane rural highway in your district to let a faster vehicle pass.

	Never	Sometimes	Frequently
a. Texas drivers;	____	____	____
b. Out-of-state drivers;	____	____	____
c. Passenger car drivers;	____	____	____
d. Truck drivers;	____	____	____
e. School bus drivers;	____	____	____
f. Farm equipment drivers.	____	____	____

Are there locations in your district where this type of shoulder usage by vehicular traffic is discouraged? If so, where and why was it done and how was it accomplished?

Are there locations in your district where this type of shoulder usage is known to exist and seems to work well? If so, list several of the locations.

5. In your district, how frequently are safety problems associated with driving on the paved shoulder of rural two-lane highways at the following locations?

	Never	Sometimes	Frequently
a. Intersections;	____	_______	_______
b. Driveways;	____	_______	_______
c. Hills;	____	_______	_______
d. Curves;	____	_______	_______
e. Bridges;	____	_______	_______
f. Other. Please list.			

6. What factors create maintenance problems for paved shoulders on rural two-lane highways in your area? Rank the following factors on a scale of 1 to 10 (1 is no problem and 10 is a big problem).

	Rank
a. Rain;	____
b. Freeze-thaw;	____
c. Truck traffic;	____
d. Initial construction;	____
e. Other. Please list.	

7. Do paved shoulders on two-lane rural highways have the same priorities as the rest of the highway for maintenance dollars? Rank the priority for maintenance dollars of the following highway parts on a scale of 1 to 10 (1 is low priority and 10 is high priority).

	Rank
a. Mainlanes;	____
b. Shoulders;	____
c. Sideslope;	____
d. Traffic control devices;	____
e. Other. Please list	____

APPENDIX B

Laboratory Studies
Questionnaires, Scripts and Slides

THE TEXAS A&M UNIVERSITY SYSTEM
TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION TEXAS 77843

Transportation Systems Division

Area Code 713
Telephone 845-1727

Project 2265

Driver Questionnaire

1. Age: ______

2. Sex: ______

3. Circle the highest educational level you have completed:

Elem. School					Junior High			High School				College				Graduate School	
1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	1	2

4. How many years have you been driving? ______________________

5. About how many miles per year do you usually drive? ___________

6. Please estimate what percent of your total driving time is spent in the following environments (figures should add to 100%):

   a. Rural __________

   b. Small City __________

   c. Large City __________

Lab. No. 2 - PAVED SHOULDERS

T.A. ____________________ Date: ____________________

L.S. ____________________ Time: ____________________

No = 1 Don't Know = 3 Yes = 5

Question Number	Subject Number				
	1	2	3	4	5
1.1					
1.2					
1.3					
1.4					
1.5					
2.1					
2.2					
2.3					
2.4					
3.1					
3.2					
3.3					
3.4					
4.1					
4.2					
4.3					
4.4					
4.5					
4.6					
4.7					
5.1					
5.2					
5.3					
5.4					
5.5					
6.1					
6.2					
6.3					
6.4					
6.5					

Lab. No. 2 - PAVED SHOULDERS, continued

No = 1 Don't Know = 3 Yes = 5

Question Number	Subject Number				
	1	2	3	4	5
7.1					
7.2					
7.3					
7.4					
7.5					
7.6					
7.7					
7.8					
7.9					
7.10					
7.11					
7.12					
7.13					
7.14					
7.15					
7.16					
7.17					
7.18					
8.1					
8.2					
8.3					
8.4					
9.1					
9.2					
9.3					
9.4					
9.5					
10.1					
10.2					
10.3					

LABORATORY NO. 2 - GENERAL PUBLIC'S EXPERIENCE WITH, PREFERENCE FOR AND UNDERSTANDING OF PAVED SHOULDER USAGE

(Slide 1)

Introduction

This laboratory study is considerably different from the previous one. We will be studying mostly 2-lane rural highways and asking questions about your experiences and observations of driver behavior that primarily occurs only on Texas highways.

(Slide 2)

Texas drivers have been observed to drive on the paved shoulders of rural highways, perhaps due to the general courteous driving habits of Texas motorists. There may be both advantages and disadvantages of this driving practice. We would like to obtain your driving experiences and opinions about this issue.

You will be shown a series of driving situations. We want you to give us your answers to questions such as these:

"Have you ever made this driving maneuver before?"

"Do you think it is dangerous to drive like this?"

"Do you think the other driver will remain in his lane?"

(Slide 3)

Answers

Most of our questions can be answered by pushing one of three buttons on the recording unit in front of you.

This slide shows the three possible answers:

"No"	"Don't Know"	"Yes"

Please push the button for your answer as soon as you have made your decision.

We recognize that we will be asking you to guess, judge and give opinions about the future and you may be somewhat uncertain or not very confident about your answers. Don't worry about these problems. Just give us your opinion or initial reaction to the situation.

To illustrate how we will interpret your answers, please consider the following guidelines when selecting either "Yes", "No" or "Don't Know" as an answer:

Yes - Includes:	Always, usually, or probably yes, etc.
No - Includes:	Never, not likely, or probably not, etc.
Don't Know - Means:	No previous driving experience with this situation, or no basis for a decision.

In the process of deciding on your answer, try to determine if the situation is more of one than the other. Please do not consider "Don't Know" to mean "Sometimes Yes, Sometimes No."

(Slide 4)

SUMMARY

Again, this is a study of your driving experiences and observations made only on rural Texas highways. While you may not always be certain of your answer, we do want to know your opinion, or what you think would happen.

QUESTIONS ?

Are there any questions?

(Slide 5 Blank)

SCENARIO NO. 1

(Slide 6)

You are driving along a rural, two-lane highway in Texas and are overtaking a car that is about to make a left turn into a driveway.

(Slides 7, 8)

Hopefully, these slides illustrate this idea. While the slides do not show it well, the blue car was initially traveling 55 M.P.H., was signaling to turn left, and is slowing to a stop before turning left into the driveway. (Point out driveway.)

Does everyone understand the traffic situation?

QUESTIONS

1.1 Would you pass this car on the right side by driving on the paved shoulder?

1.2 If the white strip were not present, would you pass the car on the right side by driving on the paved shoulder?

1.3 Have you ever passed a left turning vehicle on the right side by driving on the paved shoulder?

1.4 Have you ever been making a left turn and been passed on the right by another vehicle driving on paved shoulder?

(Slide 9)

1.5 Do you think passing a left turning vehicle on the right by driving on the paved shoulder is dangerous?

(Slide 10-Blank)

SCENARIO NO. 2

(Slide 11)

We would like to point out some of the limitations and problems with our slides before continuing on with the laboratory. Vehicles shown in the highway and shoulder are always traveling at a reasonable speed, or the speed noted, even though they appear to be stopped in the slides. The car you are driving is usually not shown in the slide even though most of the photos were taken through the windshield using a telephoto lens. Distant hills appear much closer than they really are.

Are there any questions? If not, let's continue.

Assume you are driving along a Texas highway and observe a car traveling 50 M.P.H. along a paved shoulder. You are driving faster, and continue to catch up to the car driving on the shoulder.

(Slide 12, 13)

QUESTIONS

2.1 Would you drive past this vehicle without crossing the centerline of the highway?

2.2 Have you ever passed a vehicle like this before?

2.3 Have you ever driven along a paved shoulder for a considerable distance and had vehicles pass you without crossing the centerline of the highway?

2.4 Do you think passing a vehicle driving 50 M.P.H. along a paved shoulder is dangerous?

(Slide 14-Blank)

SCENARIO NO.3

(Slide 15)

Suppose a slow moving vehicle is traveling 20 M.P.H. along the paved shoulder of a Texas highway where many driveways are present. (Point out slow moving vehicle is pickup).

QUESTIONS

3.1 Would you drive past the pickup without crossing the centerline of the highway?

3.2 Have you ever passed a slow-moving vehicle which was driving on the paved shoulder?

3.3 Have you ever driven slowly along the paved shoulder and been passed by another vehicle?

3.4 Do you think passing a slow moving vehicle which is driving along a paved shoulder like this is dangerous?

(Slide 16-Blank)

SCENARIO NO.4

(Slide 17)

You are overtaking another car that is traveling 50 M.P.H. on a rural Texas highway.

(Slide 18)

QUESTIONS

4.1 Would you expect to pass this car by crossing onto the left side of the highway when it is safe to do so?

4.2 Do you think the car ahead of you will pull over onto the paved shoulder to allow you to drive past?

4.3 Do you think the car ahead of you should pull onto the paved shoulder to allow you to drive past?

4.4 Have you ever had a car ahead of you to pull over onto the paved shoulder so that you could drive past?

4.5 Have you ever pulled over onto the paved shoulder while driving a Texas highway to allow another car to pass you?

4.6 Do you think it is dangerous for a driver to pull over onto a shoulder like this one and for you to pass him without crossing the centerline of the highway?

(Slide 21)

4.7 Do you think you would be more likely to pull onto the shoulder if no edgeline or contrasting shoulder was present?

(Slide 22-Blank)

SCENARIO NO. 5

(Slide 23)

You are overtaking a slower moving vehicle that is about to make a left turn at an intersection with another state highway. (Point out intersection).

(Slide 24, 25)

QUESTIONS

5.1 Would you slow down and wait in your lane for the vehicle to turn left before driving on?

5.2 Would you pass the vehicle on the right by driving on the paved shoulder?

5.3 Have you ever passed a vehicle on the right side by driving on the paved shoulder?

5.4 Have you ever been making a left turn at an intersection and been passed on the right by another vehicle driving on the paved shoulder?

5.5 Do you think passing a vehicle on the right like this is dangerous?

(Slide 27-Blank)

SCENARIO NO. 6

(Slide 28)

You are being overtaken by a large truck.

(Slide 29, 30)

QUESTIONS

6.1 Would you maintain your present speed and lane position so that the truck would have to pass you by crossing onto the other side of the road?

6.2 Would you pull onto the paved shoulder to allow the truck to drive past you?

(Slide 31)

6.3 Have you ever pulled onto the paved shoulder to allow a large truck to pass you?

6.4 Do you think it is dangerous to pull onto the paved shoulder to allow a large truck to pass?

6.5 Do you think it is more dangerous to remain in your thru lane than it is to pull onto the paved shoulder?

(Slide 32-Blank)

Stop For Break

SCENARIO NO. 7

(Slide 33)

You will be shown a series of traffic passing situations each presented by a single slide. We want you to judge: (1) the legality of passing the vehicle shown without crossing the centerline of the highway, (2) the legality of the vehicle driving on the paved shoulder, and (3) the desirability of the maneuver. Please consider the fact that sometimes edgeline paint markings or contrasting color materials are used; sometimes they are not.

Examples of some typical painted edgeline markings and shoulder pavements are shown in the following slides.

(Point out edgeline and no contrasting shoulder).

(Slide 34)

(Point out edgeline with contrasting shoulder).

(Slide 35)

(Point out no edgeline with contrasting shoulder).

(Slide 36)

(Point out no edgeline and no contrasting shoulder).

Again, all vehicles in the slides are traveling at reasonable speeds. The speed of the vehicle on the shoulder is about 50 M.P.H.

(Slide 37-Blank)

QUESTIONS (REPEAT "DO YOU THINK IT...)

(Slide 38)

7.1 is legal for you to pass this vehicle without crossing the centerline?

7.2 is legal for the motorist to be driving on the paved shoulder?

7.3 is legally a requirement in this situation that the slower traveling vehicle pull onto the paved shoulder to permit a faster vehicle to pass?

(Slide 39)

7.4 is legal for you to pass this vehicle without crossing the centerline?

7.5 is legal for the motorist to be driving on the paved shoulder?

7.6 is legally a requirement in this situation that the slower traveling vehicle pull onto the paved shoulder to permit a faster vehicle to pass?

(Slide 40)

7.7 is legal for you to pass this vehicle without crossing the centerline?

7.8 is legal for the motorist to be driving on the paved shoulder?

7.9 is legally a requirement in this situation that the slower traveling vehicle pull onto the paved shoulder to permit a faster vehicle to pass?

(Slide 41)

7.10 is legal for you to pass this vehicle without crossing the centerline?

7.11 is legal for the motorist to be driving on the paved shoulder?

7.12 is legally a requirement in this situation that the slower traveling vehicle pull onto the paved shoulder to permit a faster vehicle to pass?

(Slide 42)

7.13 is legal to pass the school bus driving along the shoulder as shown?

7.14 is legal for the bus driver to be driving along the shoulder?

7.15 is legally a requirement in this situation that the school bus drive on the shoulder if it is traveling slower than following vehicles?

(Slide 43)

7.16 is legal for you to pass the blue car without crossing the centerline?

7.17 is legal for the motorist to be driving on the paved shoulder?

7.18 is legally a requirement in this situation that the slower traveling vehicle pull onto the paved shoulder to permit a faster vehicle to pass?

(Slide 44-Blank)

SCENARIO NO. 8

(Slide 45)

The following single slide situations consider the legal questions of passing vehicles on the right.

QUESTIONS

8.1 The vehicle is about to turn left into a private driveway. (Point out driveway). Do you think it is legal to pass it on the right by driving on the paved shoulder?

(Slide 46)

8.2 The vehicle is about to make a left turn at an intersection. Do you think it is legal to pass this vehicle by driving in the right lane?

(Slide 47)

8.3 The vehicle is about to make a left turn at an intersection. Do you think it is legal to pass this vehicle on the right by driving on the paved shoulder?

(Slide 48)

8.4 This vehicle is just driving along a 4-lane highway. Do you think it is legal to pass it on the right by using the right lane?

(Slide 49-Blank)

SCENARIO NO.9

(Slide 50)

The following driving practice of Texas motorists on paved shoulders is significantly different from the previous cases. It is very important that you notice the difference from our slides.

The following slides will show the truck on the shoulder passing the truck traveling 50 M.P.H. on the main lanes of the highway. That is, the driver passes on the right rather than on the left side of the highway. On this particular road, many cars were observed to pass the same way.

(Slides 51, 52)

Did you notice the way the pass was made?

QUESTIONS

9.1 Have you ever passed another car traveling along the highway by driving on the right shoulder like the truck did in the slides?

9.2 Have you ever been passed on the right shoulder while traveling along the highway at normal speeds?

9.3 Is it dangerous to pass another vehicle by using the right shoulder like this?

9.4 Do you think it is legal to pass another vehicle by using the right shoulder like this?

9.5 Do you think it should be legal to pass a vehicle that is traveling on a rural two-lane highway by passing it on the right shoulder?

(Slide 53-Blank)

SCENARIO NO. 10

(Slide 54)

You will be asked to judge the relative safety of several sets of passing maneuvers. Each set will contain two slides on the same section of highway. Slide No. 1 always will be "passing a vehicle traveling 50 M.P.H. on the left of centerline." Slide No. 2 will be "a shoulder passing situation." Both slides will be shown once. An answer will then be requested.

The issue is: "Which of the two passing situations do you think is safer for everybody concerned?" (Slide No. 1 or Slide No.2). Answer by pushing Button No.1 if you think Slide No. 1 is safer (That is, passing on the left side of the roadway); push Button No. 2 if you think the shoulder passing maneuver is safer. Again, the question is "Which is safer for all motorists involved?"

Any questions?

QUESTIONS

(Slide 55)

This is Slide No. 1. (Point out that there is plenty of passing distance before the next hill and no vehicles are approaching from the far hill even though it may look like it. Disregard the short no-passing zone in the wrong direction. The white car to be passed on the left is traveling 50 M.P.H.).

(Slide 56)

This is Slide No. 2. (Point out that one should disregard any gravel or other debris that you may see on the paved shoulder. The white car to be passed without crossing the centerline is traveling 50 M.P.H.).

(Slide 57-Blank)

10.1 Which slide do you think presented an overall safer passing situation for all motorists involved including yourself?

(Slide 58)

This is Slide No. 1. (Point out that you are traveling on a slight upgrade section of highway where considerable passing distance exist but where some mirage effects are occurring. Sight distances are still very long on the whole. The white car to be passed on the left is traveling 50 M.P.H.).

(Slide 59)

This is Slide No. 2. (Point out that the car to be passed without crossing the centerline is traveling 50 M.P.H.).

(Slide 60-Blank)

10.2 Which slide do you think presented an overall safer passing situation for all motorists involved, including yourself: Slide No. 1 or Slide No. 2?

(Slide 61)

This is Slide No. 1. (Point out that the brown van is passing the blue van on a high volume rural highway).

(Slide 62)

This is Slide No. 2. (Point out that the small blue car is passing the brown van by using the right shoulder on the same high volume rural highway).

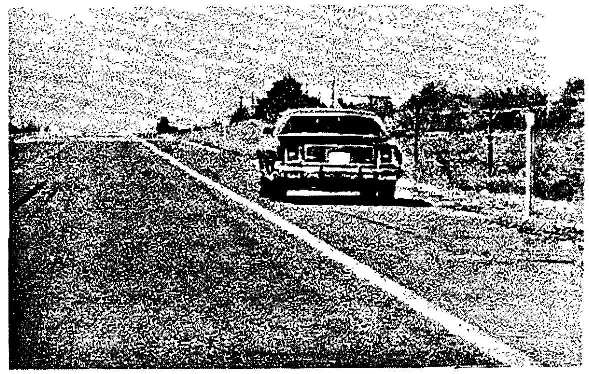
(Slide 63-Blank)

10.3 Which slide do you think presented an overall safer passing situation for all motorists involved? Slide No. 1 or Slide No. 2?

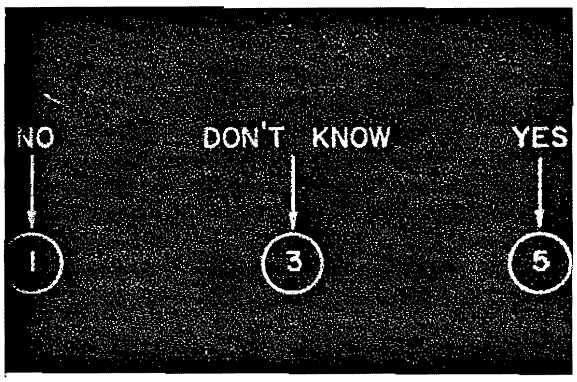
(Slide 64)

Thank you for participating in the lab.

Slide No. 1



Slide No. 2



Slide No. 3

Slide No. 4

Figure B-1. Introductory Slides

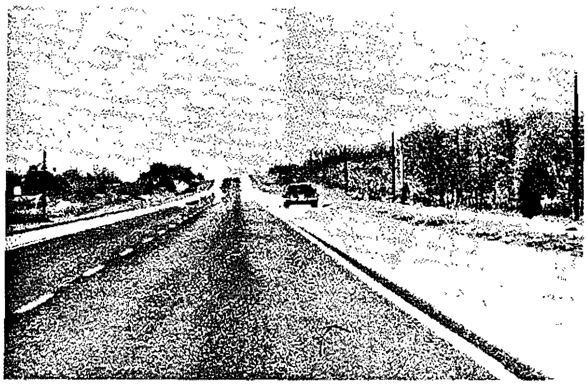
Slide No. 6

Slide No. 7

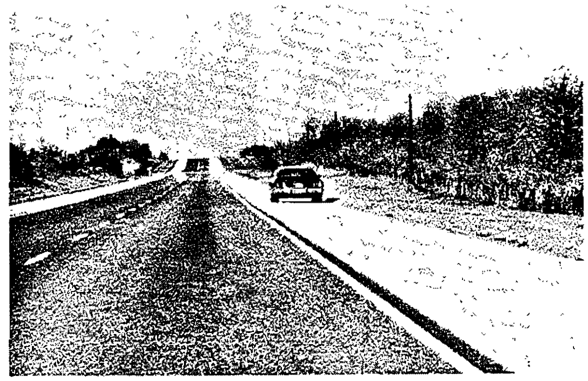
Slide No. 8

Slide No. 9

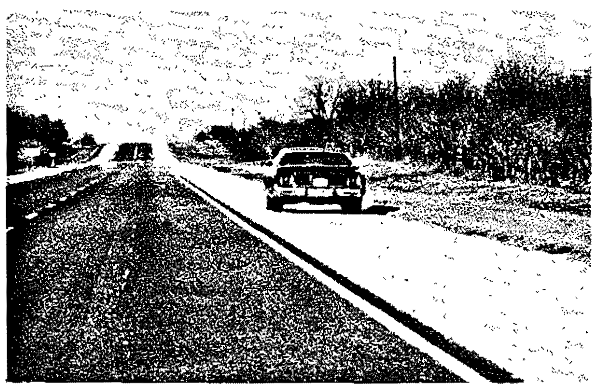
Figure B-2. Scenario No. 1 - Pass Using Shoulder
A Vehicle Slowing to Turn Left into a Driveway



Slide No. 11



Slide No. 12



Slide No. 13

Figure B-3. Scenario No. 2 - Pass Without Crossing Center Line
A Vehicle Driving 50 MPH on Shoulder

Slide No. 15

Figure B-4. Scenario No. 3 - Pass Without Crossing Center Line
A Pickup Driving 20 MPH on Shoulder

Slide No. 17

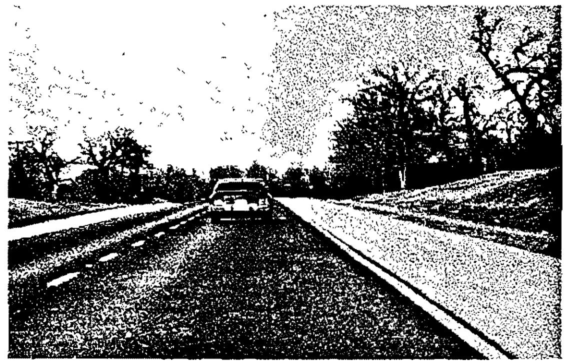
Slide No. 18

Slide No. 19

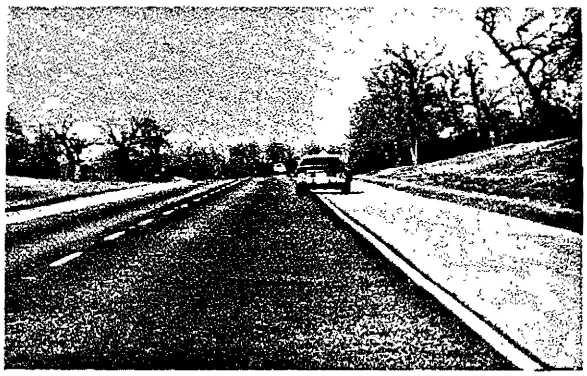
Slide No. 20

Figure B-5. Scenario No. 4 - Pass Using Shoulder
A Vehicle Slowing to Turn Left into an Intersection

Slide No. 22



Slide No. 23



Slide No. 24

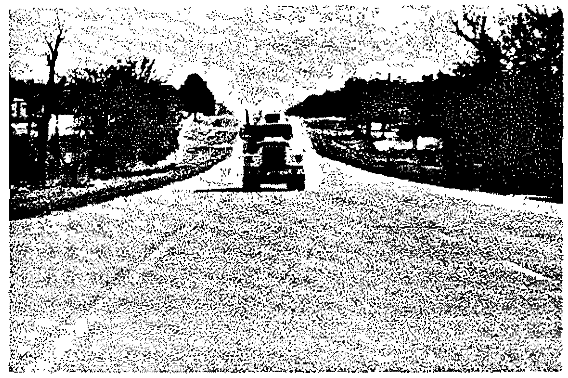
Slide No. 25

Slide No. 26

Figure B-6. Scenario No. 5 - Pass by Crossing Center Line

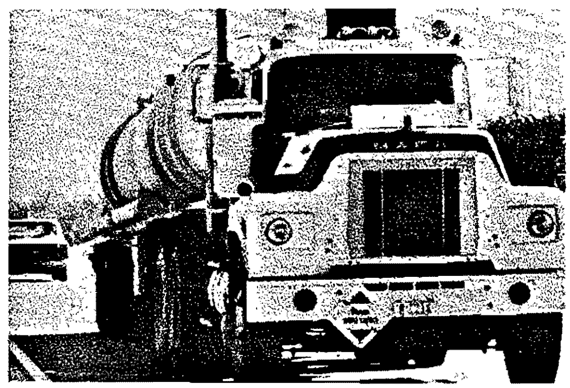
A Vehicle Driving 50 MPH in a Lane

Slide No. 28



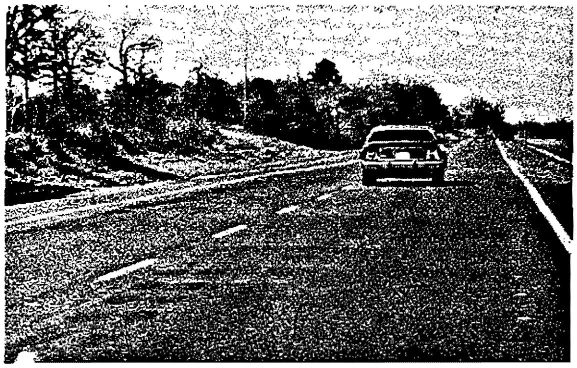
Slide No. 29

Slide No. 30



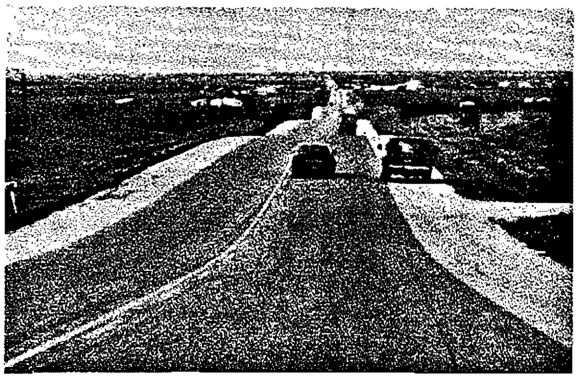
Slide No. 31

Figure B-7. Scenario No. 6 - Pull Onto Shoulder to Let a Large Truck Pass



Slide No. 33 - No Contrast Edgeline

Slide No. 34 - Contrast Edgeline

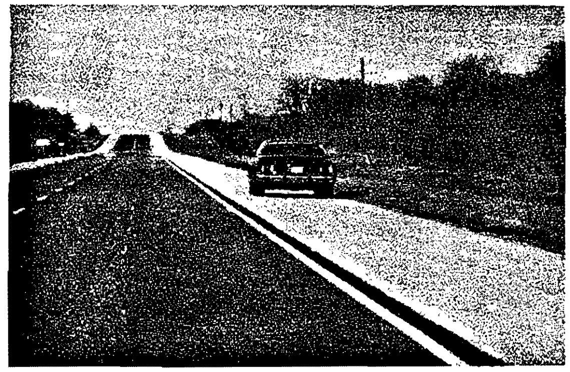


Slide No. 35 - Contrast No Edgeline

Slide No. 36 - No Contrast No Edgeline

Figure B-8. Scenario No. 7 - Examples of Some Typical Painted Edgeline Markings and Shoulder Pavements

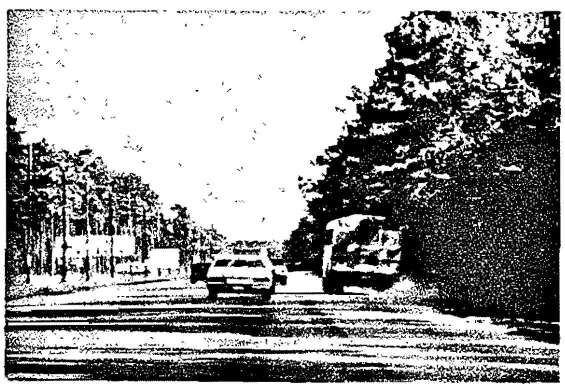
Slide No. 38 - No Contrast No Edgeline



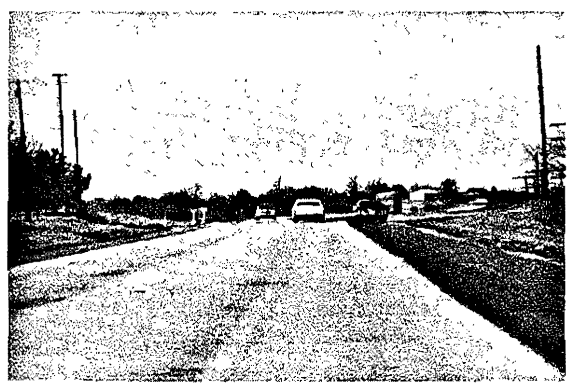
Slide No. 39 - Contrast Edgeline

Slide No. 40 - Truck on Shoulder

Slide No. 41 - No Contrast Edgeline



Slide No. 42 - Bus on Shoulder

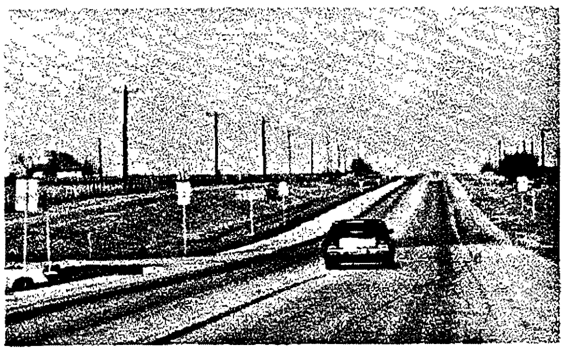


Slide No. 43 - Contrast No Edgeline

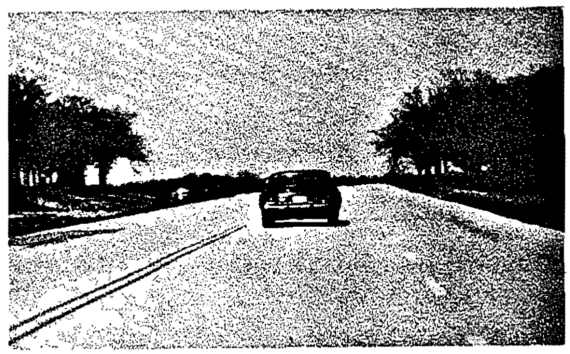
Figure B-9. Scenario No. 7 - Legality Questions

Slide No. 45

Slide No. 46

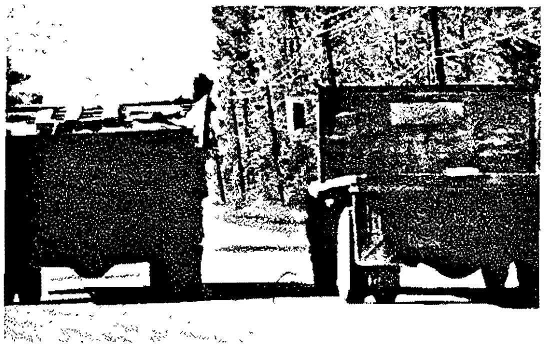


Slide No. 47

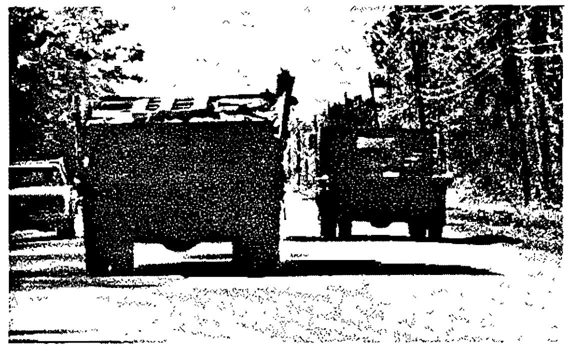


Slide No. 48

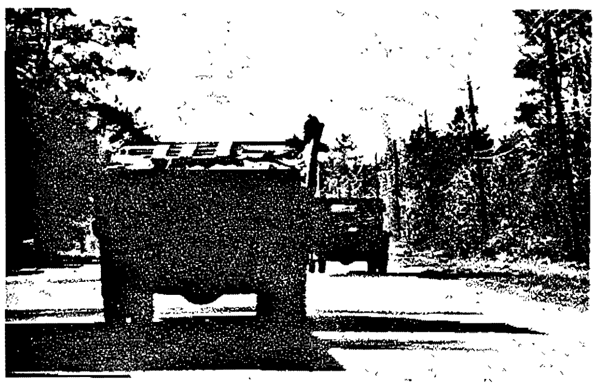
Figure B-10. Scenario No. 8 - Legality of Passing on the Right



Slide No. 50



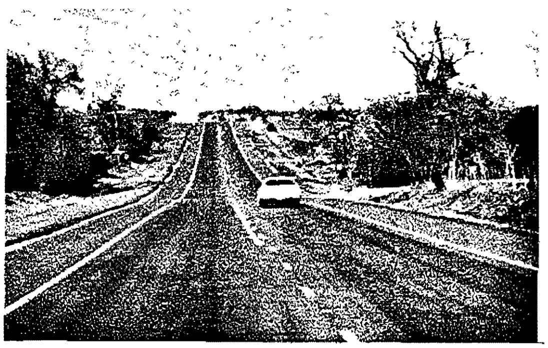
Slide No. 51



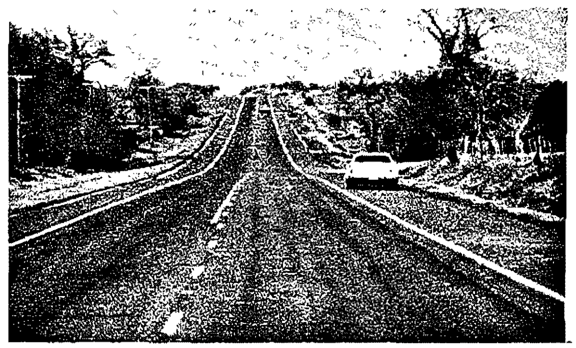
Slide No. 52

Figure B-11. Scenario No. 9 - Pass Using Shoulder
A Vehicle Driving 50 MPH in the Traffic Lane

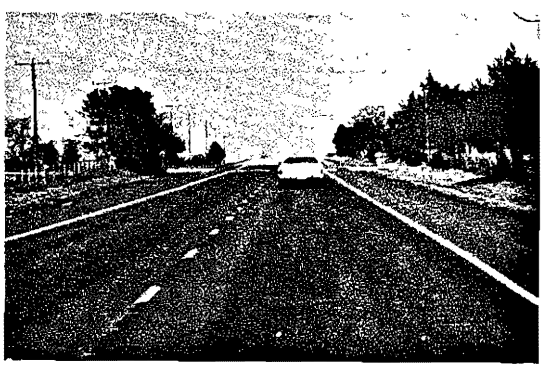
Slide No. 54



Slide No. 55



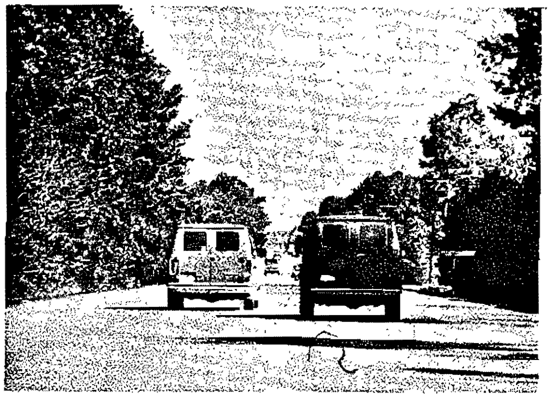
Slide No. 56



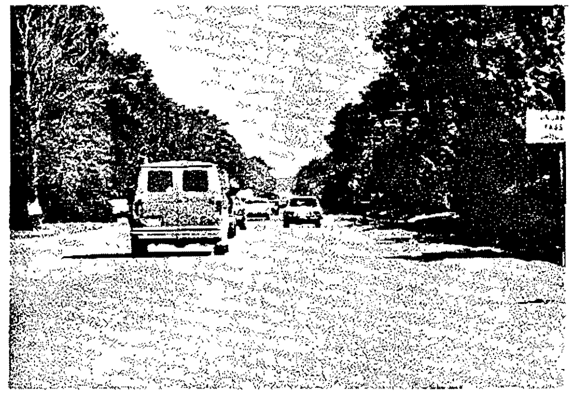
Slide No. 58

Slide No. 59

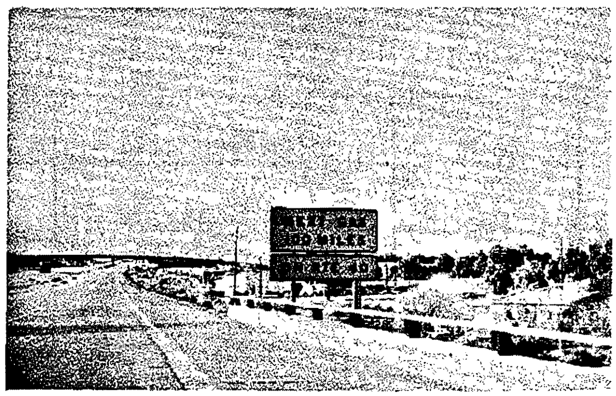
Figure B-12. Scenario No. 10 - Relative Safety of Different Passing Maneuvers



Slide No. 61



Slide No. 62



Slide No. 64

Figure B-13. Scenario No. 10 - Relative Safety of Different Passing Maneuvers

TEXAS A&M UNIVERSITY
TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION TEXAS 77843

Transportation Systems Division

Project 2265

Driver Questionnaire

1. Age: ______
2. Sex: ______
3. Circle the highest educational level you have completed:

Elem. School	Junior High	High School	College	Graduate School
1 2 3 4 5	6 7 8	9 10 11 12	1 2 3 4	1 2

4. How many years have you been driving? ______
5. About how many miles per year do you usually drive? ______
6. Please estimate what percent of your total driving time is spent in the following environments (figures should add to 100%):
   a. Rural ______
   b. Small City ______
   c. Large City ______
7. How many years have you been a peace officer? ______

Laboratory Number 2A - PAVED SHOULDERS

February 5, 1980

Question Number	Yes	No	Question Number	Yes	No
1.1			7.4		
1.2			7.5		
1.3			7.6		
1.4			7.7		
2.1			7.8		
2.2			7.9		
2.3			7.10		
3.1			7.11		
3.2			7.12		
3.3			7.13		
4.1			7.14		
4.2			7.15		
4.3			7.16		
4.4			7.17		
4.5			7.18		
5.1			8.1		
5.2			8.2		
5.3			8.3		
5.4			8.4		
6.1			9.1		
6.2			9.2		
6.3			9.3		
6.4			9.4		
6.5					
7.1			10.1		
7.2			10.2		
7.3			10.3		

LABORATORY NO. 2 - DPS OFFICERS' EXPERIENCE WITH, PREFERENCE FOR AND UNDERSTANDING OF PAVED SHOULDER USAGE

(Slide 1)

Introduction

The Texas Transportation Institute in cooperation with the Texas Department of Highways and Public Transportation is conducting research to study the effects (both good and bad) of motorists driving on paved shoulders. Texas driving practices with regard to paved shoulder usage are relatively unique. The general courteous driving habits of Texas motorists have promoted the idea that a slower driver should pull over to allow faster vehicles to pass. Extensive hightype rural highway design standards using 8-10 foot paved shoulders have provided a wide pavement surface for this maneuver. As road users are apparently benefitting from this type of operation, there has been little research on how, when, where and why Texas motorists should be allowed to drive on the paved shoulders of rural highway.

In order to provide additional insight and credible information regarding field experience with shoulder usage, the research staff has prepared a short laboratory study. The study addresses shoulder usage, safety problems and enforcement practices. Your assistance in providing us with this information is appreciated.

We will be studying mostly 2-lane rural highways and asking questions about your experiences and observations of driver behavior that primarily occurs only on Texas highways.

(Slide 2)

Texas drivers have been observed to drive on the paved shoulders of rural highways, perhaps due to the general courteous driving habits of Texas motorists. There may be both advantages and disadvantages of this driving practice. We would like to obtain your driving experiences and observations concerning this issue.

You will be shown a series of driving situations. We want you to give us your answers to questions such as these:

"Have you ever seen a motorist make this driving maneuver before?"

"Do you think it is dangerous to drive like this?"

"Is it legal for a motorist to make this driving maneuver?"

Answers

Most of our questions can be answered by either yes or no. Please record your answer as soon as you have made your decision.

There are no trick questions in this study. The roadway ahead of the motorist looks exactly the same as the roadway you will see in the slides. No one is parked or stopped on the shoulder in any of the driving situations that will be shown. There are no signs prohibiting any of the maneuvers that will be described. And finally, the motorist will not cause an accident by performing this maneuver.

(Slide 3)

SUMMARY

Again, this is a study of your driving experiences and observations made only on rural Texas highways.

QUESTIONS ?

Are there any questions?

(Slide 4-Blank)

SCENARIO NO. 1

(Slide 5)

A motorist is driving along a rural, two-lane highway in Texas and is overtaking a car that is about to make a left turn into a driveway.

(Slides 6, 7)

Hopefully, these slides illustrate this idea. While the slides do not show it well, the blue car was initially traveling 55 M.P.H., was signaling to turn left, and is slowing to a stop before turning left into the driveway. (Point out driveway).

Does everyone understand the traffic situation?

QUESTIONS

1.1 Would the motorist pass this car on the right side by driving on the paved shoulder?

1.2 If the white strip were not present, would the motorist pass the car on the right side by driving on the paved shoulder?

1.3 Have you ever seen a motorist pass a left turning vehicle on the right side by driving on the paved shoulder?

(Slide 8)

1.4 Do you think passing a left turning vehicle on the right by driving on the paved shoulder is dangerous?

(Slide 9-Blank)

SCENARIO NO. 2

(Slide 10)

We would like to point out some of the limitations and problems with our slides before continuing on with the laboratory. Vehicles shown in the highway and shoulder are always traveling at a reasonable speed, or the speed noted, even though they appear to be stopped in the slides. The car the motorist is driving is usually not shown in the slide even though most of the photos were taken through the windshield using a telephoto lens. Distant hills appear much closer than they really are.

Are there any questions? If not, let's continue.

Assume a motorist is driving along a Texas highway and observes a car traveling 50 M.P.H. along a paved shoulder. He is driving faster, and continues to catch up to the car driving on the shoulder.

(Slide 11, 12)

QUESTIONS

2.1 Would the motorist drive past this vehicle without crossing the centerline of the highway?

2.2 Have you ever seen a motorist pass a vehicle like this before?

2.3 Do you think passing a vehicle driving 50 M.P.H. along a paved shoulder is dangerous?

(Slide 13-Blank)

SCENARIO NO. 3

(Slide 14)

Suppose a slow moving vehicle is traveling 20 M.P.H. along the paved shoulder of a Texas highway where many driveways are present. (Point out slow moving vehicle is pickup).

QUESTIONS

3.1 Would a motorist drive past the pickup without crossing the centerline of the highway?

3.2 Have you ever seen a motorist pass a slow-moving vehicle which was driving on the paved shoulder?

3.3 Do you think passing a slow moving vehicle which is driving along a paved shoulder like this is dangerous?

(Slide 15-Blank)

SCENARIO NO. 4

(Slide 16)

A motorist is overtaking another car that is traveling 50 M.P.H. on a rural Texas highway.

(Slide 17)

QUESTIONS

4.1 Would you expect the motorist to pass this car by crossing onto the left side of the highway when it is safe to do so?

(Slides 18, 19)

4.2 Do you think the car ahead of you should pull onto the paved shoulder to allow you to drive past?

4.3 Have you ever seen a car pull over onto the paved shoulder so that a faster vehicle could drive past?

4.4 Do you think it is dangerous for a driver to pull over onto a shoulder like this one and be passed?

(Slide 20)

4.5 Do you think the motorist would be more likely to pull onto the shoulder if no edgeline or contrasting shoulder was present?

(Slide 21-Blank)

SCENARIO NO. 5

(Slide 22)

A motorist overtaking a slower moving vehicle that is about to make a left turn at an intersection with another state highway. (Point out intersection).

(Slide 23, 24)

QUESTIONS

5.1 Would the motorists slow down and wait in your lane for the vehicle to turn left before driving on?

5.2 Would the motorist pass the vehicle on the right by driving on the paved shoulder?

(Slide 25)

5.3 Have you ever seen a motorist pass a vehicle making a left turn at an intersection on the right side by driving on the paved shoulder?

5.4 Do you think passing a vehicle on the right like this is dangerous?

(Slide 26-Blank)

SCENARIO NO. 6

(Slide 27)

The motorist is being overtaken by a large truck.

(Slide 28, 29)

QUESTIONS

6.1 Would he maintain his present speed and lane position so that the truck would have to pass him by crossing onto the other side of the road?

6.2 Would he pull onto the paved shoulder to allow the truck to drive past him?

(Slide 30)

6.3 Have you ever seen a motorist pull onto the paved shoulder to allow a large truck to pass him?

6.4 Do you think it is dangerous for a motorist to pull onto the paved shoulder to allow a large truck to pass?

6.5 Do you think it is more dangerous for him to remain in his thru lane than it is to pull onto the paved shoulder?

(Slide 31-Blank)

SCENARIO NO. 7

(Slide 32)

You will be shown a series of traffic passing situations each presented by a single slide. We want you to judge: (1) the legality of passing the vehicle shown without crossing the centerline of the highway, (2) the legality of the vehicle driving on the paved shoulder, and (3) the desirability of the maneuver. Please consider the fact that sometimes edgeline paint markings or contrasting color materials are used; sometimes they are not.

Examples of some typical painted edgeline markings and shoulder pavements are shown in the following slides.

(Point out edgeline and no contrasting shoulder).

(Slide 33)

(Point out edgeline with contrasting shoulder).

(Slide 34)

(Point out no edgeline with contrasting shoulder).

(Slide 35)

(Point out no edgeline and no contrasting shoulder).

Again, all vehicles in the slides are traveling at reasonable speeds. The speed of the vehicle on the shoulder is about 50 M.P.H.

(Slide 36-Blank)

(Slide 37)

QUESTIONS

7.1 Is it legal for a motorist to pass this vehicle without crossing the centerline?

7.2 Is it legal for the motorist to be driving on the paved shoulder?

7.3 Is it legally a requirement in this situation that the slower traveling vehicle pull onto the paved shoulder to permit a faster vehicle to pass?

(Slide 38)

7.4 Is it legal for a motorist to pass this vehicle without crossing the centerline?

7.5 Is it legal for the motorist to be driving on the paved shoulder?

7.6 Is it legally a requirement in this situation that the slower traveling vehicle pull onto the paved shoulder to permit a faster vehicle to pass?

(Slide 39)

7.7 Is it legal for a motorist to pass this vehicle without crossing the centerline?

7.8 Is it legal for the motorist to be driving on the paved shoulder?

7.9 It is legally a requirement in this situation that the slower traveling vehicle pull onto the paved shoulder to permit a faster vehicle to pass?

(Slide 40)

7.10 Is it legal for a motorist to pass this vehicle without crossing the centerline?

7.11 Is it legal for the motorist to be driving on the paved shoulder?

7.12 Is it legally a requirement in this situation that the slower traveling vehicle pull onto the paved shoulder to permit a faster vehicle to pass?

(Slide 41)

7.13 Is it legal to pass the school bus driving along the shoulder as shown?

7.14 Is it legal for the bus driver to be driving along the shoulder?

7.15 Is it legally a requirement in this situation that the school bus drive on the shoulder if it is traveling slower than following vehicles?

(Slide 42)

7.16 Is it legal for a motorist to pass the blue car without crossing the centerline?

7.17 Is it legal for the motorist to be driving on the paved shoulder?

7.18 Is it legally a requirement in this situation that the slower traveling vehicle pull onto the paved shoulder to permit a faster vehicle to pass?

(Slide 43-Blank)

SCENARIO NO. 8

(Slide 45)

The following single slide situations consider the legal questions of passing vehicles on the right.

QUESTIONS

8.1 The vehicle is about to turn left into a private driveway. (Point out driveway). Is it legal to pass it on the right by driving on the paved shoulder?

(Slide 46)

8.2 The vehicle is about to make a left turn at an intersection. Is it legal to pass this vehicle by driving in the right lane?

(Slide 46)

8.3 The vehicle is about to make a left turn at an intersection. Is it legal to pass this vehicle on the right by driving on the paved shoulder?

(Slide 47)

8.4 This vehicle is just driving along a 4-lane highway. Is it legal to pass it on the right by using the right lane?

(Slide 48-Blank)

SCENARIO NO. 9

(Slide 49)

The following driving practice of Texas motorists on paved shoulders is significantly different from the previous cases. It is very important that you notice the difference from our slides.

The following slides will show the truck on the shoulder passing the truck traveling 50 M.P.H. on the main lanes of the highway. That is, the driver passes on the right rather than on the left side of the highway. On this particular road, many cars were observed to pass the same way.

(Slides 50, 51)

Did you notice the way the pass was made?

QUESTIONS

9.1 Have you ever seen a motorist pass another car traveling along the highway by driving on the right shoulder like the truck did in the slides?

9.2 Is it dangerous to pass another vehicle by using the right shoulder like this?

9.4 Is it legal to pass another vehicle by using the right shoulder like this?

9.5 Do you think it should be legal to pass a vehicle that is traveling on a rural two-lane highway by passing it on the right shoulder.

(Slide 52-Blank)

SCENARIO NO. 10

(Slide 53)

You will be ask to judge the relative safety of several sets of passing maneuvers. Each set will contain two slides on the same section of highway. Slide No. 1 always will be "passing a vehicle traveling 50 M.P.H. on the left of centerline." Slide No. 2 will be "a shoulder passing situation." Both slides will be shown once. An answer will then be requested. The issue is: "Which of the two passing situations do you think is safer for everybody concerned?" (Slide No. 1 or Slide No. 2).

Any questions?

QUESTIONS

(Slide 54)

This is Slide No. 1. (Point out that there is plenty of passing distance before the next hill and no vehicles are approaching from the far hill even though it may look like it. Disregard the short no-passing zone in the wrong direction. The white car to be passed on the left is traveling 50 M.P.H.).

(Slide 55)

This is Slide No. 2. (Point out that one should disregard any gravel or other debris that you may see on the paved shoulder. The white car to be passed without crossing the centerline is traveling 50 M.P.H.).

(Slide 56-Blank)

10.1 Which slide do you think presented an overall safer passing situation for all motorists involved? Slide No. 1 or Slide No. 2?

(Slide 57)

This is Slide No. 1. (Point out that you are traveling on a slight upgrade section of highway where considerable passing distance exist but where some mirage effects are occurring. Sight distances are still very long on the whole. The white car to be passed on the left is traveling 50 M.P.H.).

(Slide 58)

This is Slide No. 2. (Point out that the car to be passed without crossing the centerline is traveling 50 M.P.H.).

(Slide 59-Blank)

10.2 Which slide do you think presented an overall safer passing situation for all motorists involved? Slide No. 1 or Slide No. 2?

(Slide 60)

This is Slide No. 1. (Point out that the brown van is passing the blue van on a high volume rural highway).

(Slide 61)

This is Slide No. 2. (Point out that the samll blue car is passing the brown van by using the right shoulder on the same high volume rural highway).

(Slide 62-Blank)

10.3 Which slide do you think presented an overall safer passing situation for all motorists involved? Slide No. 1 or Slide No. 2?

(Slide 63)

Thank you for participating in the lab.

APPENDIX C

Accident Studies
Site Locations and Accident Histories

TWO-LANE WITHOUT PAVED SHOULDER ROADWAYS USED IN THE COMPARATIVE ACCIDENT STUDY, ALL-ACCIDENT DATA.

SITE NUMBER	DISTRICT NUMBER	COUNTY NAME	HIGHWAY NUMBER	CONTROL-SECTION	LENGTH (MILES)	ADT	ACC. RATE (ACC/MVM)
105	9	Bosque	TX 6	258-4	6.381	1227	1.98
102	22	Val Verde	US 90	22-7	10.803	1226	1.86
107	11	Polk	US 287	341-3	11.154	1343	1.77
108	8	Taylor	US 277	407-5	13.207	1132	1.71
109	15	Bandera	FM 689	421-6	9.915	1281	1.37
110	6	Reeves	TX 17	103-2	7.033	1052	1.24
106	10	Van Zandt	TX 19	108-2	12.082	1832	0.95
104	5	Yoakum	US 380	297-1	14.552	1098	0.80
103	21	Duval	US 59	542-4	17.997	1001	0.76
101	7	Irion	US 67	77-3	10.336	1291	0.75
210	12	Ft. Bend	TX 36	188-2	5.534	3189	2.54
207	17	Walker	US 190	213-1	5.874	3622	2.36
209	12 11 12	Montgomery San Jacinto Montgomery	TX 105	338-4 338-6 338-7	7.251	3964	2.35
205	1	Hunt	276	1017-3	5.061	3060	1.89
201	19	Titus	TX 49	222-1	4.990	3587	1.89
203	15	Guadalupe	FM 25	216-2	6.978	4155	1.42
206	11	Shelby	US 96	809-2	4.865	3145	1.37
208	12	Matagorda	TX 35	179-6	8.142	3387	0.99
204	15	Bexar	Lp 1604	2452-3	5.855	5943	0.81
202	19	Panola	TX 149	393-3	4.990	2971	0.71
306	12	Montgomery	TX 105	338-3	5.399	5627	2.83
303	12	Harris	FM 2100	1062-4	7.480	4543	2.50
302	10	Gregg	TX 42	545-4	5.318	4329	2.14
309	12	Brazoria	TX 35	179-3	3.834	5188	2.11
304	12	Harris	US 90	28-2	5.594	5090	1.76
307	1	Grayson	FM 691	666-1	4.130	4345	1.32
308	13	Victoria	US 87	144-1 144-2	6.740	5032	1.16
305	12	Ft. Bend	TX 6	192-1	3.858	5269	0.81

TWO-LANE WITH PAVED SHOULDER ROADWAYS USED IN THE COMPARATIVE ACCIDENT STUDY; ALL-ACCIDENT DATA.

SITE NUMBER	DISTRICT NUMBER	COUNTY NAME	HIGHWAY NUMBER	CONTROL-SECTION	LENGTH (MILES)	ADT	ACC. RATE (ACC/MVM)
408	17	Washington	TX 105	315-6	11.75	1976	1.53
406	13	Gonzales	US 183	143-1 143-2	11.09	1859	1.11
410	21	Starr	US 83	38-6	15.76	2012	1.01
403	8	Jones	US 83	33-4	6.95	2027	0.84
405	5	Floyd	US 62	145-6	12.06	1233	0.74
401	23	Stephens	US 180	11-9	16.04	1267	0.72
404	24	Mc Cullough	US 87	70-6	13.44	2456	0.69
402	24	Presidio	US 67	20-8	13.69	1483	0.63
407	22	Dimmit	US 277	300-3	17.75	1445	0.61
409	7	Glasscock	TX 158	463-4	17.69	1931	0.43
506	17	Burleson	TX 36	186-3	13.38	3232	1.33
508	23	Lampassas	US 190	231-1	14.01	3998	1.32
502	4	Moore	US 287	66-4	8.89	4139	1.12
505	5	Palmer	US 60	168-3	12.18	3209	1.10
510	10	Cherokee	US 69	199-3	11.37	3330	0.92
507	1	Lamar	US 271	221-1	5.48	3395	0.79
503	7	Concho	US 87	70-3 70-4	17.76	3388	0.77
504	2 18	Wise Denton	US 380	134-8 134-9	19.66	4134	0.63
509	21	Brooks	US 281	255-5	7.24	3738	0.54
501	22	Uvalde	US 90	24-2	10.00	3562	0.28
610	10	Smith	TX 155	520-6	5.12	5629	1.74
608	15	Bexar	TX 16	613-1	5.29	6127	1.24
607	20	Hardin	US 69	200-10	8.98	5374	1.21
607	13 16	Victoria Refugio	US 77	371-1 371-2	30.64	5366	1.16
603	2	Erath	US 67	79-5	9.03	5155	1.08
602	20	Jasper	US 96	65-3	8.68	5871	0.99
601	15	Medina	US 90	24-5 24-6	6.11	5083	0.91
605	16	San Patricio	TX 35	180-6	5.49	6257	0.85
604	12	Brazoria	TX 35	178-3	16.25	6411	0.66
609	16	Jim Wells	TX 44	373-4	5.45	5076	0.63

UNDIVIDED FOUR-LANE WITHOUT PAVED SHOULDER ROADWAYS
USED IN THE COMPARATIVE ACCIDENT STUDY, ALL-ACCIDENT DATA.

SITE NUMBER	DISTRICT NUMBER	COUNTY NAME	HIGHWAY NUMBER	CONTROL-SECTION	LENGTH (MILES)	ADT	ACC. RATE (ACC/MVM)
1009	14	Gillespie	US 290	112-2	10.31	858	1.76
1005	14	Lee	US 77	211-3 211-4	12.72	2206	1.50
1007	14	Williamson	US 183	273-4	12.36	2243	1.25
1006	14	Burnet	US 281	251-7 251-8	18.13	2522	1.22
1004	19	Harrison	TX 43	207-5	5.20	2484	1.06
1001	24	El Paso	TX 20	2-2	6.15	1904	0.94
1008	14	Bastrop	TX 21	472-1	6.06	1526	0.89
1010	14	Williamson	TX 29	151-3	6.38	2760	0.83
1002	11	Shelby	TX 7	59-4	6.43	2495	0.80
1003	14	Gillespie	US 87	72-1	8.80	2082	0.75
705	14	Burnet	TX 29	150-5	7.03	3199	2.19
707	15	Guadalupe	TX 123	366-2	8.22	3934	1.61
708	14	Lee	US 290	114-7	6.09	3200	1.12
709	14	Caldwell	US 183	152-2	5.54	4400	1.09
710	14	Williamson	US 79	204-1	5.25	3655	1.05
704	14	Burnet	TX 29	151-1	5.12	3139	1.02
703	14	Bastrop	US 290	114-4 114-5 114-6	15.11	3503	0.97
706	14	Burnet	US 281	252-1	10.41	3720	0.83
702	16	Karnes	US 181	100-6	8.87	3629	0.71
803	14	Travis	US 183	152-1	8.47	5276	1.57
802	14	Travis	US 290	113-8	4.54	4940	1.49
804	15	Guadalupe	TX 123	366-2	2.79	5142	0.89
806	19	Pan	US 59	63-5	3.68	5340	0.65
905	15	Kerr	TX 27	142-4	3.47	7220	1.90
903	12	Brazoria	TX 288	111-4	2.83	8394	1.51
906	19	Cass	US 59	218-3	7.29	8377	1.17
904	14	Travis	US 290	114-2 114-3	7.58	6743	1.02

TWO-LANE WITHOUT PAVED SHOULDER ROADWAYS USED IN
THE COMPARATIVE ACCIDENT STUDY, NON-INTERSECTION DATA.

SITE NUMBER	DISTRICT NUMBER	COUNTY NAME	HIGHWAY NUMBER	CONTROL-SECTION	LENGTH (MILES)	ADT	ACC. RATE (ACC/MVM)
105	9	Bosque	TX 6	258-4	6.38	1227	1.75
108	8	Taylor	US 277	407-5	13.21	1132	1.71
107	11	Polk	US 287	341-3	11.15	1343	1.46
102	22	Val Verde	US 90	22-7	10.80	1226	1.45
109	15	Bandera	FM 689	421-6	9.92	1281	1.29
110	6	Reeves	TX 17	103-2	7.03	1052	1.24
106	10	Van Zandt	TX 19	108-2	12.08	1832	0.91
103	21	Duval	US 59	542-4	17.997	1001	0.76
101	7	Irion	US 67	77-3	10.34	1291	0.75
104	5	Yoakum	US 380	297-1	14.55	1098	0.74
207	17	Walker	US 190	213-1	5.88	3622	1.97
	12	Montgomery		338-4			
209	11	San Jacinto	TX 105	338-6	7.25	3964	1.91
	12	Montgomery		338-7			
205	1	Hunt	276	1017-3	5.06	3060	1.89
210	12	Ft. Bend	TX 36	188-2	5.53	3189	1.76
201	19	Titus	TX 49	222-1	4.99	3587	1.42
206	11	Shelby	US 96	809-2	4.87	3145	1.31
203	15	Guadalupe	FM 25	216-2	6.98	4155	1.01
202	19	Panola	TX 149	393-3	4.77	2971	0.71
208	12	Matagorda	TX 35	179-6	8.14	3387	0.66
204	15	Bexar	Lp 1604	2452-3	5.86	5943	0.45
306	12	Montgomery	TX 105	338-3	5.40	5627	2.10
309	12	Brazoria	TX 35	179-3	3.83	5188	2.07
303	12	Harris	FM 2100	1062-4	7.48	4543	1.80
302	10	Gregg	TX 42	545-4	5.32	4329	1.27
307	1	Grayson	FM 691	666-1	4.13	4345	1.07
304	12	Harris	US 90	28-2	5.60	5090	1.06
308	13	Victoria	US 87	144-1 144-2	6.74	5032	0.73
305	12	Ft. Bend	TX 6	192-1	3.86	5269	0.54

TWO-LANE WITH PAVED SHOULDER ROADWAYS USED IN THE COMPARATIVE ACCIDENT STUDY, NON-INTERSECTION DATA.

SITE NUMBER	DISTRICT NUMBER	COUNTY NAME	HIGHWAY NUMBER	CONTROL-SECTION	LENGTH (MILES)	ADT	ACC. RATE (ACC/MVM)
408	17	Washington	TX 105	315-6	11.75	1976	1.42
410	21	Starr	US 83	38-6	15.76	2012	0.95
406	13	Gonzales	US 183	154-1 154-2	11.09	1859	0.84
401	23	Stephens	US 180	11-9	16.04	1267	0.72
403	8	Jones	US 82	33-4	6.95	2027	0.65
402	24	Presidio	US 67	20-8	13.69	1483	0.63
404	23	Mc Cullough	US 87	70-6	13.44	2456	0.61
405	5	Floyd	US 62	145-7	12.06	1233	0.61
407	22	Dimmit	US 277	300-3	17.75	1445	0.61
409	7	Glasscock	TX 158	463-4	17.69	1931	0.43
508	23	Lampassas	US 190	231-1	14.01	3998	1.21
505	5	Parmer	US 60	168-2	12.18	3209	1.00
506	17	Burleson	TX 36	186-3	13.38	3232	0.97
502	4	Moore	US 287	66-4	8.89	4139	0.94
510	10	Cherokee	US 69	199-3	11.37	3330	0.80
503	7	Concho	US 87	7-3 7-4	17.76	3388	0.76
507	1	Lamar	US 271	221-1	5.48	3395	0.69
504	2 18	Wise Denton	US 380	134-8 134-9	19.66	4134	0.54
509	21	Brooks	US 281	255-5	7.24	3738	0.47
501	22	Uvalde	US 90	24-2	10.00	3562	0.28
610	10	Smith	TX 155	520-6	5.12	5629	1.17
606	13 16	Victoria Refugio	US 77	371-1 371-2	30.64	5366	1.13
608	15	Bexar	TX 16	613-1	5.29	6127	1.10
602	20	Jasper	US 96	65-3	8.68	5871	0.91
607	20	Hardin	US 69	200-10	8.98	5374	0.91
603	2	Erath	US 67	79-5	9.03	5155	0.86
601	15	Medina	US 90	24-5 24-6	6.11	5083	0.74
605	16	San Patricio	TX 35	180-6	5.49	6257	0.72
609	16	Jim Wells	TX 44	373-4	5.42	5076	0.56
604	12	Brazoria	TX 35	178-3	16.25	6411	0.53

UNDIVIDED FOUR-LANE WITHOUT PAVED SHOULDER ROADWAYS USED IN THE COMPARATIVE ACCIDENT STUDY, NON-INTERSECTION DATA.

SITE NUMBER	DISTRICT NUMBER	COUNTY NAME	HIGHWAY NUMBER	CONTROL-SECTION	LENGTH (MILES)	ADT	ACC. RATE (ACC/MVM)
1009	14	Gillespie	US 290	112-2	10.31	858	1.65
1006	14	Burnett	US 281	251-7, 251-8	18.13	2522	1.22
1005	14	Lee	US 77	211-3, 211-4	12.72	2206	1.17
1007	14	Williamson	US 183	273-4	12.36	2243	1.09
1004	19	Harrison	TX 43	207-5	5.20	2484	0.99
1008	14	Bastrop	TX 21	472-1	6.06	1526	0.89
1001	24	El Paso	TX 20	2-2	6.15	1904	0.78
1010	14	Williamson	TX 29	151-3	6.38	2760	0.83
1003	14	Gillespie	US 87	72-1	8.80	2082	0.65
1002	11	Shelby	TX 7	59-4	6.43	2493	0.51
705	14	Burnett	TX 29	150-5	7.03	3199	1.95
707	15	Guadalupe	TX 123	366-2	8.22	3934	1.30
709	14	Caldwell	US 183	152-2	5.54	4400	1.09
708	14	Lee	US 290	114-7	6.09	3200	1.03
710	14	Williamson	US 79	209-1	5.25	3655	1.00
704	14	Burnett	TX 29	151-1	5.12	3139	0.97
706	14	Burnett	US 281	252-1	10.41	3720	0.80
703	14	Bastrop	US 290	114-4, 114-5, 114-6	15.11	3503	0.79
702	16	Karnes	US 181	100-6	8.87	3629	0.68
803	14	Travis	US 183	152-1	8.47	5276	1.29
802	14	Travis	US 290	133-8	4.54	4990	0.93
806	19	Panola	US 59	63-5	3.68	5430	0.56
804	15	Guadalupe	TX 123	366-2	2.79	5142	0.51
905	15	Kerr	TX 27	192-4	3.47	7220	1.60
903	12	Brazoria	TX 288	111-4	2.73	8394	1.28
904	14	Travis	US 290	114-2, 114-3	7.58	6743	0.95
906	19	Cass	US 59	218-3	7.29	8377	0.85

BEFORE-AFTER ACCIDENT STUDY SITES WHERE FULL-WIDTH PAVED SHOULDERS WERE ADDED TO A TWO-LANE HIGHWAY

DISTRICT NUMBER	COUNTY NAME	HIGHWAY NUMBER	CONTROL SECTION	MILEPOSTS	ADT	YEARS INCLUSIVE
CLASS 1						
4	Hartley	385	41-2	13.979-27.940	1065	1969-1973
4	Hemphill	83	30-5	0.000- 5.850	1094	1974-1978
4	Ochiltree	15	355-3	19.950-33.430	1493	1971-1975
			355-4	2.710- 7.200	1541	1974-1978
4	Sherman	54	238-6	17.273-24.480	1959	1968-1972
5	Castro	194	439-1	1.360- 8.068	1335	1972-1976
			439-2	8.068-14.395	1213	
5	Gaines	83	583-2	0.000-13.572	1218	1973-1977
7	Tom Green	277	159-2	18.820-24.557	1429	1973-1977
8	Jones	180	296-4	0.000-14.350	1246	1968-1972
10	Cherokee	79	206-5	1.000-6.850	1650	1971-1975
11	San Augustine	96	809-3	0.000-5.870	2007	1972-1976
			809-4	1.534-10.143	1989	
15	Frio	57	276-7	0.000-11.076	700	1973-1977
20	Tyler	92	703-1	12.472-19.451	1795	1970-1974
CLASS 2						
1	Grayson	11	2192-1	0.738- 3.207	2072	1968-1972
10	Anderson	175	198-3	4.890- 8.219	1971	1969-1973
10	Gregg	259	392-3	9.274-12.760	5735	1969-1973
12	Matagorda	60	241-2	0.000- 8.791	1973	1968-1972
13	Calhoun	35	180-1	12.249-16.293	5449	1970-1974
17	Burleson	36	186-2	0.000- 8.940	2438	1969-1973
20	Jasper	96	65-2	7.519-11.879	3583	1970-1978
			65-4	52.000-56.800	4394	1968-1972
20	Liberty	321	593-1	3.499-16.303	2162	1969-1973
20	Newton	12	499-2	0.000- 3.118	3100	1969-1973
20	Orange	12	499-3	2.848- 9.300	3188	1969-1973
CLASS 3						
10	Smith	155	520-6	16.288-23.867	3379	1971-1975
10		93	393-1	9.800-13.100		1970-1974
20	Jasper	96	65-4	52.000-56.800	4394	1968-1972

BEFORE-AFTER ACCIDENT STUDY SITES WHERE TWO-LANE WITH SHOULDER HIGHWAYS WERE CONVERTED TO FOUR-LANE WITHOUT SHOULDER HIGHWAYS

DISTRICT NUMBER	COUNTY NAME	HIGHWAY NUMBER	CONTROL SECTION	MILEPOSTS	ADT	YEARS INCLUSIVE
CLASS 4						
14	Burnet	29	151-2	0.329- 4.175	1992	1969-1973
			251-7	5.401-18.366	1989	1969-1973
14	Burnet	281	251-8	5.401-18.366	1989	1969-1973
			252-2	38.613-40.440	1989	1970-1975
14	Caldwell	183	152-3	11.940-16.120	2067	1971-1975
14	Gillespie	290	113-2	8.720-12.498	2430	1971-1975
		87	72-1	19.680-23.883	2161	1974-1978
			211-1	0.000- 8.247	1822	
14	Lee	77	211-3	17.906-24.440	1878	1971-1975
			211-4	17.906-24.440	1878	
14	Williamson	183	273-4	0.000-13.107	1519	1971-1975
		95	320-3	0.800- 5.305	2077	1973-1977
23	Stephens	180	11-7	0.000- 6.720	2441	1973-1977
CLASS 5						
14	Lee	290	114-7	1.185- 7.226	2517	1968-1972
14	Burnet	29	151-1	13.730-10.850	2510	1969-1973
14	Williamson	29	151-3	0.000- 8.757	2071	1970-1974
			151-4		2521	
14	Williamson	79	204-4	0.000- 4.586	3135	1969-1975
15	Guadalupe	123	366-2	0.000- 3.189	3226	1969-1973
23	Coleman	84	54-4	4.591-11.538	2978	1973-1978
			114-4			
14	Bastrop	290	114-5	3.440-19.228	4046	1971-1975
			114-6			
CLASS 6						
13	Jackson	59	89-5	0.000- 4.156	5449	1972-1976
14	Caldwell	183	152-2	0.000- 8.123	3276	1971-1974
14	Travis	183	152-1	31.000-39.600	3490	1969-1973
14	Travis	290	113-8	0.000- 3.460	2908	1969-1973
15	Guadalupe	123	366-2	10.250-13.043	3226	1969-1973
19	Cass	59	218-3	2.300- 8.100	6269	1973-1978

BEFORE-AFTER ACCIDENT STUDY: CLASS 1 SITES
Adjusted Frequencies for All Accidents

Type of Improvement: Addition of Full-Width Paved Shoulders
Number of Sites: 16
Average ADT Before: 1454
Average ADT After: 1580

Type of Accident	Accident Frequency						Total Change (Percent)
	Two Years Before			Two Years After			
	Day	Night	Total	Day	Night	Total	
Angle	16		16	14.7	4.6	19.3	+ 20.6
Head-On	3	5	8	5.9	2.6	8.5	+ 6.3
Right-Turn	4		4	2.8		2.8	- 30.0
Rear-End	13	6	19	9.6	3.6	13.2	- 30.5
Left-Turn	19	1	20	18.6	3.7	22.3	+ 11.5
Same Direct	1	1	2	1.7	1.7	3.4	+ 70.0
Fixed-Obj.	13	9	22	7.8	10.8	18.6	- 15.5
Off-Road	24	28	52	7.4	8.2	15.6	- 70.0
Animal	2	15	17		13.3	13.3	- 21.8
Other	8	4	12	9.5	8.9	18.4	+ 53.3
Total	103	69	172	78.0	57.4	135.4	- 21.3
Injury Acc.	35	22	57	26.5	19.1	45.6	- 20.0
Fatal Acc.	6	2	8	5.9	4.4	10.3	+ 28.8
No. Inj.	71	34	105	45.3	35.1	80.4	- 23.4
No. Fatal	7	1	8	7.9	4.4	12.3	+ 53.8

BEFORE-AFTER ACCIDENT STUDY: CLASS 2 SITES
Adjusted Frequencies for All Accidents

Type of Improvement: Addition of Full-Width Paved Shoulders
Number of Sites: 11
Average ADT Before: 2555
Average ADT After: 2727

Type of Accident	Accident Frequency						Total Change (Percent)
	Two Years Before			Two Years After			
	Day	Night	Total	Day	Night	Total	
Angle	4	1	5	9.9	2.9	12.8	+156.0
Head-On	13	8	21	9.4	8.5	17.9	- 14.8
Right-Turn	4		4	4.7	0.8	5.5	+ 37.5
Rear-End	15	7	22	10.4	4.8	15.2	- 30.9
Left-Turn	28	6	34	27.1	7.1	34.2	+ 0.6
Same Direct	4		4	5.5		5.5	+ 37.5
Fixed-Obj.	14	13	27	11.3	7.1	18.4	- 31.8
Off-Road	31	16	47	28.9	20.4	49.3	+ 4.9
Animal	3	16	19	2.9	20.4	23.3	+ 22.6
Other	9	3	12	28.9	7.6	36.5	+205.0
Total	125	70	195	139.0	79.6	218.6	+ 12.1
Injury Acc.	41	27	68	39.0	25.0	64.0	- 5.6
Fatal Acc.	3	27	11	4.8	1.8	6.6	- 40.0
No. Inj.	61	41	102	67.8	40.3	108.1	+ 6.0
No. Fatal	4	11	15	12.9	1.8	14.7	- 2.0

BEFORE-AFTER ACCIDENT STUDY: CLASS 3 SITES
Adjusted Frequencies for All Accidents

Type of Improvement: Addition of Full-Width Paved Shoulders
Number of Sites: 3
Average ADT Before: 3845
Average ADT After: 4875

Type of Accident	Accident Frequency						Total Change (Percent)
	Two Years Before			Two Years After			
	Day	Night	Total	Day	Night	Total	
Angle	3		3	0.9	1.0	1.9	- 36.7
Head-On	4	2	6	6.4	1.6	8.0	+ 33.3
Right-Turn	1		1	0.7		0.7	- 30.0
Rear-End	7	4	11	8.8	1.8	10.6	- 3.6
Left-Turn	15	3	18	8.1	3.2	11.3	- 37.2
Same Direct	5		5	0.7	0.8	1.5	- 70.0
Fixed-Obj.	4	1	5	3.7	1.5	5.2	+ 4.0
Off-Road	7	5	12	6.5	3.2	9.7	- 19.2
Animal		4	4	0.7	1.5	2.2	- 45.0
Other	3		3	3.8	2.2	6.0	+100.0
Total	49	19	68	40.3	16.8	57.1	- 16.0
Injury Acc.	10	8	18	13.7	5.6	19.3	+ 7.2
Fatal Acc.	3	0	3	1.9	2.5	4.4	+ 46.7
No. Inj.	16	12	28	26.5	13.1	39.6	+ 41.4
No. Fatal	3	0	3	2.9	4.9	7.8	+160.0

BEFORE-AFTER ACCIDENT STUDY: CLASS 4 SITES
Adjusted Frequencies for All Accidents

Type of Improvement: Conversion to 4-Lane Undivided Roadway
Number of Sites: 12
Average ADT Before: 1995
Average ADT After: 2196

Type of Accident	Accident Frequency						Total Change (Percent)
	Two Years Before			Two Years After			
	Day	Night	Total	Day	Night	Total	
Angle	12	4	16	11.5	5.1	16.6	+ 3.8
Head-On	3	3	6	5.1	4.4	9.5	+ 58.3
Right-Turn	5	0	5	7.8		7.8	+ 56.0
Rear-End	4	3	7	4.6	7.4	12.0	+ 71.4
Left-Turn	18	3	21	10.9		10.9	- 48.1
Same Direct	5	1	6	7.0	4.4	11.4	+ 90.0
Fixed-Obj.	25	24	49	12.0	17.4	29.4	- 40.0
Off-Road	22	19	41	21.4	24.4	45.8	+ 11.7
Animal	3	22	25	4.2	21.3	25.5	+ 2.0
Other	2	6	8	10.9	8.9	19.8	+147.5
Total	99	85	184	95.4	93.3	188.7	+ 2.6
Injury Acc.	35	19	54	26.4	28.5	52.9	- 2.0
Fatal Acc.	4	3	7	1.8	2.5	4.3	- 38.6
No. Inj.	62	30	92	42.4	45.2	87.6	- 4.8
No. Fatal	4	3	7	2.8	4.9	7.7	+ 10.0

BEFORE-AFTER ACCIDENT STUDY: CLASS 5 SITES
Adjusted Frequencies for All Accidents

Type of Improvement: Conversion to 4-Lane Undivided Roadway
Number of Sites: 11
Average ADT Before: 2913
Average ADT After: 3312

Type of Accident	Accident Frequency						Total Change (Percent)
	Two Years Before			Two Years After			
	Day	Night	Total	Day	Night	Total	
Angle	15	4	19	14.3	5.8	20.1	+ 5.8
Head-On	12	10	22	5.4	5.8	11.2	- 49.1
Right-Turn	6		6	1.6	1.7	3.3	- 45.0
Rear-End	18	7	25	10.4	6.1	16.5	- 34.0
Left-Turn	22	5	27	11.9	3.6	15.5	- 42.6
Same Direct	4	1	5	6.1	4.3	10.4	+108.0
Fixed-Obj.	21	18	39	16.2	22.6	38.8	- 0.5
Off-Road	20	24	44	15.0	17.8	32.8	- 25.5
Animal	1	25	26	3.9	10.8	14.7	- 43.5
Other	9	7	16	9.0	11.7	20.7	+ 29.4
Total	128	101	229	93.8	90.2	184.0	- 19.7
Injury Acc.	43	29	72	26.3	45.0	71.3	- 1.0
Fatal Acc.	4	7	11	3.3	5.5	8.8	- 20.0
No. Inj.	62	50	112	46.9	75.0	121.9	+ 8.8
No. Fatal	7	9	16	3.3	6.5	9.8	- 38.8

BEFORE-AFTER ACCIDENT STUDY: CLASS 6 SITES
Adjusted Frequencies for All Accidents

Type of Improvement: Conversion to 4-Lane Undivided Roadway
Number of Sites: 6
Average ADT Before: 4103
Average ADT After: 5133

Type of Accident	Accident Frequency						Total Change (Percent)
	Two Years Before			Two Years After			
	Day	Night	Total	Day	Night	Total	
Angle	4	7	11	11.4	3.2	14.6	+ 32.7
Head-On	14	4	18	4.6	7.9	12.5	- 30.6
Right-Turn	2		2	1.6	1.6	3.2	+ 60.0
Rear-End	11	12	23	14.1	4.7	18.8	- 18.3
Left-Turn	14	6	20	9.2	7.1	16.3	- 18.5
Same Direct	5	1	6	5.6	1.7	7.3	+ 21.7
Fixed-Obj.	9	10	19	6.0	11.1	17.1	- 10.0
Off-Road	21	17	38	7.4	11.3	18.7	- 50.8
Animal	5	16	21	0.8	6.8	7.6	- 63.8
Other	3	2	5	9.5	7.3	16.8	+236.0
Total	97	70	167	70.2	62.7	132.9	- 20.4
Injury Acc.	30	20	50	22.2	19.8	42.0	- 16.0
Fatal Acc.	7	4	11	3.3	3.2	6.5	- 40.9
No. Inj.	51	33	84	41.1	37.4	78.5	- 6.5
No. Fatal	13	6	19	4.3	8.6	12.7	- 33.2

BEFORE-AFTER ACCIDENT STUDY: CLASS 1 SITES
Adjusted Frequencies for Non-Intersection Accidents

Type of Improvement: Addition of Full-Width Paved Shoulders
Number of Sites: 16
Average ADT Before: 1454
Average ADT After: 1580

Type of Accident	Accident Frequency						Total Change (Percent)
	Two Years Before			Two Years After			
	Day	Night	Total	Day	Night	Total	
Angle	2		2	1.1		1.1	- 45.0
Head-On	3	3	6	5.9	2.6	8.5	+ 41.7
Right-Turn	2		2	2.8		2.8	+ 40.0
Rear-End	6	4	10	7.6	4.6	12.2	+ 22.0
Left-Turn	11	1	12	6.5	1.9	8.4	- 30.0
Same Direct	2	1	3	1.7	1.7	3.4	+ 13.3
Fixed-Obj.	12	4	16	8.3	6.9	15.2	- 5.0
Off-Road	20	22	42	2.7	8.2	10.9	- 74.0
Animal	2	15	17	2.3	7.3	9.6	- 43.5
Other	4	6	10	7.6	7.9	15.5	+ 55.0
Total	64	56	120	46.5	41.1	87.6	- 27.0
Injury Acc.	22	18	40	17.2	14.4	31.6	- 21.0
Fatal Acc.	4	1	5	3.8	4.4	8.2	+ 64.0
No. Inj.	35	22	57	27.7	24.3	52.0	- 8.8
No. Fatal	5	1	6	5.8	4.4	10.2	+ 70.0

BEFORE-AFTER ACCIDENT STUDY: CLASS 2 SITES
Adjusted Frequencies for Non-Intersection Accidents

Type of Improvement: Addition of Full-Width Paved Shoulders
Number of Sites: 11
Average ADT Before: 2973
Average ADT After: 3257

Type of Accident	Accident Frequency						Total Change (Percent)
	Two Years Before			Two Years After			
	Day	Night	Total	Day	Night	Total	
Angle	1		1	2.6	.8	3.4	+240.0
Head-On	13	9	22	9.2	7.5	16.7	- 24.1
Right-Turn	2		2	3.9		3.9	+ 95.0
Rear-End	12	6	18	6.2	3.8	10.0	+ 80.0
Left-Turn	18	4	22	13.0	2.5	15.5	- 29.5
Same Direct	3		3	4.4		4.4	+ 46.7
Fixed-Obj.	11	12	23	7.5	5.9	13.4	- 41.7
Off-Road	26	18	44	23.5	16.0	39.5	- 10.2
Animal	3	17	20	2.9	20.2	23.1	+ 15.5
Other	7	2	9	8.3	5.3	13.6	+ 51.1
Total	96	68	164	81.3	62.0	143.3	- 12.6
Injury Acc.	30	24	54	28.9	20.4	49.3	- 8.7
Fatal Acc.	3	6	9	1.7	.9	2.6	- 71.1
No. Inj.	46	32	78	51.3	29.6	80.9	+ 3.7
No. Fatal	4	9	13	1.7	.9	2.6	- 80.0

BEFORE-AFTER ACCIDENT STUDY: CLASS 3 SITES
Adjusted Frequencies for Non-Intersection Accidents

Type of Improvement: Addition of Full-Width Paved Shoulders
Number of Sites: 3
Average ADT Before: 3845
Average ADT After: 4875

Type of Accident	Accident Frequency						Total Change (Percent)
	Two Years Before			Two Years After			
	Day	Night	Total	Day	Night	Total	
Angle	1		1				-100.0
Head-On	4	1	5	5.6	1.6	7.2	+ 44.0
Right-Turn							
Rear-End	4	3	7	1.6	1.8	3.4	- 51.4
Left-Turn	8	1	9	4.8		4.8	- 46.7
Same Direct	5		5	.7	.8	1.5	- 70.0
Fixed-Obj.	2		2	2.3	.7	3.0	+ 50.0
Off-Road	5	5	10	5.8	3.2	9.0	- 11.1
Animal		4	4	.7	1.5	2.2	- 45.0
Other	2		2	3.8	2.2	6.0	+200.0
Total	31	14	45	25.2	11.9	37.1	- 17.6
Injury Acc.	7	8	15	9.7	3.1	12.8	- 14.7
Fatal Acc.	2	0	2	1.9	2.5	4.4	+120.0
No. Inj.	10	12	22	16.0	5.4	21.4	- 2.7
No. Fatal	2	0	2	2.9	4.9	7.8	+280.0

BEFORE-AFTER ACCIDENT STUDY: CLASS 4 SITES
Adjusted Frequencies for Non-Intersection Accidents

Type of Improvement: Conversion to 4-Lane Unidvided Roadway
Number of Sites: 12
Average ADT Before: 2005
Average ADT After: 2232

Type of Accident	Accident Frequency						Total Change (Percent)
	Two Years Before			Two Years After			
	Day	Night	Total	Day	Night	Total	
Angle	2	3	5	3.8	4.2	8.0	+ 60.0
Head-On	3	3	6	3.3	2.4	5.7	- 5.0
Right-Turn	3		3	5.1	3.7	8.8	+193.3
Rear-End	4	2	6	3.9	3.6	7.5	+ 25.0
Left-Turn	10	1	11	2.7	1.6	4.3	- 60.9
Same Direct	3	1	4	6.8	3.7	10.5	+162.5
Fixed-Obj.	16	22	38	14.1	22.4	36.5	- 3.9
Off-Road	16	18	34	17.3	15.6	32.9	- 3.2
Animal	2	21	23	4.2	21.3	25.5	+ 10.9
Other	3	7	10	9.2	8.7	17.9	+ 79.0
Total	62	78	140	70.4	87.0	157.4	+ 12.4
Injury Acc.	23	17	40	20.3	24.2	44.5	+ 11.3
Fatal Acc.	2	3	5	1.8	2.5	4.3	- 14.0
No. Inj.	43	28	71	35.5	40.0	75.5	+ 6.3
No. Fatal	2	3	5	2.8	4.9	7.7	+ 54.0

BEFORE-AFTER ACCIDENT STUDY: CLASS 5 SITES
Adjusted Frequencies for Non-Intersection Accidents

Type of Improvement: Conversion to 4-Lane Undivided Roadway
Number of Sites: 11
Average ADT Before: 2851
Average ADT After: 3233

Type of Accident	Accident Frequency						Total Change (Percent)
	Two Years Before			Two Years After			
	Day	Night	Total	Day	Night	Total	
Angle	5	1	6	2.8	1.5	4.3	- 28.3
Head-On	11	10	21	3.7	5.9	9.6	- 54.3
Right-Turn	3		3		.8	.8	- 73.3
Rear-End	16	6	22	6.8	5.2	12.0	- 45.5
Left-Turn	13	3	16	5.1	2.6	7.7	- 51.9
Same Direct	3	2	5	5.3	4.3	9.6	+ 92.0
Fixed-Obj.	16	16	32	14.0	20.1	34.1	+ 6.6
Off-Road	16	24	40	16.0	18.6	34.6	- 14.0
Animal	2	24	26	3.9	11.0	14.9	- 42.7
Other	7	7	14	7.4	14.8	22.2	+ 58.6
Total	92	93	185	64.9	84.9	149.8	- 19.0
Injury Acc.	26	25	51	18.6	43.3	61.9	+ 21.4
Fatal Acc.	3	7	10	1.5	4.4	5.9	- 41.0
No. Inj.	54	39	93	29.9	60.8	90.7	- 2.5
No. Fatal	6	9	15	1.5	5.4	6.9	- 54.0

BEFORE-AFTER ACCIDENT STUDY: CLASS 6 SITES
Adjusted Frequencies for Non-Intersection Accidents

Type of Improvement: Conversion to 4-Lane Undivided Roadway
Number of Sites: 6
Average ADT Before: 4102
Average ADT After: 5133

Type of Accident	Accident Frequency						Total Change (Percent)
	Two Years Before			Two Years After			
	Day	Night	Total	Day	Night	Total	
Angle		1	1	.8	1.6	2.4	+140.0
Head-On	14	4	18	3.8	7.1	10.9	- 39.4
Right-Turn				.8		.8	
Rear-End	10	11	21	6.2	4.0	10.2	- 51.4
Left-Turn	6	3	9	3.2	4.8	8.0	- 11.1
Same Direct	3	1	4	6.5	.8	7.3	+ 82.5
Fixed-Obj.	11	7	18	3.7	8.7	12.4	- 31.1
Off-Road	21	16	37	5.1	11.3	16.4	- 55.7
Animal	5	16	21	.8	6.7	7.5	- 64.3
Other	5	3	8	12.1	10.7	22.8	+185.0
Total	75	62	137	37.9	46.9	84.8	- 38.1
Injury Acc.	25	16	41	11.9	17.2	29.1	- 29.0
Fatal Acc.	5	4	9	1.6	3.2	4.8	- 46.7
No. Inj.	45	28	73	19.2	33.2	52.4	- 28.2
No. Fatal	9	6	15	1.6	8.6	10.2	- 32.0

APPENDIX D

Field Studies
Site Locations

SITE 101

TWO-LANE ROADWAY WITH GRAVEL SHOULDERS

Highway: US 67 Control-Section: 77-3 County: Irion

Length: 7.941 Miles Accident History: 0.75 Acc/Mvm

Operational Data	Eastbound	Westbound
Total Traffic		
Volume	217	174
Average Speed (mph)	62.4	61.7
Standard Deviation (Speed)	7.3	6.8
Truck Traffic		
Volume	22	23
Average Speed (mph)	58.6	58
Standard Deviation (Speed)	6.5	6.4
Percentages of Total Traffic		
Motorcycle	0	0.6
Pick-Up	30	31.0
Farm Vehicle	4.6	4.6
Recreational and Other	3.2	1.7
Truck	10.1	13.2

Site 101, located in southern Irion County, is a 7.941 mile segment of US 67. It is a two-lane roadway with no edgelines, but with gravel shoulders. Horizontal curvature is mild, while the vertical curvature is moderate necessitating frequent no-passing zones through the hilly west Texas terrain.

SITE 108

TWO-LANE ROADWAY WITH GRAVEL SHOULDERS

Highway: US 277   Control-Section: 407-5   County: Taylor

Length: 13.207 Miles   Accident History: 1.71 Acc/Mvm

Operational Data	Northbound	Southbound
Total Traffic		
Volume	230	219
Average Speed (mph)	60.7	61.2
Standard Deviation (Speed)	8.4	8.3
Truck Traffic		
Volume	44	35
Average Speed (mph)	57.8	59.5
Standard Deviation (Speed)	9.4	8.8
Percentage of Total Traffic		
Motorcycle	0	0
Pick-Up	24.3	26.5
Farm Vehicle	1.3	2.3
Recreational and Others	0	3.2
Truck	19.1	16.0

Site 108, located in southwestern Taylor County, is a 13.207 mile segment of US 277. It is a two-lane roadway without edgelines, but with gravel shoulders. Horizontal and vertical curvature are moderately severe requiring numerous climbing lanes and severely limiting passing sight distance while traversing the rolling central Texas terrain.

SITE 205

TWO-LANE ROADWAY, NO SHOULDERS

Highway: US 276   Control-Section: 1017-3   County: Hunt

Length: 5.061 Miles   Accident History: 0.28 Acc/Mvm

Operational Data	Eastbound	Westbound
Total Traffic		
Volume	253	257
Average Speed (mph)	54.2	53.4
Standard Deviation (Speed)	7.7	7.4
Truck Traffic		
Volume	26	24
Average Speed (mph)	51.8	54.0
Standard Deviation (Speed)	9.3	6.8
Percentages of Total Traffic		
Motorcycles	1.2	1.2
Pick-Up	30.4	30.4
Farm Vehicle	3.6	3.4
Recreational and Other	1.6	1.6
Truck	10.3	9.3

Site 205, located in southwestern Hunt County, is a 5.061 mile segment of US 276. It is a two-lane roadway with solid white edgelines, but no shoulders. It has moderate horizontal and vertical curvature which necessitates numerous no-passing zones in traversing the rolling north Texas terrain.

SITE 208

TWO-LANE ROADWAY, NO SHOULDERS

Highway: Tx-35 Control-Section: 179-6 County: Matagorda

Length: 8.142 Miles Accident History: 0.99 Acc/Mvm

Operational Data	Northbound	Southbound
Total Traffic		
Volume	472	465
Average Speed (mph)	57.2	56.3
Standard Deviation (Speed)	1.3	8.2
Truck Traffic		
Volume	92	105
Average Speed (mph)	56.3	56.3
Standard Deviation (Speed)	8.0	8.5
Percentages of Total Traffic		
Motorcycle	0	0.4
Pick-Up	26.5	28.0
Farm Vehicle	0.2	0.2
Recreational and Others	2.1	6.5
Truck	20.3	22.6

Site 208, located in north central Matagorda County, is an 8.142 mile segment of Texas 35. It is a two-lane roadway with solid white edgelines, but no shoulders. Horizontal and vertical curvature are mild in traversing the flat gulf coast plain.

SITE 303

TWO-LANE ROADWAY WITH GRAVEL SHOULDERS

Highway: FM 2100 Control-Section: 1062-4 County: Harris

Length: 7.480 Miles Accident History: 2.50 Acc/Mvm

Operational Data	Eastbound	Westbound
Total Traffic		
Volume	738	828
Average Speed (mph)	53.0	52.0
Standard Deviation (Speed)	9.0	10.2
Truck Traffic		
Volume	74	109
Average Speed (mph)	52.4	49.9
Standard Deviation (Speed)	10.1	9.5
Percentages of Total Traffic		
Motorcycle	0.3	0.5
Pick-Up	37.8	34.5
Farm Vehicle	1.4	1.2
Recreational and Other	1.0	0.8
Truck	10.1	13.2

Site 303, located in northeast Harris County, is a 7.480 mile segment of FM 2100. It is a two-lane roadway with no edgelines, but with gravel shoulders. It has mild horizontal and vertical curvature in traversing the flat gulf coast terrain.

SITE 308

TWO-LANE ROADWAY WITH CRUSHED SHELL SHOULDERS

Highway: US 87 Control-Section: 144-1,2 County: Victoria

Length: 6.740 Miles Accident History: 1.16 Acc/Mvm

Operational Data	Northbound	Southbound
Total Traffic		
Volume	957	832
Average Speed (mph)	55.4	54.1
Standard Deviation (Speed)	7.5	8.7
Truck Traffic		
Volume	99	85
Average Speed (mph)	55.3	52.6
Standard Deviation (Speed)	7.2	9.1
Percentages of Total Traffic		
Motorcycle	0.2	0.1
Pick-Up	27.0	32.0
Farm Vehicle	0.7	1.0
Recreational and Others	1.0	3.0
Truck	10.3	10.2

Site 308, located in southeastern Victoria County, is a 6.740 mile segment of US 87. It is a two-lane roadway with solid white edgelines and crushed shell shoulders. Horizontal and vertical curvature are mild in traversing the flat gulf coast plain.

SITE 408

TWO-LANE ROADWAY WITH PAVED SHOULDERS

Highway: Tx-105 Control-Section: 315-6 County: Washington

Length: 11.750 Miles Accident History: 1.53 Acc/Mvm

Operational Data	Eastbound	Westbound
Total Traffic		
Volume	319	413
Average Speed (mph)	58	60.8
Standard Deviation (Speed)	8.9	6.4
Truck Traffic		
Volume	56	71
Average Speed (mph)	56.6	57.3
Standard Deviation (Speed)	13.2	11.8
Percentages of Total Traffic		
Motorcycles	0.5	0.7
Pick-Up	22.3	27.4
Farm Vehicle	3.1	3.4
Recreational and Other	2.8	2.4
Truck	14.3	17.2

Site 408, located in northeastern Washington County, is a 11.750 mile segment of Texas 105. It is a two-lane roadway with no edgelines, but with a 6-foot paved shoulder or climbing lane (with no shoulder). It has moderate horizontal and vertical curvature in the rolling south central Texas terrain.

SITE 409

TWO-LANE ROADWAY WITH PAVED SHOULDERS

Highway: Tx-158 Control-Section: 463-4 County: Glasscock

Length: 17.693 Miles Accident History: 0.43 Acc/Mvm

Operational Data	Eastbound	Westbound
Total Traffic		
Volume	382	316
Average Speed (mph)	62.2	63.4
Standard Deviation (Speed)	10.8	8.5
Truck Traffic		
Volume	96	77
Average Speed (mph)	60.1	61.6
Standard Deviation (Speed)	12.2	8.3
Percentages of Total Traffic		
Motorcycle	0	0
Pick-Up	0.2	0.2
Farm Vehicle	0.1	0
Recreational and Other	0	0
Truck	0.3	0.2

Site 409, located in west central Glasscock County, is a 17.693 mile segment of Texas 158. It is a two-lane roadway without edgelines, but with paved shoulders. Horizontal and vertical curvature are mild in the flat west central Texas terrain, only minimally restricting passing sight distance.

SITE 501

TWO-LANE ROADWAY WITH PAVED SHOULDERS

Highway: US 90 Control-Section: 24-2 County: Uvalde

Length: 4.521 Miles Accident History: 0.28 Acc/Mvm

Operational Data	Eastbound	Westbound
Total Traffic		
Volume	470	518
Average Speed (mph)	58.4	60.6
Standard Deviation (Speed)	8.2	6.3
Truck Traffic		
Volume	104	123
Average Speed (mph)	57.5	59.7
Standard Deviation (Speed)	8.4	6.7
Percentages of Total Traffic		
Motorcycle	0.4	0.6
Pick-Up	24.0	28.2
Farm Vehicle	3.6	2.5
Recreational and Other	3.6	2.5
Truck	22.1	23.8

Site 501, located in eastern Uvalde County, is a 4.521 mile segment of US 90. It is a two-lane roadway with a painted four-foot median, solid white edgelines, and contrasting, paved shoulders. Horizontal and vertical curvature are mild in traversing the flat south Texas plain. This roadway operates very similar to a poor-boy section because of its 56 foot paved roadway surface width.

SITE 508

TWO-LANE ROADWAY WITH PAVED SHOULDERS

Highway: US 190 Control-Section: 231-1 County: Lampasas

Length: 14.012 Miles Accident History: 1.32 Acc/Mvm

Operational Data	Eastbound	Westbound
Total Traffic		
Volume	650	629
Average Speed (mph)	54.7	54.5
Standard Deviation (Speed)	10.2	8.8
Truck Traffic		
Volume	78	85
Average Speed (mph)	51.1	55.3
Standard Deviation (Speed)	11.2	8.0
Percentages of Total Traffic		
Motorcycle	0.6	0.2
Pick-Up	32.2	29.7
Farm Vehicle	1.0	1.0
Recreational and Others	2.6	1.8
Truck	12.0	13.5

Site 508, located in southwestern Lampasas County, is a 14.012 mile segment of US 190. It is a two-lane roadway without edgelines, but with contrasting paved shoulders. The changes in horizontal alignment are moderate, while the vertical curvature is moderately severe, necessitating numerous climbing lanes while traversing the rolling central Texas terrain.

SITE 604

FOUR-LANE ROADWAY WITHOUT SHOULDERS

Highway: Tx-35 Control-Section: 112-2 County: Brazoria

Length: 16.248 Miles Accident History: 0.66 Acc/Mvm

Operational Data	Eastbound	Westbound
Total Traffic		
Volume	1204	1039
Average Speed (mph)	55.9	56.6
Standard Deviation (Speed)	7.2	19.6
Truck Traffic		
Volume	126	128
Average Speed (mph)	55.0	54.5
Standard Deviation (Speed)	8.5	6.5
Percentage of Total Traffic		
Motorcycle	0.2	0.5
Pick-Up	29.5	27.2
Farm Vehicle	0.3	0.1
Recreational and Others	1.1	1.4
Truck	10.5	12.3

Site 604, located in western Brazoria County, is a 16.248 mile segment of Texas 35. It is a two-lane roadway with solid white edgelines and crushed shell shoulders. The changes in horizontal and vertical alignment are minimal while traversing the flat gulf coast plain, only midly restricting passing sight distance.

SITE 606

TWO-LANE ROADWAY WITH PAVED SHOULDERS

Highway: US 77 Control-Section: 371-1,2 Counties: Victoria and Refugio

Length: 30.636 Miles Accident History: 1.16 Acc/Mvm

Operational Data	Northbound	Southbound
Total Traffic		
Volume	1465	1656
Average Speed (mph)	57.0	58.2
Standard Deviation (Speed)	7.4	6.8
Truck Traffic		
Volume	334	378
Average Speed (mph)	56.4	59.0
Standard Deviation (Speed)	6.8	6.3
Percentage of Total Traffic		
Motorcycle	0.3	0.2
Pick-Up	23.6	27.1
Farm Vehicle	1.0	1.4
Recreational and Others	3.7	4.2
Truck	22.8	22.8

Site 606, located in southern Victoria and northern Refugio Counties, is a 30.636 mile segment of US 77. It is a two-lane roadway with intermittent solid white edgelines and continuous, paved shoulders. Horizontal and vertical curvature are mild and traversing the flat gulf coast terrain except for a couple of sharp horizontal curves. There are several no-passing zones and narrow bridges.

SITE 703

FOUR-LANE ROADWAY WITHOUT SHOULDERS

Highway: US 290   Control-Section: 114-4,5,6   County: Bastrop

Length: 15.106 Miles   Accident History: 0.97 Acc/Mvm

Operational Data	Eastbound	Westbound
Total Traffic		
Volume	674	757
Average Speed (mph)	61.3	60.1
Standard Deviation (Speed)	11.1	7.6
Truck Traffic		
Volume	85	117
Average Speed (mph)	59.0	59.4
Standard Deviation (Speed)	5.4	8.1
Percentages of Total Traffic		
Motorcycles	0.5	0.3
Pick-Up	21.8	19.4
Farm Vehicles	2.1	1.6
Recreational and Other	1.6	1.1
Truck	12.6	15.5

Site 703, located in northeast Bastrop County, is a 15.106 mile segment of US 290. It is a four-lane roadway without edgelines or shoulders. The changes in horizontal alignment are minimal, while the vertical curvature is moderate through the rolling central Texas terrain.

SITE 705

FOUR-LANE ROADWAY WITHOUT SHOULDERS

Highway: Tx-29 Control-Section: 150-5 County: Burnet

Length: 7.034 Miles Accident History: 2.19 Acc/Mvm

Operational Data	Eastbound	Westbound
Total Traffic		
Volume	674	727
Average Speed (mph)	52.8	54.6
Standard Deviation (Speed)	8.2	13.3
Truck Traffic		
Volume	60	76
Average Speed (mph)	52.6	54.5
Standard Deviation (Speed)	8.5	9.5
Percent of Total Traffic		
Motorcycle	0.6	0.8
Pick-Up	29.8	25.0
Farm Vehicle	1.3	1.2
Recreational and Other	4.6	5.5
Truck	8.9	10.5

Site 705, located in east central Burnet County, is a 7.034 mile segment of Texas 29. It is a four-lane undivided roadway without edgelines or shoulders. Horizontal and vertical curvatures are severe in the rolling terrain.

SITE 803

FOUR-LANE ROADWAY WITHOUT SHOULDERS

Highway: US 183 Control-Section: 152-1 County: Travis

Length: 8.472 Miles Accident History: 1.57 Acc/Mvm

Operational Data	Northbound	Southbound
Total Traffic		
Volume	643	676
Average Speed (mph)	58.3	57.0
Standard Deviation (Speed)	10.5	9.2
Truck Traffic		
Volume	72	82
Average Speed (mph)	56.3	54.9
Standard Deviation (Speed)	11.4	7.7
Percentages of Total Traffic		
Motorcycle	0.9	0.2
Pick-Up	27.2	22.9
Farm Vehicle	2.2	2.5
Recreational and Other	1.7	2.8
Truck	11.2	12.1

Site 803, located in southern Travis County, is an 8.472 mile segment of US 183. It is a four-lane roadway with no edgelines or shoulders. It has mild horizontal and vertical curvature in the gently rolling central Texas terrain.

SITE 906

FOUR-LANE ROADWAY WITHOUT SHOULDERS

Highway: US 59 Control-Section: 218-3 County: Cass

Length: 7.293 Miles Accident History: 1.17 Acc/Mvm

Operational Data	Northbound	Southbound
Total Traffic		
Volume	1143	1235
Average Speed (mph)	59.6	58.2
Standard Deviation (Speed)	14.3	6.6
Truck Traffic		
Volume	247	238
Average Speed (mph)	58.6	56.9
Standard Deviation (Speed)	6.5	7.7
Percentage of Total Traffic		
Motorcycle	0.1	0.3
Pick-Up	21.9	22.2
Farm Vehicle	0.4	0.2
Recreational and Others	2.4	1.5
Truck	21.6	19.3

Site 906, located in northeast Cass County, is a 7.293 mile segment of US 59. It is a four-lane roadway with solid white edgelines, but without shoulders. The changes in horizontal alignment are minimal, while the vertical curvature is moderate through the gently rolling northeast Texas terrain.

SITE 1002

TWO-LANE ROADWAY WITH PAVED SHOULDERS

Highway: Tx-21 Control-Section: 116-2 Counties: Burleson and Lee

Length: 10.186 Miles Accident History: 0.80 Acc/Mvm

Operational Data	Eastbound	Westbound
Total Traffic		
Volume	376	348
Average Speed (mph)	58.5	59.3
Standard Deviation (Speed)	9.9	9.9
Truck Traffic		
Volume	78	45
Average Speed (mph)	56.3	55.8
Standard Deviation (Speed)	9.4	12.7
Percentages of Total Traffic		
Motorcycle	0.8	0
Pick-Up	25.3	27.3
Farm Vehicle	1.9	4.0
Recreational and Other	3.7	3.2
Truck	20.7	12.9

Site 1002, located in southwest Burleson and northeast Lee Counties is a 10.186 mile segment of Texas 21. It is a four-lane roadway with no shoulders. Horizontal and vertical curvature are moderate in the gently rolling central Texas hills.

SITE 1009

FOUR-LANE ROADWAY WITHOUT SHOULDERS

Highway: US 290 Control-Section: 112-2 County: Gillespie

Length: 10.310 Miles Accident History: 1.76 Acc/Mvm

Operational Data	Eastbound	Westbound
Total Traffic		
Volume	138	107
Average Speed (mph)	58.7	61.0
Standard Deviation (Speed)	10.4	7.4
Truck Traffic		
Volume	19	8
Average Speed (mph)	61.0	62.4
Standard Deviation (Speed)	7.9	7.9
Percentages of Total Traffic		
Motorcycle	2.9	0
Pick-Up	28.3	26.2
Farm Vehicle	2.9	0.9
Recreational and Other	5.8	6.5
Truck	13.8	7.5

Site 1009, located in western Gillespie County, is a 10.310 mile segment of US 290. It is a four-lane roadway without edgelines or shoulders. The changes in horizontal alignment are severe, while the vertical curvature is moderate through the rolling central Texas terrain.