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16. Abstract This report describes a study in which driver understanding of 52 traffic control devices was evaluated through five different evaluation procedures. The traffic control devices evaluated in the study include 13 regulatory signs, 18 warning signs, 10 other types of signs, 7 pavement markings, and 5 signal indications. The five procedures described in the report include a statewide survey of 1,745 drivers, two different surveys administered at auto shows to a total of 608 drivers, a Spanish-language survey of 31 drivers, and 3 focus groups of 10 drivers each. The statewide, 1992 Auto Show, and Spanish-language surveys used a multiple-choice format, while the 1993 Auto Show and focus groups utilized an open-ended response format. In all, 2,414 drivers participated in the evaluations. The report also describes the findings, recommendations, and implementation efforts associated with each of the 52 traffic control devices. Recommendations include changes to the Texas MUTCD, changes in TxDOT practices, revisions of the <i>Texas Drivers Handbook</i> , changes in the driver education/driver safety course curriculums, a public information campaign, and the conduct of additional research.			
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**MOTORIST UNDERSTANDING OF
TRAFFIC CONTROL DEVICES:
STUDY RESULTS AND RECOMMENDATIONS**

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IMPLEMENTATION STATEMENT

The results of this study are a series of recommendations identifying changes in the design, use, and/or education regarding existing traffic control devices, plus the identification of areas needing additional study. Implementation of the recommendations may be instituted through changes in TxDOT practices regarding the design and use of traffic control devices, changes to the *Texas Manual on Uniform Traffic Control Devices*, possible changes to the curriculum in driver education and driver safety courses, possible changes to the *Texas Drivers Handbook* published by the Texas Department of Public Safety, development of public information campaign on selected traffic control devices, and the conduct of additional research to evaluate alternative designs for selected traffic control devices.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation, and is not intended for construction, bidding or permit purposes.

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TABLE OF CONTENTS

	Page
LIST OF FIGURES	xiii
LIST OF TABLES	xxi
SUMMARY	xxv
CHAPTER I - INTRODUCTION	I-1
STUDY OBJECTIVES	I-2
RESEARCH APPROACH	I-3
USE OF METRIC UNITS IN RESEARCH	I-6
CHAPTER II - STATEWIDE EVALUATION	II-1
PREVIOUS RESEARCH	II-1
SURVEY DEVELOPMENT	II-2
SURVEY ADMINISTRATION	II-4
SUMMARY OF STATEWIDE SURVEY RESULTS	II-5
LIMITATIONS OF STATEWIDE SURVEY RESULTS	II-6
USE OF STATEWIDE SURVEY RESULTS	II-7
CHAPTER III - FOLLOW-UP EVALUATIONS	III-1
1992 AUTO SHOW SURVEY	III-1
1993 AUTO SHOW SURVEY	III-13
SPANISH LANGUAGE SURVEY	III-18
FOCUS GROUP EVALUATIONS	III-20

CHAPTER IV - FINDINGS AND RECOMMENDATIONS	IV-1
INTERPRETATION OF SURVEY RESULTS	IV-3
DEVICES EVALUATED IN RESEARCH STUDY	IV-5
REGULATORY SIGNS	IV-5
WARNING SIGNS	IV-27
OTHER TYPES OF SIGNS	IV-52
PAVEMENT MARKINGS	IV-64
SIGNAL INDICATIONS	IV-71
CHAPTER V - IMPLEMENTATION ACTIVITIES	V-1
NO ACTION	V-1
CHANGES TO TxDOT PRACTICES	V-2
DRIVER TRAINING PROGRAMS	V-4
ADDITIONAL RESEARCH	V-9
SUMMARY OF IMPLEMENTATION ACTIVITIES	V-11
CHAPTER VI - SUMMARY OF RECOMMENDATIONS AND IMPLEMENTATION EFFORTS	VI-1
CHAPTER VII - REFERENCES	VII-1
APPENDIX A - STATEWIDE SURVEY SUMMARY	A-1
APPENDIX B - 1992 AUTO SHOW SURVEY SUMMARY	B-1
APPENDIX C - 1993 AUTO SHOW SURVEY SUMMARY	C-1
APPENDIX D - FOCUS GROUPS VISUALS	D-1
APPENDIX E - TxDOT MEMO REVISING SIGNING PRACTICES	E-1

LIST OF FIGURES

Figure	Title	Page
III-1	Double Turn Sign	III-5
III-2	Two-Way Left Turn Lane Signs	III-6
III-3	Slow Down on Wet Road Sign and Alternatives - 1992 Auto Show Survey	III-8
III-4	School Advance Signs	III-9
III-5	Uneven Pavement Construction Signs	III-10
III-6	ONE-WAY Sign	III-12
III-7	Keep Right Sign	III-15
III-8	Reverse Turn and Winding Road Signs	III-16
III-9	LANE ENDS MERGE LEFT Sign	III-17
III-10	RAMP METERED WHEN FLASHING Sign	III-18
III-11	Lane Reduction Transition Sign and Alternatives	III-22
III-12	Slow Down on Wet Road Sign and Alternatives - Focus Groups	III-23
IV-1	R1-2 Sign	IV-5
IV-2	R5-2a Sign	IV-11
IV-3	R2-5c Sign	IV-11
IV-4	R3-7 Sign	IV-13
IV-5	R3-8 Sign	IV-14
IV-6	Two-Way Left Turn Lane Markings	IV-16
IV-7	R3-9b Sign	IV-16
IV-8	Alternative Sign	IV-17
IV-9	HOV Restriction Sign	IV-18
IV-10	Diamond Marking	IV-18
IV-11	R4-3 Sign	IV-21
IV-12	R4-7 Sign	IV-23
IV-13	R10-9 Sign	IV-24
IV-14	R10-9a Sign	IV-24
IV-15	R10-12 Sign	IV-24

IV-16	W1-1 Sign	IV-28
IV-17	W1-2 Sign	IV-28
IV-18	W1-3 Sign	IV-28
IV-19	W1-5 Sign	IV-28
IV-20	W3-1a Sign	IV-33
IV-21	W4-2 Sign	IV-34
IV-22	W9-1 Sign	IV-34
IV-23	W9-2 Sign	IV-34
IV-24	First Alternative	IV-36
IV-25	Second Alternative	IV-36
IV-26	W5-2a Sign	IV-37
IV-27	W6-2 Sign	IV-39
IV-28	W8-5 Sign	IV-40
IV-29	Std. Sign with Educational Plaque	IV-41
IV-30	Word Message Alternative Sign	IV-41
IV-31	Symbol Alternative Sign	IV-42
IV-32	W8-8 Sign	IV-43
IV-33	W8-12 Sign	IV-43
IV-34	W11-10 Sign	IV-45
IV-35	W14-4 Sign	IV-47
IV-36	W19-2 Sign	IV-48
IV-37	W19-3 Sign	IV-50
IV-38	W10-1 Sign	IV-55
IV-39	W10-3 Sign	IV-55
IV-40	S1-1 Sign	IV-57
IV-41	Alternative Sign	IV-58
IV-42	S5-1 Sign	IV-60
IV-43	Uneven Pavement Construction Warning Signs	IV-62
IV-44	Type 3 Object Marker	IV-64
IV-45	Center Line Patterns	IV-65
IV-46	Lane Line Patterns	IV-68
IV-47	R4-3b Sign	IV-68
IV-48	Steady Red X LCS Indication	IV-76

A-1a	In-Context Picture: Slow Down on Wet Road sign	A-4
A-1b	Close-up Picture with Response Choices: Slow Down on Wet Road sign . .	A-4
A-2a	In-Context Picture: Railroad Advance Warning sign	A-5
A-2b	Close-up Picture with Response Choices: Railroad Advance Warning sign .	A-5
A-3a	In-Context Picture: SPEED ZONE AHEAD sign	A-6
A-3b	Close-up Picture with Response Choices: SPEED ZONE AHEAD sign . . .	A-6
A-4a	In-Context Picture: YIELD sign	A-7
A-4b	Close-up Picture with Response Choices: YIELD sign	A-7
A-5a	In-Context Picture: Mandatory Turn sign	A-8
A-5b	Close-up Picture with Response Choices: Mandatory Turn sign	A-8
A-6a	In-Context Picture: Two-Way Left Turn markings	A-9
A-6b	Close-up Picture with Response Choices: Two-Way Left Turn markings . . .	A-9
A-7a	In-Context Picture: WATCH FOR ICE ON BRIDGE sign	A-10
A-7b	Close-up Picture with Response Choices: WATCH FOR ICE ON BRIDGE sign	A-10
A-8a	In-Context Picture: Curve sign	A-11
A-8b	Close-up Picture with Response Choices: Curve sign	A-11
A-9a	In-Context Picture: Keep Right sign	A-12
A-9b	Close-up Picture with Response Choices: Keep Right sign	A-12
A-10a	In-Context Picture: SLOWER TRAFFIC KEEP RIGHT sign	A-13
A-10b	Close-up Picture with Response Choices: SLOWER TRAFFIC KEEP RIGHT sign	A-13
A-11a	In-Context Picture: Flashing Yellow Beacon signal	A-14
A-11b	Close-up Picture with Response Choices: Flashing Yellow Beacon signal .	A-14
A-12a	In-Context Picture: LIMITED SIGHT DISTANCE sign	A-15
A-12b	Close-up Picture with Response Choices: LIMITED SIGHT DISTANCE sign	A-15
A-13a	In-Context Picture: Solid White Edge Line marking	A-16
A-13b	Close-up Picture with Response Choices: Solid White Edge Line marking .	A-16
A-14a	In-Context Picture: Type 3 Object Marker	A-17
A-14b	Close-up Picture with Response Choices: Type 3 Object Marker	A-17
A-15a	In-Context Picture: Narrow Bridge sign	A-18
A-15b	Close-up Picture with Response Choices: Narrow Bridge sign	A-18

A-16a	In-Context Picture: Stop Ahead sign	A-19
A-16b	Close-up Picture with Response Choices: Stop Ahead sign	A-19
A-17a	In-Context Picture: Double Solid White Lane Line	A-20
A-17b	Close-up Picture with Response Choices: Double Solid White Lane Line	A-20
A-18a	In-Context Picture: REDUCED SPEED AHEAD sign	A-21
A-18b	Close-up Picture with Response Choices: REDUCED SPEED AHEAD sign	A-21
A-19a	In-Context Picture: Lane Reduction Transition sign	A-22
A-19b	Close-up Picture with Response Choices: Lane Reduction Transition sign	A-22
A-20a	In-Context Picture: Single Broken Yellow Centerline marking	A-23
A-20b	Close-up Picture with Response Choices: Single Broken Yellow Centerline marking	A-23
A-21a	In-Context Picture: Reverse Turn Sign	A-24
A-21b	Close-up Picture with Response Choices: Reverse Turn Sign	A-24
A-22a	In-Context Picture: Flashing Red Beacon signal	A-25
A-22b	Close-up Picture with Response Choices: Flashing Red Beacon signal	A-25
A-23a	In-Context Picture: Divided Highway Ends sign	A-26
A-23b	Close-up Picture with Response Choices: Divided Highway Ends sign	A-26
A-24a	In-Context Picture: No-Passing Zone markings	A-27
A-24b	Close-up Picture with Response Choices: No-Passing Zone markings	A-27
A-25a	In-Context Picture: Parallel Railroad Advance Warning sign	A-28
A-25b	Close-up Picture with Response Choices: Parallel Railroad Advance Warning sign	A-28
A-26a	In-Context Picture: Turn sign	A-29
A-26b	Close-up Picture with Response Choices: Turn sign	A-29
A-27a	In-Context Picture: GROOVED PAVEMENT AHEAD sign	A-30
A-27b	Close-up Picture with Response Choices: GROOVED PAVEMENT AHEAD sign	A-30
A-28a	In-Context Picture: LANE ENDS MERGE LEFT sign	A-31
A-28b	Close-up Picture with Response Choices: LANE ENDS MERGE LEFT sign	A-31
A-29a	In-Context Picture: SCHOOL SPEED LIMIT sign	A-32
A-29b	Close-up Picture with Response Choices: SCHOOL SPEED LIMIT sign	A-32

A-30a	In-Context Picture: PROTECTED LEFT ON GREEN sign	A-33
A-30b	Close-up Picture with Response Choices: PROTECTED LEFT ON GREEN sign	A-33
A-31a	In-Context Picture: Single Broken White Lane Line marking	A-34
A-31b	Close-up Picture with Response Choices: Single Broken White Lane Line marking	A-34
A-32a	In-Context Picture: Flashing Yellow Ball signal	A-35
A-32b	Close-up Picture with Response Choices: Flashing Yellow Ball signal . . .	A-35
A-33a	In-Context Picture: Two-Way Left Turn Lane sign	A-36
A-33b	Close-up Picture with Response Choices: Two-Way Left Turn Lane sign .	A-36
A-34a	In-Context Picture: PROTECTED LEFT ON GREEN ARROW sign	A-37
A-34b	Close-up Picture with Response Choices: PROTECTED LEFT ON GREEN ARROW sign	A-37
A-35a	In-Context Picture: Truck Crossing sign	A-38
A-35b	Close-up Picture with Response Choices: Truck Crossing sign	A-38
A-36a	In-Context Picture: DO NOT CROSS DOUBLE WHITE LINE sign	A-39
A-36b	Close-up Picture with Response Choices: DO NOT CROSS DOUBLE WHITE LINE sign	A-39
A-37a	In-Context Picture: RAMP METERED WHEN FLASHING sign	A-40
A-37b	Close-up Picture with Response Choices: RAMP METERED WHEN FLASHING sign	A-40
A-38a	In-Context Picture: ROUGH ROAD sign	A-41
A-38b	Close-up Picture with Response Choices: ROUGH ROAD sign	A-41
A-39a	In-Context Picture: Double Turn sign	A-42
A-39b	Close-up Picture with Response Choices: Double Turn sign	A-42
A-40a	In-Context Picture: LEFT TURN YIELD ON GREEN Ball sign	A-43
A-40b	Close-up Picture with Response Choices: LEFT TURN YIELD ON GREEN Ball sign	A-43
A-41a	In-Context Picture: Preferential Lane marking (diamond)	A-44
A-41b	Close-up Picture with Response Choices: Preferential Lane marking (diamond)	A-44
A-42a	In-Context Picture: Yellow Arrow signal	A-45
A-42b	Close-up Picture with Response Choices: Yellow Arrow signal	A-45

A-43a	In-Context Picture: Steady Red X Lane-Use Control signal	A-46
A-43b	Close-up Picture with Response Choices: Steady Red X Lane-Use Control signal	A-46
A-44a	In-Context Picture: HOV Restriction sign	A-47
A-44b	Close-up Picture with Response Choices: HOV Restriction sign	A-47
A-45	Close-Up Picture with Response Choices: Warning Sign Shape and Color .	A-48
A-46	Close-Up Picture with Response Choices: Guide Sign Color	A-49
B-1	Example of Image Used in 1992 Auto Show Survey	B-3
B-2	Double Turn Sign (R3-8)	B-4
B-3	Two-Way Left Turn Lane Sign (R3-9b)	B-5
B-4	One-Way Sign (R6-1) and Pavement Marking Color	B-5
B-5	Turn Sign (W1-1) with and without Advisory Speed Plate (W13-1)	B-6
B-6	Slow Down on Wet Road Sign (W8-5) and Alternatives	B-6
B-7	School Advance Sign (S1-1) and Alternative	B-7
B-8	Uneven Pavement Construction Signs	B-7
B-9	Intersection Control Beacon with no Supplemental Plaques	B-8
B-10	Intersection Control Beacon with One 2-WAY Supplemental Plaque	B-8
B-11	Intersection Control Beacon with Two 2-WAY Supplemental Plaques	B-9
B-12	Summary of Results for Intersection Control Beacon Questions	B-9
C-1	Signs Evaluated in the 1993 Auto Show Survey	C-1
C-2a	Interview Form Used for the Signs in 1993 Auto Show Survey	C-2
C-2b	Interview Form Used in 1993 Auto Show Survey	C-3
C-3	Keep Right (R4-7) Sign	C-5
C-4	Reverse Turn (W1-3) Sign	C-6
C-5	Winding Road (W1-5) Sign	C-6
C-6	Lane Ends Merge Left (W9-2) Sign	C-7
C-7	Ramp Metered When Flashing (W19-3) Sign	C-8
D-1	Typical Two-Way Stop Controlled Intersection	D-2
D-2	Use of 2-WAY Supplemental Plate Below the STOP Sign	D-2
D-3	Use of 2-WAY Supplemental Plate Below the Beacon	D-3

D-4	Use of 2-WAY Supplemental Plate Below the STOP Sign and the Beacon . .	D-3
D-5	Use of Yellow STOP Sign to Identify Two-Way Stop Intersection	D-4
D-6	Use of Purple STOP Sign to Identify Two-Way Stop Intersection	D-4
D-7a	Black-on-Yellow Supplemental Plaque	D-5
D-7b	Warning Sign for Two-Way Stop	D-5
D-7c	Black-on-White Supplemental Plaque	D-5
D-8	Standard Lane Reduction Transition Sign and Alternatives	D-7
D-9	Use of Word Message Signs with the Symbol Sign	D-7
D-10	Slow Down on Wet Road Symbol Sign	D-8
D-11	Slow Down on Wet Road Symbol and Word Message Signs	D-8
D-12	Slow Down on Wet Road Standard Signs and Alternative Symbol Sign . . .	D-8
E-1	R2-5a Sign	E-5
E-2	R2-5c Sign	E-5
E-3	W1-1 Sign	E-6
E-4	W1-2 Sign	E-6
E-5	W6-2 Sign	E-7
E-6	W8-8 Sign	E-8
E-7	W8-12 Sign	E-8
E-8	R4-3b Sign	E-9

LIST OF TABLES

Table	Title	Page
I-1	Types of Traffic Control Devices	I-1
II-1	Factors Considered in Selection of Devices	II-2
II-2	Sociodemographic Characteristics of Survey Sample	II-4
II-3	Driving Characteristics of Survey Sample	II-5
III-1	Summary of Follow-Up Evaluations	III-2
III-2	Traffic Control Devices Included in Follow-Up Evaluations	III-2
III-3	Organization of 1992 Auto Show Survey	III-4
III-4	Sociodemographic Characteristics of 1992 Auto Show Survey	III-4
III-5	1992 Auto Show Survey Results for the Double Turn Sign	III-5
III-6	1992 Auto Show Survey Results for the Two-Way Left Turn Lane Sign . .	III-6
III-7	1992 Auto Show Survey Results for the Turn Sign	III-7
III-8	1992 Auto Show Survey Results for the Slow Down on Wet Road Sign . .	III-8
III-9	1992 Auto Show Survey Results for the School Advance Sign	III-9
III-10	1992 Auto Show Results for the Uneven Pavement Construction Signs . .	III-11
III-11	1992 Auto Show Survey Scenarios and Results for the Flashing Red Intersection Control Beacon	III-11
III-12	1992 Auto Show Survey Results for the ONE-WAY Sign and Color of Pavement Markings	III-12
III-13	Sociodemographic Characteristics of 1993 Auto Show Survey	III-14
IV-1	Z Test for Two Binomial Proportions	IV-4
IV-2	Precision of Survey Responses	IV-4
IV-3	Regulatory Signs Evaluated in Research Study	IV-6
IV-4	Warning Signs Evaluated in Research Study	IV-7
IV-5	Other Types of Signs Evaluated in Research Study	IV-8
IV-6	Pavement Markings Evaluated in Research Study	IV-9
IV-7	Traffic Signal Indications Evaluated in Research Study	IV-9

IV-8	Research Summary for the YIELD Sign	IV-10
IV-9	Research Summary for the REDUCED SPEED AHEAD and SPEED ZONE AHEAD Signs	IV-12
IV-10	Research Summary for the Mandatory Turn Sign	IV-14
IV-11	Research Summary for the Double Turn Sign	IV-15
IV-12	Research Summary for the Two-Way Left Turn Lane Sign and Pavement Marking	IV-18
IV-13	Comprehension of HOV Sign in Dallas and Houston	IV-20
IV-14	Comprehension of HOV Pavement Marking in Dallas and Houston	IV-20
IV-15	Research Summary for the HOV Restriction Sign and Diamond Pavement Marking	IV-21
IV-16	Research Summary for the SLOWER TRAFFIC KEEP RIGHT Sign . . .	IV-22
IV-17	Research Summary for the Keep Right Sign	IV-24
IV-18	Uses of Left Turn Signal Signs	IV-24
IV-19	Summary of Statewide Survey Results for Left Turn Signal Signs	IV-25
IV-20	Research Summary for the Left Turn Signal Signs	IV-27
IV-21	Advance Warning Signs for Changes in Horizontal Alignment	IV-28
IV-22	Survey Results for the Turn Sign	IV-30
IV-23	Research Summary for Horizontal Alignment Signs	IV-32
IV-24	Research Summary for the Stop Ahead Sign	IV-34
IV-25	Research Summary for the Lane Reduction Transition Signs	IV-37
IV-26	Research Summary for the Narrow Bridge Sign	IV-39
IV-27	Research Summary for the Divided Highway Ends Sign	IV-40
IV-28	Research Summary for the Slow Down on Wet Road Sign	IV-43
IV-29	Research Summary for Pavement Surface Condition Signs	IV-45
IV-30	Research Summary for the Truck Crossing Sign	IV-46
IV-31	Research Summary for the LIMITED SIGHT DISTANCE Sign	IV-48
IV-32	Research Summary for the WATCH FOR ICE ON BRIDGE Sign	IV-49
IV-33	Comprehension of Ramp Meter Sign in Dallas and Houston	IV-51
IV-34	Research Summary for the RAMP METERED WHEN FLASHING Sign	IV-52
IV-35	Comprehension of Sign Shape and Color	IV-54
IV-36	Research Summary for Sign Shape and Color	IV-55
IV-37	Research Summary for the Railroad Warning Signs	IV-57

IV-38	Research Summary for the School Advance Sign	IV-59
IV-39	Research Summary for the SCHOOL SPEED LIMIT Sign	IV-61
IV-40	Intended Applications of Uneven Pavement Construction Signs	IV-62
IV-41	Research Summary for the Uneven Pavement Construction Signs	IV-63
IV-42	Research Summary for a Type 3 Object Marker	IV-65
IV-43	Research Summary for Center Line Pavement Markings	IV-67
IV-44	Research Summary for Lane Line Markings and Signing	IV-70
IV-45	Research Summary for the Solid White Edge Line Marking	IV-71
IV-46	Research Summary for the Yellow Traffic Signal Indications	IV-73
IV-47	Research Summary for the Flashing Intersection Beacon Indications . . .	IV-75
IV-48	Research Summary for the Steady Red X Lane-Use Control Indication . .	IV-77
V-1	Possible Public Information Campaigns for Implementation of Study Findings	V-10
VI-1	Summary of Evaluation Procedures	VI-1
VI-2	Summary of Regulatory Signs Evaluations	VI-3
VI-3	Summary of Warning Signs Evaluations	VI-4
VI-4	Summary of Other Signs Evaluations	VI-5
VI-5	Summary of Markings Evaluations	VI-6
VI-6	Summary of Signal Indications Evaluations	VI-7
VI-7	Summary of Implementation Activities for Regulatory Signs	VI-8
VI-8	Summary of Implementation Activities for Warning Signs	VI-9
VI-9	Summary of Implementation Activities for Other Signs	VI-10
VI-10	Summary of Implementation Activities for Markings	VI-10
VI-11	Summary of Implementation Activities for Traffic Signal Indications . . .	VI-11
A-1	Cross-Reference for Traffic Sign Questions	A-2
A-2	Cross-Reference for Pavement Marking and Traffic Signal Indication Questions	A-3
A-3	Sociodemographic Characteristics of Survey Sample	A-3
B-1	Traffic Control Devices Evaluated in the 1992 Auto Show Survey	B-1
B-2	Sociodemographic Characteristics of 1992 Auto Show Survey	B-2

C-1	Sociodemographic Characteristics of 1993 Auto Show Survey	C-4
C-2	1993 Auto Show Survey Results for Keep Right Sign	C-5
C-3	1993 Auto Show Survey Results for Reverse Turn and Winding Road Signs	C-6
C-4	1993 Auto Show Survey Results for Lane Ends Merge Left Sign	C-7
C-5	Summary of Responses for RAMP METERED WHEN FLASHING SIGN .	C-8
E-1	Statewide Survey Results for Changes in Speed Limit Signs	E-5
E-2	Survey Results for the Turn Sign	E-6
E-3	Statewide Survey Results for the Curve Sign	E-7
E-4	Statewide Survey Results for the Divided Highway Ends Sign	E-7
E-5	Statewide Survey Results for Pavement Condition Signs	E-8
E-6	Statewide Survey Results for Double White Line Marking	E-9
E-7	Statewide Survey Results for the Do Not Cross Double White Line Sign .	E-10

SUMMARY

In 1990, the Texas Transportation Institute (TTI) began a research study evaluating motorist understanding of traffic control devices. TTI conducted this study, which was sponsored by the Texas Department of Transportation (TxDOT), in order to improve one of the key means of communicating information to drivers. There were two major objectives in this research study: 1) assess driver understanding of selected existing traffic control devices, and 2) recommend actions to increase understanding of those devices which demonstrated a potential for improvement.

A total of 52 different traffic control devices were evaluated through the use of 5 evaluation procedures. A total of 2,414 drivers took part in the evaluations. Four of the procedures utilized a survey format and the other procedure used focus groups. The largest and most detailed of the evaluation procedures was a statewide survey of 46 devices which was given to 1,745 drivers in 12 Texas cities. The results of the statewide survey were used to identify and select devices for further examination in the follow-up evaluations. These evaluations included two smaller surveys on 5 and 10 devices each which were administered to about 300 drivers at the Houston Auto Show. A Spanish-language survey was given to 31 drivers and three focus groups of 10 drivers each were also conducted. Appendices A, B, C, and D contain the images, questions, and responses for the statewide, Auto Shows, and focus groups evaluations.

The results of all five evaluations were carefully analyzed and the findings were used to identify devices which demonstrated the potential for improving driver understanding. Recommendations for improving driver understanding focused on four basic implementation activities: no action, a change in TxDOT practices, increasing emphasis in driver education/training programs, and conducting additional research. Changes in TxDOT practices can be further divided into changes implemented through a memorandum to districts, changes in the *Texas Manual on Uniform Traffic Control Devices*, adoption of a new Part VI on traffic control for construction and maintenance operations, and other future actions. Driver education/training activities include potential changes in the course curriculums for driver education and driver safety courses, potential changes to the *Texas Drivers Handbook*, or a public information campaign. The additional research will be conducted in future efforts of this study.

CHAPTER I

INTRODUCTION

Traffic control devices are a vital element of the highway environment as they provide one of the primary means of communicating important information about the roadway to road users. The primary purpose of traffic control devices is to regulate, warn, and/or guide traffic in such a manner as to promote the safe and uniform operation of motorized and non-motorized traffic using the roadway. As shown in Table I-1, there are three basic types of traffic control devices (signs, markings, and signals) and several subtypes for each basic type. These devices use shape, color, symbols, and/or words to convey the information needed by a driver. Drivers rely upon these devices to: provide information about applicable traffic laws/regulations, identify potential hazards that they may not be aware of, provide information to help them find their way or identify points of reference, and to confirm or reassure their intended driving behavior.

Table I-1. Types of Traffic Control Devices

Basic Type	Description	Most Common Subtypes ¹
Signs	Devices mounted on a post or overhead structure which provide road users with information about traffic laws/regulations, potential hazards on or adjacent to the roadway, guidance information to direct road users to destinations, or general information about services and points of interest	Regulatory Signs
		Warning Signs
		Guide Signs
Markings	Devices placed on or adjacent to the roadway which are used to direct road users along an identified path or away from potential hazards.	Pavement Markings
		Object Markers
		Delineators
Signals	Electrically powered devices which are used to control the movement of vehicles and pedestrians at an intersection, to warn road users of potential intersection conflicts, or to identify the proper use of reversible traffic lanes.	Traffic Control Signals
		Pedestrian Signals
		Intersection Beacons
		Lane-Use Control Signals

Notes: ¹Other subtypes may also exist.

The effectiveness of these devices is a function of many different factors. A study of the effectiveness of symbol signs suggested that the criteria listed below should be considered in an overall evaluation of the effectiveness of a symbol traffic sign (1). The study also evaluated the relative importance of the criteria. They are listed in the order of importance.

- **Understandability.** The ability to understand or comprehend the meaning of a sign by associating the color, shape, and legend (text or symbol) with the intent of the sign.
- **Recognition Time.** The time required to identify the meaning of the sign.
- **Conspicuity.** The ability to see or detect a sign in a complex environment.
- **Legibility Distance.** The greatest distance at which the sign can be clearly "read."
- **Glance Legibility.** The ability to comprehend a sign which is seen for only a fraction of a second.
- **Learnability.** The ability to remember the meaning of a sign once the actual meaning has been learned.

The same study found that understandability, or comprehension, was considered to be the most important of all the criteria. A driver must be able to understand a traffic control device, or some part of it, before the proper response can be made. Potential explanations for confusion over the meaning of traffic control devices include:

- The increasing age of the driving population,
- The increasing complexity of the driving task in urban areas,
- Specialized traffic control devices utilized with priority transportation facilities,
- The increased proportion of Hispanic drivers in Texas,
- A limited explanation of traffic control devices given in the driver education and licensing process, and/or
- Non-uniform and/or non-standard design or application of some traffic control devices.

STUDY OBJECTIVES

This study was conducted to measure and assess how well motorists understand the meaning of selected traffic control devices. The objectives associated with this study include:

- Identify traffic control devices which have the potential for driver misunderstanding, as indicated in previous research.
- Identify additional traffic control devices which have not been evaluated, but for which there may be concern over driver misunderstanding.
- Select the most important of these misunderstood devices for evaluation.

- Measure driver understanding of the selected devices using a representative survey of Texas drivers.
- Evaluate driver understanding as a function of the following characteristics:
 - ▶ Age.
 - ▶ Sex.
 - ▶ Education.
 - ▶ Ethnic background.
 - ▶ Language.
 - ▶ Driving experience.
 - ▶ Geographic region.
- Conduct additional evaluations of certain devices as necessary in order to refine the assessment of driver understanding.
- Develop recommendations for improving driver understanding of the selected traffic control devices.

RESEARCH APPROACH

This study utilizes scientific evaluation methods to assess motorist understanding of traffic control devices. During the course of the study, a number of research activities were conducted in an effort to meet the study objectives described above. The activities associated with the statewide survey were conducted in the first two years of the study. Previous research reports describe those activities (2, 3). Other activities were associated with several follow-up evaluations conducted in the second and third years of the study. The follow-up evaluations included two Auto Show surveys, a Hispanic survey, and three focus groups.

Statewide Survey

The major effort of this research study was the development and administration of a statewide survey to assess driver comprehension of traffic control devices. A total of 46 devices were selected for inclusion in this survey. The survey instrument was a 17-minute video in which two images were shown to the driver for each traffic control device. The first image was an actual in-context picture of the device. The second image was a close-up image of the device along with four possible response choices. The survey was administered to 1,745 drivers at

driver license stations in twelve Texas cities. Research activities associated with the development of the survey instrument and survey methodology are described in the first year report (2). The results of the statewide survey are described in the second year report (3). Chapter II of this report summarizes the major activities associated with the development and administration of the statewide survey. Appendix A contains the images that were presented to survey participants for each device. It also indicates the percentage of drivers who selected each of the response choices.

Follow-Up Evaluations

The results of the statewide survey indicated that additional evaluations were necessary for several traffic control devices. Therefore, four follow-up evaluations were conducted. These evaluations included two Auto Show surveys, a Hispanic survey, and focus groups. Typically, the devices included in the follow-up evaluations were selected because previous evaluations demonstrated that drivers do not fully understand one or more of the messages conveyed by the devices. One of the follow-up evaluations (the Spanish-language survey) addressed all 46 of the devices included in the statewide survey. A total of 16 traffic control devices were evaluated in the other three follow-up evaluations. Five of the 16 had not been included in the statewide survey. Alternative designs were evaluated for five of the 16 devices. The activities associated with these follow-up evaluations are described in Chapter III of this report.

1992 Auto Show Survey

The first follow-up evaluation was a survey administered at the 1992 Houston Auto Show. The survey instrument consisted of a close-up image of a traffic control device with the possible response choices, where appropriate. Ten devices were evaluated in this survey. Eight of the questions used a multiple-choice format, one used a true/false format, and one was an open-ended question. Alternative designs were evaluated for four of the devices. The survey was administered to 322 participants. Appendix B contains the images that were presented to survey participants. It also indicates the percentage of drivers who selected each of the response choices for each question.

1993 Auto Show Survey

Another follow-up survey was administered at the 1993 Houston Auto Show. This survey evaluated five devices in an open-ended format. A total of 286 drivers were shown a close-up picture of a sign and were then asked to describe the meaning of, or appropriate driving response to, the sign. Appendix C contains the questionnaire form that was used by the survey administrators in questioning survey participants. Appendix C also summarizes the responses for each of the devices in the 1993 Auto Show survey.

Hispanic Survey

In order to assess the relationship between primary language and understanding of traffic control devices, the statewide survey was administered to drivers who spoke Spanish as their primary language. Before administering the Hispanic survey, the statewide survey video was dubbed in Spanish. However, the images and response choices presented in the video remained in English. A Spanish-speaking surveyor administered the survey to 31 drivers in Eagle Pass, Texas, which was one of the cities included in the statewide survey.

Focus Groups

Three focus groups were conducted in order to obtain driver opinions about three traffic control devices and potential alternative designs or uses. The focus groups were conducted in Rockport, Somerville, and College Station, Texas. There were 10 participants in each focus group. The images presented to drivers participating in the focus groups are contained in Appendix D.

Findings and Recommendations

The results of all of the study evaluations were used to determine the findings for each of the traffic control devices evaluated in this research study. The findings were then used to develop recommendations for improving motorist understanding of those traffic control devices targeted for improvement. When recommendations were made for a traffic control device, they typically included one or more of the following: a change in the use of the device, a change in

the design of the device, adding a description of the device to the *Texas Drivers Handbook* (TDH) (4), revising the existing TDH description of the device, increasing emphasis in driver education curriculums, or conducting additional research to develop alternative designs or uses for the device. Chapter IV describes the findings and recommendations for each of the devices evaluated in the study.

Implementation Activities

The results of this research are being used to identify implementation activities that can be undertaken to improve motorist understanding of traffic control devices. Specific implementation activities which are described in Chapter V include no action, changes to TxDOT practices, revising the Texas MUTCD, possibly increasing the emphasis in driver education/driver safety courses, possibly revising the *Texas Drivers Handbook*, developing a public information campaign, and conducting additional research.

Summary and Conclusions

Chapter VI of this report summarizes the study findings and implementation recommendations reported in the preceding chapters.

USE OF METRIC UNITS IN RESEARCH

The United States is currently in the process of transitioning to the International System (SI) of metric units. One of the major concerns associated with the change to metric units is the conversion of traffic signs to metric units. However, as of the present time, traffic signs have not been converted to metric units, nor have standard metric legends been developed. The Federal Highway Administration (FHWA) has determined that the conversion of sign legends to metric units will take place sometime after September 1998, if at all. The conversion of sign legends to metric units has been specifically excluded from the September 30, 1996 federal requirement for completing the transition to metric units. Therefore, this research has continued to use American customary units in all evaluations in which drivers are asked to respond to a traffic control device. This was done in order to reduce the potential for driver confusion over the meaning of the device. To use metric units in the evaluations would have undermined the results due to driver confusion which would have resulted from the unfamiliar units. American

customary units are also used in the recommendations for traffic control devices where they relate to a sign legend or driver understanding of a traffic control device.

In this report, all illustrations of signs and references to sign legends use American customary units without the equivalent metric unit. The basis for this use of units is that the sign legends were presented to the drivers using American customary units, standard sign legends for metric units have not been developed, and the conversion of traffic signs to metric units has been delayed for at least two years. References to units of measure that are not related to sign legends use metric units with the American customary units in parentheses.

CHAPTER II

STATEWIDE EVALUATION

The cornerstone of this research study was a survey given to 1,745 drivers throughout Texas. The survey was intended to evaluate driver understanding of 46 traffic control devices, which included 14 regulatory signs, 18 warning signs, 7 pavement markings, 5 traffic signal indications, 1 guide sign, and 1 object marker. The activities associated with this statewide survey consisted of four major efforts: 1) a review of previous research, 2) the development of the survey instrument, 3) the actual administration of the survey, and 4) the analysis of the survey results. The first and second year reports describe these activities in detail (2, 3). However, this chapter provides a brief overview of the key elements of the statewide survey.

PREVIOUS RESEARCH

A literature review was conducted to identify previous research addressing how well motorists comprehend specific traffic control devices. A total of 917 references which pertained to some aspect of traffic control devices were identified. Of these, 162 were initially identified as related to the study objectives and were obtained for review. Several studies (5, 6, 7, 8, 9) of driver understanding of traffic control devices were identified as noteworthy. These studies were comprehensive in nature and addressed a number of devices. There have also been many studies which evaluated one or a limited number of traffic control devices. Chapter 2 of the second year report (3) describes the findings of previous research on driver comprehension of 49 different traffic control devices.

A number of conclusions were drawn from the review of previous research on comprehension of traffic control devices. The findings of previous research studies indicated that it can be very difficult to measure how well drivers understand certain traffic control devices. In several cases, different studies found widely varying comprehension levels for any given device, depending on the research method, specific wording of a question, and the format of the answer. Therefore, the fact that one study concluded that a given sign is not well understood does not mean there is a need to change the device. It is also important to keep in

mind that knowing how well a driver understands a traffic control device does not necessarily provide an indication of how a driver will respond to that device.

The review of previous research highlighted many traffic control devices which have been shown to have some type of comprehension difficulty. Therefore, the results of previous research was one of six factors used to select the devices which would be included in the survey, as described in the first year report (2).

SURVEY DEVELOPMENT

The development of the survey instrument was a major effort which took place over a period of several months. The major activities conducted in the course of developing the survey instrument included: 1) selecting the traffic control devices to include in the survey, 2) selecting a format for the survey, 3) evaluating the effectiveness of the survey instrument, and 4) developing a plan for administering the survey.

Selection of Traffic Control Devices

A ranking procedure was developed to determine which devices were the most appropriate to include in the survey. The ranking procedure evaluated each traffic control device with regard to the major and minor factors shown in Table II-1. A total score for each traffic control device was determined by adding the individual weighted scores for the six factors. Devices with the highest total scores were identified as candidates for the survey.

Table II-1. Factors Considered in Selection of Devices

Major Factors		Minor Factors	
Factor	Weight	Factor	Weight
Findings of Previous Research	25 %	Inclusion in <i>Texas Drivers Handbook</i> (4)	8.3 %
Results of a Poll of Transportation Professionals	25 %	Frequency of Use	8.3 %
Assessment of Consequences of Misunderstanding	25 %	Special Interest of Research Study	8.3 %

The results of the ranking process identified 60 traffic control devices for possible inclusion in the survey. These 60 devices were later reduced to 46 during the evaluation of the survey instrument. The 60 devices did not represent the least understood nor the highest ranked traffic control devices. Several traffic control devices were not included in the survey for a variety of reasons, including: an abundance of prior research indicating a traffic control device is not adequately understood, the inability to include a traffic control device in the survey format, or the inclusion of a closely related traffic control device in the survey.

Survey Format

Once the 60 devices were selected, questions, responses, and graphics were developed for each device and a 30-minute pretest survey instrument was produced. In order to evaluate a large representative sample in the survey, the survey instrument required a format that would be portable, with the ability to administer it in a convenient, quick, and consistent manner. These requirements led to the decision to use a videotape prepared from 35 mm slides as the survey instrument. The same requirements also led to the use of a multiple-choice format for the survey questions. There were four possible choices for each question, one of which was always "not sure."

For each question in the survey, the driver was presented with two images. The first was an in-context picture of the device showing the device in a typical environment. While the in-context photo was displayed, the narrator in the videotape asked a question about the device. The second image contained a close-up view of the device with the possible response choices for the question. The video narrator read the response choices to the survey participant. Appendix A contains the images that were presented in the statewide survey.

Survey Evaluation

The effectiveness of the initial survey instrument was evaluated in a two-step process. The first step was a pretest survey administered to 38 individuals. The findings of the pretest survey were used to delete 14 devices from the survey and to modify several questions and responses to reduce confusion. In the second step, the revised survey was given to 165 drivers. The results of this step indicated that the survey instrument was effective and could be administered on a statewide basis.

SURVEY ADMINISTRATION

The statewide survey was administered at driver license (DL) stations located in six cities under 50,000 population (Paris, Lufkin, Beeville, Eagle Pass, Levelland, Athens) and six cities over 50,000 population (Tyler, Houston, San Antonio, El Paso, Amarillo, Temple) throughout Texas. Driver licensing stations were chosen as logical places to recruit drivers because the individuals which enter the DL stations represent a reasonable cross section of demographic and socioeconomic subgroups of drivers. A quota sampling plan was used for the survey. Quota based age, gender, and ethnicity distributions were developed for the various areas of the state where the survey was administered. Sixteen questions at the end of the survey provided demographic and background information about the survey respondents. Table II-2 describes the sociodemographic characteristics of the survey sample, and Table II-3 describes the driving-related characteristics of the survey sample. These two tables also include the statewide characteristics for the general population and the driving population for some of the categories.

Table II-2. Sociodemographic Characteristics of Survey Sample

Characteristic		Number	Percent	Texas Population	
				General	Driving
Gender	Male	894	51.2	49.3	51.5
	Female	851	48.8	50.7	48.5
Age	16 - 24	455	26.1	18.9	15.2
	25 - 64	1,202	68.9	67.6	72.8
	65 +	88	5.0	13.6	12.0
Ethnicity	Anglo	1,057	60.6	60.6	---
	Black	207	11.9	11.6	---
	Hispanic	391	22.4	25.6	---
	Other	90	5.2	2.2	---
English Language	Primary	1,529	87.6	---	---
	Secondary	216	12.4	---	---
Years of Education	Less than High School	282	16.2	28.1	---
	High School Graduate	480	27.5	25.9	---
	Tech/Business School	96	5.5	---	---
	Some College	433	24.8	27.8	---
	College Graduate	303	17.4	12.6	---
	Graduate School	151	8.7	5.5	---
Total		1,745	100.0	---	---

Notes: ---=Not available.

Table II-3. Driving Characteristics of Survey Sample

Characteristic		Number	Percent	Texas Driving Population
Drive for Job	Yes	435	24.9	---
	No	1,310	75.1	---
Type of License	Operator	1,586	90.9	89.1
	Commercial	188	6.8	10.9
	Motorcycle	40	2.3	< 0.1
Years Licensed	No License	99	5.7	---
	< 1	88	5.0	---
	1-10	475	27.2	---
	> 10	1,083	62.1	---
Type of Vehicle Driven	Passenger Car	1,508	86.4	---
	Pickup	205	11.7	---
	Diesel	18	1.0	---
	Motorcycle	2	0.1	---
	Other	12	0.7	---
Driver Education	Yes	1,002	57.4	---
	No	743	42.6	---
Years Since Driver Education	None	738	42.3	---
	< 1	116	6.6	---
	1-10	386	22.1	---
	> 10	505	28.9	---
Type of Driving	Within City	930	53.3	---
	Outside City	188	10.8	---
	Both	627	35.9	---
Trips/Year Less than 300 miles	None	300	17.2	---
	1-10	1,262	72.3	---
	> 10	183	10.5	---
Miles Driven per Year	< 10,000	554	31.7	---
	10,000 - 30,000	1,074	61.6	---
	> 30,000	117	6.7	---
Total		1,745	100.0	---

SUMMARY OF STATEWIDE SURVEY RESULTS

The results of the statewide survey indicated a wide variation in the percentage of correct responses selected by drivers. The correct response rates for the 46 traffic control devices ranged between 15.5 and 93.2 percent, while the "not sure" response rates varied between 0.8 and 33.2 percent. The second year report (3) includes discussion about the survey findings for each of the 46 devices in the survey. The same report also identifies statistically significant relationships between the survey responses and various demographic subgroups. Appendix A

at the end of this report includes the percentage of drivers that selected each of the possible response choices.

LIMITATIONS OF STATEWIDE SURVEY RESULTS

The survey method used in the statewide survey had several limitations which should be considered in the evaluation of the survey results. The second study report describes these limitations in detail (3); however, they are summarized below:

- **Survey Location.** Surveys were administered at DL stations. DL station respondents include drivers renewing their license (no testing required), individuals applying for a license (testing required), and others accompanying the DL patrons. Those coming to these locations for testing may have been better prepared to answer questions about traffic control devices.
- **Format of Survey.** Neither the in-context or close-up view presented a traffic control device that truly represents the driving environment in which the driver would respond to the device.
- **Response Format.** The multiple-choice format prevents drivers from developing their own explanation of a device.
- **Response Time.** Drivers were only given three to four seconds to select an answer once the narrator had finished reading the responses.
- **Focus of Individual Questions.** Some questions tested a specific aspect of the meaning of a device, as opposed to the general meaning. Even though a device may have a low response rate, drivers may still have sufficient understanding of the device to respond appropriately.
- **Presentation of Information.** Although the driver was shown an in-context picture of the device and its environment, the driver was not viewing this picture at the time the response choices were provided to the driver.
- **Comparability of Results.** The survey questions addressed different aspects of a traffic control device (general meaning, meaning of a secondary message, proper driving response, etc.). Therefore, the results for each device are not always comparable and the findings must be interpreted in isolation from each other.

- **Relationship Between Understanding and Behavior.** This survey tested only understanding of various traffic control devices. However, driver understanding, or lack of understanding, of a device does not necessarily correlate to the proper or improper driving response to the device.

USE OF STATEWIDE SURVEY RESULTS

The second year report describes the results for the statewide survey (3). However, the results were not used to draw conclusions about driver understanding of traffic control devices or to make recommendations regarding the design, use, or education of the devices. The results of the statewide survey were used to identify those devices for which additional follow-up evaluations were appropriate. Chapter III describes these follow-up evaluations.

CHAPTER III

FOLLOW-UP EVALUATIONS

The results of the statewide survey provide much useful information relative to driver understanding of the 46 traffic control devices in the survey. However, the results of the statewide survey were not sufficient to answer comprehension concerns for all 46 of the devices. Additionally, the fixed choice format prevented any in-depth study of driver understanding of the devices. Therefore, the follow-up evaluations addressed unanswered questions which remained following the statewide survey. The follow-up evaluations were also used to evaluate understanding of five additional standard signs that were not included in the statewide survey.

Four different follow-up evaluations were conducted after the results of the statewide survey had been analyzed. Table III-1 describes key aspects of these four evaluations. Table III-2 indicates the specific devices that were evaluated in three of the surveys. Table III-2 also shows where alternative designs were evaluated for selected traffic control devices. This chapter describes the approaches used in the four evaluations and the results that were obtained from the analysis of the evaluations.

1992 AUTO SHOW SURVEY

The 1992 Auto Show survey was the first evaluation conducted as a follow-up to the statewide survey. There were several reasons why a follow-up to the statewide survey was considered necessary. The following objectives of the 1992 Auto Show Survey include a summary of these reasons.

- Measure the effectiveness of additional information, such as that provided in supplemental plaques.
- Compare the relative effectiveness of symbol and word messages.
- Expand and clarify the response choices that had previously been provided in the statewide survey.
- Examine several alternative warning sign symbols that were not included in the statewide survey.

Table III-1. Summary of Follow-Up Evaluations

Name of Evaluation	Type of Evaluation	Date of Evaluation	Number of Drivers Surveyed	Number of Devices Evaluated	Alternative Designs Evaluated
1992 Auto Show Survey	Multiple-choice survey	Jan-Feb 92	322	10	Yes
1993 Auto Show Survey	Open-ended survey	Jan-Feb 93	286	5	Yes
Spanish-Language Survey	Spanish language survey	Jan 92	31	46	No
Focus Groups	Opinion and discussion	Feb-May 93	30	3	Yes

Table III-2. Traffic Control Devices Included in Follow-Up Evaluations

Device Name	Sign Label	Devices Evaluated in Follow-Up Evaluation		
		1992 Auto Show Survey	1993 Auto Show Survey	Focus Groups
Double Turn	R3-8	Std ¹		
Two-Way Left Turn Lane	R3-9b	Std + 1 Alt ²		
Keep Right	R4-7		Std	
Turn	W1-1	Std + 1 Alt		
Reverse Turn	W1-3		Std	
Winding Road ³	W1-5		Std	
Slow Down on Wet Road	W8-5	Std + 2 Alt		Std + 3 Alt
Lane Reduction Transition	W4-2			Std + 2 Alt
Right Lane Ends ³	W9-1			Std
Lane Ends Merge Left	W9-2		Std	Std
Ramp Metered When Flashing	W19-3		Std	
School Advance ³	S1-1	Std + 1 Alt		
Low Shoulder ³	CW8-9a	Std		
Shoulder Drop-Off ³	CW21-13	Std		
Uneven Lanes ³	CW21-14	Std		
Flashing Red Intersection Control Beacon	---	Std + 2 Alt		Std + 5 Alt
White Lane Line Marking	---	Std		

Notes: ¹Std indicates the standard sign was evaluated.

²Alt indicates that the number of alternative designs shown were evaluated.

³These signs were not evaluated in the statewide survey.

The Spanish-language survey included all 46 devices evaluated in the statewide survey.

This survey required the participant to answer a question by selecting a response from a list of choices. In general, the 1992 Auto Show survey was intended to clarify uncertainties in the results of the statewide survey with respect to selected traffic control devices. Table III-2 lists the ten traffic control devices which were included in the 1992 Auto Show survey. As Table III-2 indicates, a number of alternative sign designs were also evaluated in this survey. For some of the devices in the 1992 Auto Show survey, the questions and response choices were identical to those in the statewide survey. For other devices, new questions and response choices were developed.

Administration Procedure

Surveys were conducted during the Houston Auto Show, January 25 through February 1, 1992. The surveys were self-administered by volunteers who approached a booth staffed by TTI personnel. TTI personnel provided basic assistance by answering questions pertaining to the survey instrument and gave out incentive packages to those who completed the questionnaire. On occasion, TTI personnel filled out the questionnaire for respondents (for those who had difficulty seeing or writing).

Three sets of questions were devised for the survey. Table III-3 describes the subject matter of each question in the three sets. The first set (Set A) included questions pertaining to all of the traffic control devices of interest. Sets B and C included the alternatives or supplements to the traffic control devices of interest. A total of 322 drivers took part in the survey.

Sample Characteristics

The samples for all survey sets were comprised of a majority of male, Anglo, college educated, respondents between the ages of 25 and 54, who had taken a driver education course. These respondents were volunteers who were not selected at random. Table III-4 gives the frequencies and percentages for each sociodemographic characteristic for the total sample of all three sets.

Table III-3. Organization of 1992 Auto Show Survey

Question Number	Set A	Set B	Set C
1	Std W8-5	Std W8-5 w/ educ plq	Alt W8-5 word message sign
2	Std W1-1	Std W1-1 w/ W13-1	Intersection Beacon w/ 2-WAY plq below sign and beacon
3	Std R3-9b	Alt R3-9b word message sign	---
4	Intersection Control Beacon No suppl plq	Intersection Control Beacon w/ 2-WAY plq below sign	---
5	Std R6-1 and color of striping	---	---
6	Std S1-1	Alt S1-1	---
7	Std CW8-9a	Std CW21-13	Std CW21-14
8	Std R3-8	---	---
Sample Size	103	113	106

Table III-4. Sociodemographic Characteristics of 1992 Auto Show Survey

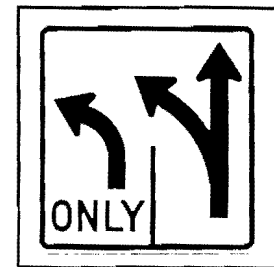
Characteristic		Number	Percent	Texas Population	
				General	Driving
Gender	Male	237	73.6	49.3	51.5
	Female	85	26.4	50.7	48.5
Age	16 - 24	123	38.2	18.9	15.2
	25 - 54	173	53.7	67.6	72.8
	55 +	26	8.1	13.6	12.0
Ethnicity	Anglo	255	79.2	60.6	---
	Black	18	5.6	11.6	---
	Hispanic	35	10.9	25.6	---
	Other	13	4.0	2.2	---
English as the Primary Language	Yes	306	95.0	---	---
	No	13	4.0	---	---
Education	Less than High School	40	12.4	28.1	---
	High School	60	18.6	25.9	---
	Some College	115	35.7	27.8	---
	College Graduate	74	22.9	12.6	---
	Advanced Degree	30	9.5	5.5	---
Driver Education	Yes	252	78.3	---	---
	No	66	20.5	---	---
Total		322	100.0	---	---

Survey Findings

The following paragraphs describe the results of the 1992 Auto Show Survey for each of the standard devices evaluated in the survey. The descriptions include the survey results for alternative designs or treatments. Appendix B shows the image and response choices presented to survey participants, which also summarizes the response percentages for each choice for the questions in all three sets.

Double Turn Sign

The **Double Turn** (R3-8) sign shown in Figure III-1 was included in the statewide survey. However, the interpretation of the results was somewhat hindered by a concern that the limited response time allowed by the video coupled with the complexity of the response choices led to a greater number of incorrect and unsure responses. Therefore, this sign was also included in the 1992 Auto Show survey to expand and clarify the response choices that had previously been provided in the statewide survey. A true/false format was used for the question on this sign in order to assess driver understanding for each movement from each lane. Drivers were asked to respond to eight different statements about the **Double Turn** sign. The results for each statement are presented in Table III-5. Page B-4 presents the image and response choices that were shown to survey participants.



**Figure III-1.
Double Turn Sign**

Table III-5. 1992 Auto Show Survey Results for the Double Turn Sign

True (percent)	False (percent)	Statement
3.9	*96.1	Left lane traffic may go straight.
*96.1	3.9	Right lane traffic may go straight.
*92.2	7.8	Left lane traffic must turn left.
3.9	*96.1	Right lane traffic must turn left.
2.9	*97.1	Left lane traffic must go straight.
12.9	*87.1	Right lane traffic must go straight.
5.9	*94.1	Left lane traffic may turn left or go straight.
*94.1	5.9	Right lane traffic may turn left or go straight.

Note: *Indicates correct response.

An evaluation of the response percentages shown in Table III-5 indicates that most drivers realized that left lane traffic must turn and right lane traffic may turn left or go straight. However, almost 13 percent of drivers also thought that right lane traffic must continue forward and could not turn left. It should also be noted that although several of the percentages in Table III-5 are the same, this is due to coincidence instead of the same drivers answering each statement correctly or incorrectly. For instance, the same number of drivers selected "false" for the first statement as those that selected "true" for the second statement. However, it was not the same drivers that selected "false" and "true" for each statement.

Two-Way Left Turn Lane Sign and Alternative Design

The **Two-Way Left Turn Lane** sign (R3-9b) was presented in the 1992 Auto Show survey in the two different forms shown in Figure III-2. Survey respondents were shown either the standard R3-9b sign, which has left turn arrows and the words CENTER LANE ONLY or an alternative design with the word message CENTER LANE LEFT TURN ONLY. This is the version of the sign as it originally appeared in the 1971 MUTCD (10). The

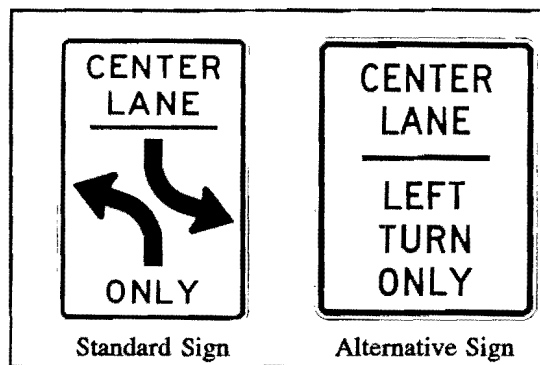


Figure III-2.
Two-Way Left Turn Lane Signs

response percentages for each of the signs are shown in Table III-6. Page B-5 illustrates the two signs used in this question, along with the response choices and response percentages.

Table III-6. 1992 Auto Show Survey Results for the Two-Way Left Turn Lane Sign

Standard (percent)	Alternative (percent)	Response
3.9	3.5	Travel in the center lane is allowed, but right turns are not.
64.1	74.3	Do not use the center lane for any purpose other than to make a left turn.
27.2	21.2	If you are in the center lane, you will be required to make a left turn at the next intersection.
4.9	0.9	Not sure.

The most common incorrect response was "if you are in the center lane, you will be required to make a left turn at the next intersection," which was selected by 27 percent of the

respondents who were shown the arrow/word combination sign (R3-9b) and 21 percent who were shown the word only message. The word only message was understood by 10 percent more respondents than the arrow/word combination (74 percent correct for the word only message and 64 percent correct for the arrow/word combination). However, a z test found that this 10 percent difference is not statistically significant at a confidence level of 90 percent. Therefore, it cannot be said that the word message sign is any better understood than the standard sign.

Turn Sign with and without Advisory Speed Plate

The Turn warning sign (W1-1) was evaluated in the 1992 Auto Show survey with and without an Advisory Speed Plate (W13-1) showing a recommended speed of 30 mph. The response choices in the Auto Show survey were identical to those of the statewide survey. Respondents who were shown the Turn arrow without the Advisory Speed Plate (ASP) chose the correct response 36 percent of the time, while those who were shown the Turn arrow with the ASP chose the correct response 95 percent of the time. Table III-7 indicates the response percentages for each sign alternative for each of the response choices. Table III-7 also contains the response choices for the statewide survey. Page B-6 contains the sign images, response choices, and response percentages for both of the signs in this survey.

Table III-7. 1992 Auto Show Survey Results for the Turn Sign

<i>What does this sign mean?</i>			
Turn Sign without ASP (percent)		Turn Sign with 30 mph ASP (percent)	Response
Statewide	Auto Show		
10.7	11.7	1.8	There is an intersecting road to the right ahead.
*31.9	*35.9	*94.7	You should drive 30 miles per hour or less to make the next turn.
45.2	49.5	3.5	You should turn right at the next intersection.
12.2	2.9	0.0	Not sure.

Note: *Indicates correct response.

These responses reinforce the findings of the statewide survey which indicated that drivers do not recognize the speed message conveyed by the Turn sign. In fact, a z test indicates that the correct response rates for the statewide and 1992 Auto Show surveys (31.9 and 35.9 percent, respectively) are not statistically different at a 99 percent confidence level.

Slow Down on Wet Road Sign and Alternative Designs

The three versions of a **Slow Down on Wet Road** message shown in Figure III-3 were evaluated in the 1992 Auto Show survey. The first sign was the standard **Slow Down on Wet Road** symbol sign (W8-5) with no additional information. The second sign was the standard symbol sign with an educational plaque below the sign. The third sign was the word message alternative to the symbol sign. This word message sign is currently used in Texas as an alternate to the symbol sign. The response percentages for each of the signs are shown in Table III-8. Page B-6 presents the images of the three signs that were shown in the survey, along with the responses and response percentages.

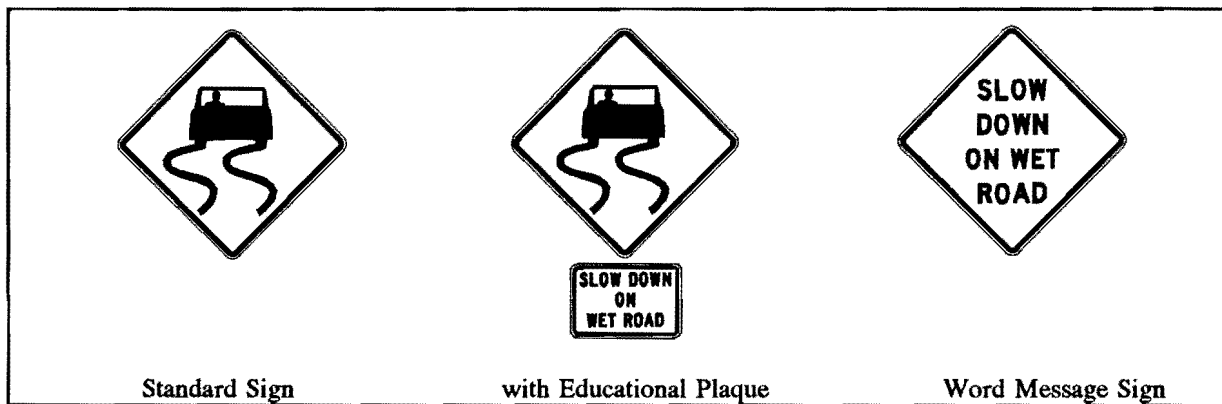


Figure III-3. Slow Down on Wet Road Sign and Alternatives - 1992 Auto Show Survey

Table III-8. 1992 Auto Show Survey Results for the Slow Down on Wet Road Sign

Symbol Sign (percent)		Symbol Sign w/ educ plq (percent)	Word Message Sign (percent)	Response
Statewide	Auto Show			
33.9	35.9	9.7	1.9	Be prepared for a winding road.
*62.3	*62.1	*90.3	*97.2	Slow down when the pavement is wet.
2.6	1.9	0.0	0.9	Watch for out-of-control vehicles.
1.1	0.0	0.0	0.0	Not sure.

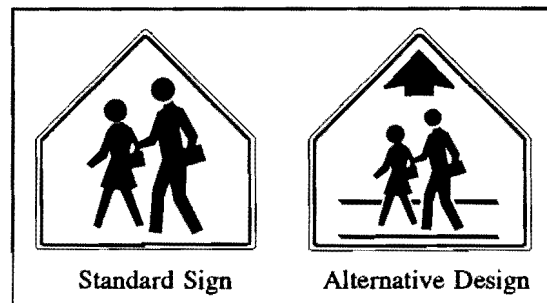
Note: *Indicates correct response.

Although the Auto Show sample was not representative of the Texas driving population, the response percentages for the symbol sign alone are virtually identical to the response percentages of the statewide survey, as shown in Table III-8. Drivers confused the symbol sign with a winding road. The Auto Show survey results indicate that the word message sign and the

symbol sign with the educational plaque are significantly better understood than the symbol sign alone. However, these results should be interpreted carefully, due to the fact that the Auto Show survey sample was primarily English speaking. Understanding of the three alternatives was not determined among enough non-English speaking or secondary English speaking drivers to draw any conclusions.

School Advance Sign and Alternative Design

The confusion between the **School Advance** (S1-1) sign and the **School Crossing** (S2-1) sign has been well documented (5, 6, 9). Therefore, neither sign was included in the statewide survey for evaluation. However, because one of the objectives of the 1992 Auto Show survey was to evaluate alternative sign designs, the standard **School Advance** sign and an alternative design shown in



**Figure III-4.
School Advance Signs**

Figure III-4 were included in the survey. The alternative design consisted of a standard **School Crossing** sign (S2-1) with an arrow at the top of the sign, in the same way that an arrow is used at the top of the **Stop Ahead** sign. This alteration was proposed to convey the *advance crossing* message more clearly. Table III-9 indicates the percentage of drivers selecting each response, and page B-7 presents the sign images, response choices, and response percentages for the two signs.

**Table III-9. 1992 Auto Show Survey Results
for the School Advance Sign**

<i>What is this sign telling you?</i>		
Std Sign	Alt. Design	Response
*44.1 %	*84.1 %	There is a school crossing ahead.
19.6 %	8.0 %	There is a school zone ahead.
34.3 %	7.1 %	There is a school crossing at this sign.
2.0 %	0.9 %	Not sure.

Notes: *Indicates correct response

As has been found in previous research, the percent of correct responses for the standard sign was relatively low. The results for the alternative sign indicated a relatively clear distinction of the advance crossing message, as can be seen from Table III-9. These results suggest that the arrow may be an effective way of decreasing confusion between the advance crossing and crossing messages for both school and pedestrian warning signs.

Uneven Pavement Construction Signs

Construction signs were not included in the statewide survey. However, a TTI study dealing with construction signing (11) indicated that there were some comprehension-related issues that had not been resolved. One of those issues was the ability to distinguish between the different meanings of construction signs which are used to warn of an uneven roadway surface. Therefore, the **Low Shoulder** (W8-9), **Shoulder Drop-Off** (CW21-13), and **Uneven Lanes** (CW21-14) construction warning signs shown in Figure III-5 were included in the 1992 Auto Show survey to determine if drivers could differentiate between the meanings of the three signs. The three response choices were the same for each sign, and each choice was the correct response for one of the signs. The responses did not include the height of an elevation difference, even though the heights are related to the use of these signs. Table III-10 summarizes the response choices for the three signs. Page B-7 illustrates the signs that were used in the survey and provides the response percentages for each of the choices.

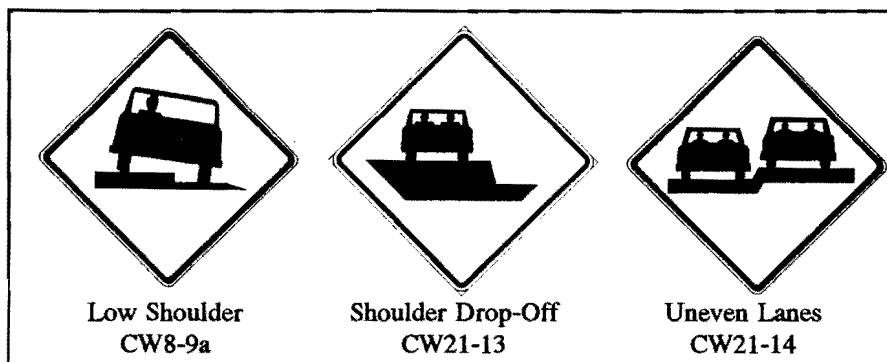


Figure III-5. Uneven Pavement Construction Signs

The results indicated that the **Uneven Lanes** warning was the most clearly understood (87.7 percent correct), followed by the **Shoulder Drop-Off** warning (52.2 percent correct). The least understood was the **Low Shoulder** warning (40.2 percent correct). Respondents had the most

difficulty determining if the location of the drop was at the pavement edge or at the lane edge. These results indicate that these signs may not be effective at informing drivers of a pavement elevation difference located at the edge of a travel lane.

Table III-10. 1992 Auto Show Results for the Uneven Pavement Construction Signs

Low Shoulder CW8-9a	Shoulder Drop-Off CW21-13	Uneven Lanes CW21-14	Response
31.4 %	*52.2 %	4.7 %	A drop-off at the edge of the shoulder.
25.5 %	17.7 %	*87.7 %	A drop-off between lanes.
*40.2 %	28.3 %	5.7 %	A drop-off between the lane and the shoulder.
2.9 %	1.8 %	1.9 %	Not sure.

Flashing Red Intersection Control Beacon and Alternative Treatments

The statewide survey indicated that less than half of the drivers facing a flashing red intersection beacon recognized that the intersecting traffic could have *either* a flashing red or flashing yellow. Therefore, three intersection control beacon scenarios were presented in the 1992 Auto Show survey in an effort to determine more clearly the effect of situational cues and to test the benefit of additional information. All three scenarios included both a flashing red beacon and a STOP sign. The only difference between the scenarios was the presence of a 2-WAY supplemental plate, as illustrated on pages B-8 and B-9. Table III-11 presents the survey results for these scenarios.

Table III-11. 1992 Auto Show Survey Scenarios and Results for the Flashing Red Intersection Control Beacon

Survey Scenarios			2-WAY plate displayed below:
No	Yes	Yes	STOP sign
No	No	Yes	Intersection control beacon
<i>What type of situation do you have at this corner?</i>			
Percent Responding			Responses
68.9	*81.4	*86.8	A 2-way stop.
8.7	6.2	6.6	A 4-way stop.
*18.4	12.4	5.7	Can be either a 2-way or a 4-way stop.
3.9	0.0	0.9	Not sure.

Note: *Indicates correct response.

As these results show, the percentage of drivers that correctly understood the intersection situation increased with each additional piece of information provided to the drivers. However, it is interesting to note that when the words **2-WAY** appeared both on the beacon and on the **STOP** sign, a greater percentage of drivers thought the situation was a four-way stop (6.6 percent) than thought it could be either two-way or four-way (5.7 percent) or thought so with **2-WAY** plaque on the **STOP** sign only (6.2 percent).

The **2-WAY** supplemental plate is not currently described in the MUTCD. However, these results indicate that such a plaque may provide useful information to drivers and that consideration should be given to including the plaque in the MUTCD.

One-Way Sign and Pavement Markings

In the statewide survey, over 40 percent of the drivers incorrectly thought that a white lane line was used to separate traffic lanes traveling in opposing directions. The 1992 Auto Show survey addressed this same issue. Drivers were shown the **ONE-WAY** sign

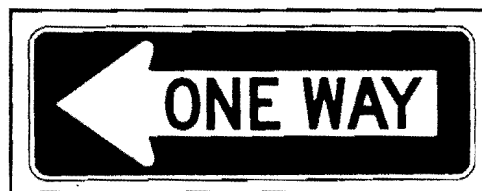


Figure III-6. ONE-WAY Sign

(R6-1) shown in Figure III-6 with the following question: "*You have just turned onto a road with this sign. What color would the center dashed line on the pavement be?*" Drivers provided a response in an open-ended format. Table III-12 summarizes the responses to this question.

Table III-12. 1992 Auto Show Survey Results for the ONE-WAY Sign and Color of Pavement Markings

<i>You have just turned onto a road with this sign. What color would the center dashed line on the pavement be?</i>	
Percent	Open-Ended Response
*79.4	White.
12.7	Yellow.
2.9	Some other color.
4.9	Not sure.

Note: *Indicates correct response.

The correct response rate for the Auto Show survey was much higher than that in the statewide survey (79 percent compared to 50 percent). These results indicate that drivers may have a better understanding of pavement marking color than indicated by the statewide survey.

1993 AUTO SHOW SURVEY

The 1993 Auto Show survey was conducted to further evaluate driver comprehension of selected traffic control devices and alternative designs using a response format which differed from those in the earlier evaluations. The goal of the evaluation was to assess behavioral responses to the selected signs by posing questions in an open-ended interview format. The five traffic signs evaluated in the 1993 Auto Show survey included the **Keep Right**, **Reverse Turn**, **Winding Road**, **Lane Ends Merge Left**, and **Ramp Metered When Flashing** signs. The specific rationale for conducting further examinations of each device is explained individually for each of the devices.

Administration Procedure

The 1993 Auto Show survey was conducted at the same Houston Auto Show one year after the 1992 Auto Show survey (January 29 through February 14, 1993). The surveys conducted were administered using an interview approach in which the respondent was shown a booklet with computer generated pictures of each sign. The interviewer asked questions corresponding to each picture and recorded respondent answers verbatim on interview forms. A total of 286 Auto Show attendees were queried regarding five traffic signs and six background questions. The signs and interview form are shown in Appendix C.

Sample Characteristics

The sample for this survey was comprised of a majority of male, Anglo, college educated, respondents between the ages of 25 and 54, who had taken a driver education course. These respondents were volunteers who were not selected at random. Table III-13 gives the frequencies for each demographic characteristic for the 1993 Auto Show survey.

Table III-13. Sociodemographic Characteristics of 1993 Auto Show Survey

Characteristic		Number	Percent	Texas Population	
				General	Driving
Gender	Male	208	72.7	49.3	51.5
	Female	78	27.3	50.7	48.5
Age	16 - 24	87	30.4	18.9	15.2
	25 - 54	170	59.4	67.6	72.8
	55 +	29	10.1	13.6	12.0
Ethnicity	Anglo	225	78.7	60.6	---
	Black	25	8.7	11.6	---
	Hispanic	26	9.1	25.6	---
	Other	10	3.5	2.2	---
English as Primary Language	Yes	276	96.5	---	---
	No	10	3.5	---	---
Education	Less than High School	23	8.1	28.1	---
	High School	50	17.5	25.9	---
	Some College	111	38.9	27.8	---
	College Graduate	60	21.1	12.6	---
	Advanced Degree	40	14.1	5.5	---
Driver Education	Yes	218	76.2	---	---
	No	68	23.8	---	---
Total		286	100.0	---	---

Survey Findings

The following paragraphs describe the results of the 1993 Auto Show survey for each of the five signs included in the survey. The driver responses to the questions are summarized in Appendix C.

Keep Right Sign

Responses to the **Keep Right** symbol sign (R4-7) in the statewide survey indicated that some drivers may believe the sign conveyed a need to move to the right-hand lane. The sign was included in the 1993 Auto Show survey to evaluate this interpretation. In this survey, respondents were asked to give the meaning of the **Keep Right** sign, to describe the appropriate driving response, to indicate where they would expect to see it, and to tell the interviewer what the solid cone shape on the sign represents.

The percentage of responses that could be considered correct as related to the meaning of the **Keep Right** sign was 95. These responses were not necessarily correct in a textbook sense as a definition of the **Keep Right** sign. However, they conveyed a meaning attached to the sign that would not be incongruent with its intended purpose. Examples of the open-ended responses included: *curve or go right* (24 percent), *median ahead* (20 percent), *divided highway* (16 percent), *keep right* (13 percent), and *something in the road* (5 percent). One percent said they did not know what the sign meant, and 7 percent gave responses that could not be considered correct.

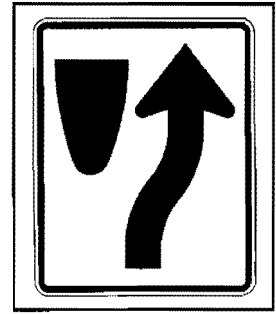


Figure III-7.
Keep Right Sign

In terms of a driving response to the **Keep Right** sign, 57 percent of the answers given mentioned *keep to the right*. Five percent of the responses were *follow the arrow* and an additional 5 percent were *merge right*. Eighteen percent of the respondents believed that slowing down would be an appropriate response to the **Keep Right** sign, and 4 percent also mentioned using caution. Four percent said the sign indicated a lane change. Two percent of the respondents did not know what to do in response to the **Keep Right** sign, and 11 percent of the answers that were given were not related to the intended function of this sign.

When asked, "*on which side of the travel lane, right or left...would you expect to see this sign,*" 60 percent of the respondents said on the right side of the travel lane and 33 percent said the sign would be on the left side of the travel lane. Five percent said the sign would be in the center of the roadway, and 2 percent said the sign could be either on the left or right side of the travel lane.

Regarding the interpretation of the symbol (the solid cone shape) itself, the majority of responses given were in the acceptable range. Examples of these responses were: *median* (50 percent), *obstruction or obstacle* (8 percent), *island* (10 percent), *divider* (8 percent), and *bridge support* (1 percent). *Curb* was given by 5 percent as the interpretation of the cone. Four percent did not know what the symbol represents, and 8 percent gave other unrelated and incorrect interpretations of the cone shape in the symbol. These responses indicate that the **Keep Right** sign is understood by a majority of drivers.

Reverse Turn and Winding Road Signs

The **Reverse Turn** and **Winding Road** signs (W1-3 and W1-5, respectively) shown in Figure III-8 were evaluated in the 1993 Auto Show survey due to concerns over possible driver confusion between the two signs. While the **Reverse Turn** sign was evaluated in the statewide survey, the **Winding Road** sign was not. Respondents were asked what their driving response would be to each of the signs.

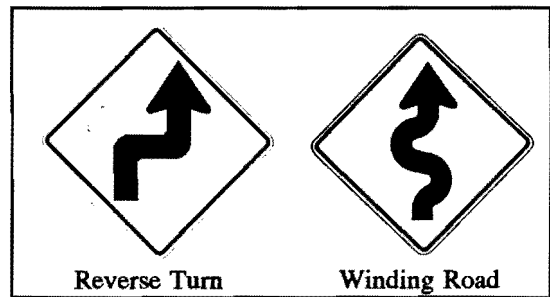


Figure III-8. Reverse Turn and Winding Road Signs

They were then asked to explain the difference between the two signs. A greater number of respondents said they would slow down in response to the **Winding Road** sign (65 percent) than said they would slow down in response to the **Reverse Turn** sign (60 percent). Concerning their expectation with regard to roadway alignment, 14 percent mentioned they would expect two *turns* ahead and 14 percent said they would expect two *curves* ahead when a **Reverse Turn** sign was displayed. Approximately the same number (29 percent) said they would prepare for curves ahead when the **Winding Road** was displayed.

When asked the difference between the **Reverse Turn** and the **Winding Road** sign, the responses fell into three major groups. The first group of approximately 47 percent said the **Reverse Turn** sign indicates turns of 90 degrees, whereas the **Winding Road** sign indicates curves. The second group of approximately 29 percent said the **Reverse Turn** indicates sharper, more severe turns or curves than the **Winding Road** sign. The third group of approximately 8 percent said the **Winding Road** sign indicates a road with more curves than indicated with the **Reverse Turn** sign. Approximately 14 percent of the responses were "don't know" or other responses that were incorrect and unrelated to each other.

These results indicate that drivers do not fully understand the different uses of these two signs. Furthermore, drivers tended to associate the **Reverse Turn** sign with 90 degree changes in horizontal alignment and the **Winding Road** with less severe alignment changes. Only about 8 percent recognized that the **Winding Road** sign is used to indicate more alignment changes than the **Reverse Turn** sign indicates.

Lane Ends Merge Left Sign

The results of the statewide survey for the **LANE ENDS MERGE LEFT** sign (W9-2) shown in Figure III-9 indicated possible confusion over the meaning of this sign as it applies to different lanes. There was also some concern over driver understanding of the word "merge." In the 1993 Auto Show survey, respondents were asked the appropriate driving response to the **LANE ENDS MERGE LEFT** warning sign from driving positions in the right and left lanes. From the merging lane (right lane), most of the respondents defined appropriate responses by using "merge" terminology. That is, 64 percent said simply *merge to the left lane*. Sixteen percent expanded the response by saying *look left, then merge*. Additionally, 14 percent said *signal, then merge*. In all, 94 percent gave an essentially correct response. Only one respondent said they did not know what to do in response to this sign, but another 5 percent gave other, incorrect responses.

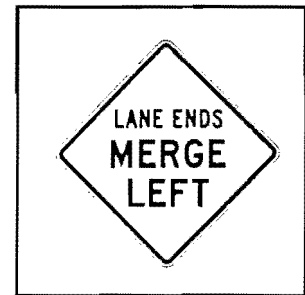


Figure III-9. LANE ENDS MERGE LEFT Sign

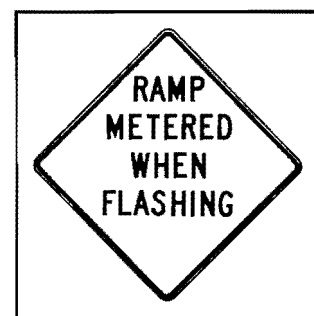
When positioned in the left lane, driver respondents gave a broader interpretation of how to respond to the **LANE ENDS MERGE LEFT** sign. Almost 6 percent gave incorrect responses that were counter to the desired response, such as, *move right, move over, merge, and stop*. Seven percent gave other unique, incorrect responses. The remaining correct responses (87 percent) were articulated in statements such as *let people in, stay in the left lane, watch for merging traffic, slow down, yield to right hand lane, and be cautious*.

These types of interpretations were reflected in the responses to the third question regarding the **LANE ENDS MERGE LEFT** sign: "*what does the word 'merge' mean?*" While 15 percent either said they did not know or gave an incorrect response, the remaining 85 percent gave appropriate responses. Definitions of "merge" included: *come together* (32 percent), *move into traffic* (23 percent), *two lanes go into one* (21 percent), *blend or mix in* (9 percent). The results of the 1993 Auto Show survey for this sign indicated that most drivers have an essentially correct understanding of the sign and its intended use.

Ramp Metered When Flashing Sign

In the statewide survey, over one-fourth of the drivers responding to the **RAMP METERED WHEN FLASHING** sign (W19-3), shown in Figure III-10, selected the "not sure" response and another one-fourth selected incorrect responses. Therefore, a question was included in the open-ended format of the 1993 Auto Show survey to derive a more accurate assessment of the interpretation of this sign.

Drivers were shown a picture of the **RAMP METERED WHEN FLASHING** sign and asked, "*What does this sign mean?*" With no response choices provided, the most prevalent response was *light controls ahead*, given by 31 percent of the respondents. However, the second most prevalent response was *don't know*, given by 25 percent of the respondents. Another 7 percent answered simply that they had never seen the sign before. It is worth noting that this question was administered at the Houston Auto Show and that ramp metering is used on freeways in the Houston area. These results confirm the findings of the statewide survey that indicated many drivers are not familiar with the sign and the concept of ramp metering.



**Figure III-10.
RAMP METERED
WHEN FLASHING
Sign**

SPANISH LANGUAGE SURVEY

The results of the statewide survey revealed an association between correct responses and primary language spoken for 35 traffic control devices. Further, for 11 traffic control devices an association was found between correct responses and Hispanics who spoke English as their primary language and Hispanics whose primary language was Spanish. An attempt was made to assess the extent of the problem attributable to the fact that the survey was administered in English to a number of drivers whose primary language was Spanish. The videotape survey was dubbed in Spanish, and a Spanish-speaking surveyor administered the survey to 31 drivers in Eagle Pass. However, it should be noted that the response choices presented to the survey participants in the close-up image were in English, just as they were in the statewide survey. The results were then compared to the survey responses of Spanish-speaking drivers in Eagle Pass who had been given the survey in English.

For the majority of traffic control devices examined, no significant differences were found in the responses to questions asked in Spanish compared to those asked in English to Spanish-speaking respondents. A significant language association was found for four signs. Two of the four were word message signs. These were the **LIMITED SIGHT DISTANCE (W14-4)**, and **GROOVED PAVEMENT AHEAD (W8-12)** warning signs. In both cases, a higher percentage of correct responses resulted when the questions were asked in Spanish. The **Truck Crossing (W11-10)** symbol sign was better understood when presented in Spanish as well. When presented in English, a greater number of Spanish-speaking respondents said the **Truck Crossing** symbol sign meant "*this is a warning that this road is heavily used by large trucks.*"

Spanish-speaking respondents answered the English version of the survey correctly more often than the Spanish version for one traffic control device. The **Steady Red X Lane-Use Control** signal question was answered correctly by 50 percent of the Spanish-speaking respondents who were given the question in English, compared to 17 percent who answered correctly when given the question in Spanish. (In the statewide survey, 75 percent of the respondents answered this question correctly.) In the survey conducted in Eagle Pass, most respondents who did not answer correctly were inclined to check the "not sure" response (42 percent who were given the English version and 73 percent who were given the Spanish version said they were not sure of the meaning of the red "X" indication).

In summary, the Eagle Pass survey found an improvement in the correct response rate for only three of the 46 traffic control devices studied when the survey was presented in the primary language of the respondent. This suggests that other factors may have a stronger effect than language. However, some caution should be used in the interpretation of the Spanish survey results, due to the small sample size (31 survey participants) and the lack of geographic diversity.

Further substantiation of these results with an expanded research sample would be beneficial. In addition, survey analysis directed to Spanish language alternative sign messages would allow further validation of language influence on understanding and responses by this group of motorists.

FOCUS GROUP EVALUATIONS

Situations related to three different traffic control devices were selected for evaluation in focus group discussions. The focus groups were conducted as part of another TTI study on rural guide signing (12). The situations discussed in the focus groups included:

- **Flashing red intersection control beacon,**
- **Slow Down on Wet Road symbol sign and two alternative symbol designs, and**
- **Lane Reduction Transition sign and two alternative symbol signs.**

Focus Group Study Method

Focus group sessions were held in Rockport, Somerville, and College Station. Each session was comprised of 10 individuals. There were five males and five females in the Rockport group and all were senior citizens. The Somerville and College Station groups each had four males and six females, and they represented driving ages from 20 to 60. The senior citizen group was recruited through a senior citizen organization. The other two groups were recruited from a volunteer sample pool. The group participants received \$15 for their participation in the focus group.

The focus group approach permitted a greater degree of exploration with regard to the three devices of interest. The participants were encouraged to give their interpretations of the devices, and further, to describe their opinions of proposed alternatives, or suggest alternatives of their own. Slides depicting the current and proposed alternative traffic control devices were used to stimulate the discussion.

Focus Group Results

The results of the focus group discussions are described in the following paragraphs for each of the three devices considered in the discussions. The slides that were used to stimulate discussion are shown in Appendix D along with descriptions of the devices shown in the slides.

Flashing Red Intersection Control Beacon

Discussion of the beacon controlled intersection centered on how drivers facing a flashing red indication can know what intersecting traffic will do and how best to communicate this information. Several different scenarios were presented to the focus groups: the use of a **2-WAY** supplemental plate below the **STOP** sign and beacon, the use of supplemental plaques or signs with the **STOP** sign to inform drivers that intersecting traffic does not stop, and the use of different colored **STOP** signs to differentiate between a two-way and four-way stop controlled intersection.

All three focus groups reached a general consensus that a **2-WAY** supplemental plate below the **STOP** sign provides sufficient information. The participants, in general, did not see the need for the **2-WAY** supplemental plate on both the **STOP** sign and the beacon, and between the two, preferred the message to appear on the **STOP** sign. Other suggestions to improve safety at beacon controlled intersections included adding an "Intersection Ahead" warning sign in advance of the intersection, and making the **STOP** sign larger.

None of the participants liked the idea of using different colored **STOP** signs to differentiate two-way and four-way stop controlled intersections. Three types of supplemental information were also shown. They included a black-on-yellow plaque with the legend **CROSS TRAFFIC DOES NOT STOP** below the **STOP** sign, a warning sign with the legend **SIDE STREET DOES NOT STOP**, and a black-on-white plaque with the legend **SH 7 TRAFFIC DOES NOT STOP**. None of these alternatives were highly endorsed by the focus group participants. The feeling was that these signs offered too much unnecessary information that could be more effectively displayed with a **2-WAY** plate on the **STOP** sign.

Lane Reduction Transition

A substantial number of drivers in the focus groups exhibited a lack of understanding of the standard **Lane Reduction Transition** sign when they were shown a picture of the standard symbol sign by itself. Once the meaning of the sign was explained, they were then presented with the signs shown in Figure III-11, and participants were asked which of the signs they preferred to communicate the concept of a lane reduction. In two of the groups, Rockport and

Somerville, the participants unanimously agreed that the standard sign (Sign A) depicts the situation more effectively than the alternative signs (Signs B and C).

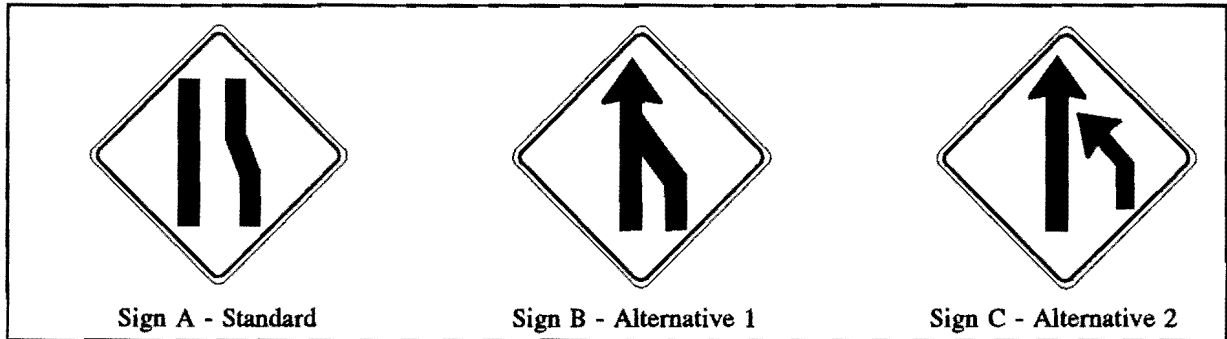


Figure III-11. Lane Reduction Transition Sign and Alternatives

The College Station focus group had more diversity of opinion regarding this sign. However, the standard sign was preferred by six of the group members, primarily because they disliked the alternatives. The four who preferred the alternatives believed they communicated the lane reduction more clearly.

However, it should also be noted that driver preference for the standard sign was indicated despite drivers unfamiliarity with the meaning of the sign. This raises the question of why some drivers prefer a sign for which they do not understand the meaning.

Slow Down on Wet Road

The focus group participants were asked their opinions regarding the alternatives shown in Figure III-12 for the **Slow Down on Wet Road** warning sign. Despite the results of previous surveys indicating a lack of comprehension for the symbol sign, the majority of the group participants preferred this sign over the proposed alternatives. The comments regarding the word message signs indicated that the words were too much to read. The participants, in general, had very good recognition of the **Slow Down on Wet Road** symbol, and knew that the suggested course of action is to slow down.

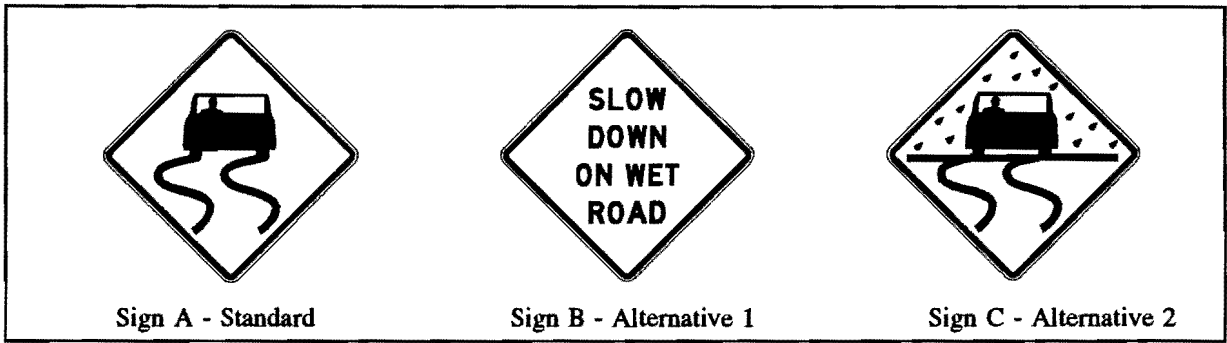


Figure III-12. Slow Down on Wet Road Sign and Alternatives - Focus Groups

CHAPTER IV

FINDINGS AND RECOMMENDATIONS

Five different evaluations of traffic control devices were conducted during the first three years of this study. These evaluations include: a statewide survey of 1,745 drivers on 46 traffic control devices, the 1992 Auto Show survey of 322 drivers on ten traffic control devices, the 1993 Auto Show survey of 286 drivers on five signs, a Spanish-language survey of 31 drivers on 46 traffic control devices, and three focus groups of ten drivers each on three traffic control devices. The statewide survey is described in detail in the two previous research reports (2, 3), and it is summarized in Chapter II of this report. The other evaluations are described in Chapter III of this report. In all, 2,414 drivers were tested on their comprehension of 52 different traffic control devices.

This chapter describes how the results from these five evaluations were used to develop recommendations for improving driver understanding of these traffic control devices. Most of the devices evaluated in this study are described individually, although similar devices have been grouped together where it is appropriate to do so. This chapter is intended to serve as an overall summary of the various evaluations and to describe the justification(s) for the recommendations provided for these traffic control devices. For each device or group of devices, the following information is provided:

- **Name or Category of Traffic Control Device(s).** A brief description of a device or group of devices is provided. The description includes the following information:
 - ▶ The intended use of the traffic control device(s).
 - ▶ Why the device(s) was selected for evaluation.
 - ▶ The survey(s) in which the device(s) was evaluated.
- **Evaluation Procedures.** The activities and findings for a given device(s) are summarized for each of the evaluations in which the device(s) was included. For each evaluation procedure, the following information is provided:
 - ▶ The purpose of the question.
 - ▶ A summary of the general findings from the evaluation.

- **Findings and Recommendations.** The overall study findings and recommendations are described. These descriptions include the following information as it relates to a device or a group of devices:
 - ▶ A summary of the findings on driver understanding of the device(s).
 - ▶ A description of the specific recommendations (if any) to improve driver understanding of the device(s).
 - ▶ Recommendations for further study of a device(s), if appropriate.
 - ▶ A table summarizing the overall evaluations, findings, and recommendations for a device(s) within this research study. Each table contains the following information:
 - The label or designation of a sign (if the device is a sign).
 - The section of the Texas MUTCD (13) in which the device is described.
 - The surveys in which the device(s) was evaluated and the page(s) of the appropriate appendix which contain the images, response choices, response percentages, or other information about the evaluation of the device(s).
 - The focus of the study evaluations.
 - A short summary of the overall study findings.
 - A list of any alternative design(s) that was evaluated.
 - A description of the meaning of the device(s) as it appears in the *Texas Drivers Handbook* (TDH) (4).
 - A summary of the overall study recommendations for the device(s).

The recommendations described in this report were developed by the research team with the assistance of the Technical Panel (TP). This group included representatives of the Texas Department of Transportation (TxDOT), the Texas Department of Public Safety (DPS), the Texas Education Agency (TEA) and the Federal Highway Administration (FHWA). The members of the TP were able to provide the researchers with valuable insights related to many different aspects of traffic control devices. The research team met with the TP several times throughout the study and the assistance and comments received from the TP were instrumental in developing the final recommendations.

INTERPRETATION OF SURVEY RESULTS

There are several different factors that should be considered when interpreting the results of the surveys conducted as part of this research study. Several of these factors are related to the use of statistics to analyze the data. Two different statistical tests, a Chi-square test and a z test, were used to analyze the data. The Chi-square test of significance was used to identify significant relationships among the variables for a specific question, with a significance level set at $p \leq .01$.

The z test shown in Table IV-1 was used to compare the results from two different samples. The typical confidence level used in the z test was 90 percent ($1-\alpha$), although other values were used in some cases. When another value is used in a comparison, it is indicated in the text. The z test is used to determine if two response percentages are statistically different. The language used to describe the results of the test can be confusing. When a z test indicates that two responses are not statistically the same, it means that there is a α percent chance of assuming the two responses are different when in fact they are the same (a Type I error). On the other hand, a test that does not indicate a statistical difference between two responses does not infer that they are the same. The typical language used to describe these two results is that there was or was not a "significant" difference between two responses. When the word "significant" is used in describing research findings, it implies a statistically measurable finding result. It does not imply a large or unacceptable difference between two response choices.

The precision of the survey results should also be considered in the interpretation of the survey results. The statistical precision of a survey response is an indication of the degree to which a response from a survey sample is expected to represent the response of the entire population. If the precision for a survey response of 50 percent is determined to be ± 1.5 percent with a 90 percent confidence level, then there is a 90 percent probability that the actual response of the entire population would be somewhere between 48.5 percent and 51.5 percent. The precision of a response becomes better as the sample size increases. Table IV-2 indicates the precision of the various surveys conducted for this research.

Table IV-1. Z Test for Two Binomial Proportions

Null hypothesis, $H_0: \pi_1 - \pi_2 = 0$
 Alternative hypothesis, $H_1: \pi_1 - \pi_2 \neq 0$

Test Statistic:
$$z = \frac{\hat{\pi}_1 - \hat{\pi}_2}{\sigma_{\hat{\pi}_1 - \hat{\pi}_2}}$$

where
$$\sigma_{\hat{\pi}_1 - \hat{\pi}_2} = \sqrt{n(1-\pi)(1/n_1 + 1/n_2)}$$

and π is approximated by
$$\hat{\pi} = \frac{y_1 + y_2}{n_1 + n_2}$$

Rejection Region: For a given value of α , reject H_0 if $|z| > z_{\alpha/2}$

Values of $z_{\alpha/2}$ for a given α :

for	$\alpha = 0.01$,	$z_{\alpha/2} = 2.575$
	$\alpha = 0.05$,	$z_{\alpha/2} = 1.960$
	$\alpha = 0.10$,	$z_{\alpha/2} = 1.645$

Table IV-2. Precision of Survey Responses

Percent Responding Correctly	90% Confidence Interval				95% Confidence Interval			
	Statewide	1st Auto Show	2nd Auto Show	Hispanic	Statewide	1st Auto Show	2nd Auto Show	Hispanic
50%	±2.0%	±8.0%	±4.9%	±14.8%	±2.3%	±9.5%	±5.8%	±17.6%
60% or 40%	±1.9%	±7.8%	±4.8%	±14.5%	±2.3%	±9.3%	±5.7%	±17.2%
70% or 30%	±1.8%	±7.3%	±4.5%	±13.5%	±2.2%	±8.7%	±5.3%	±16.1%
80% or 20%	±1.6%	±6.4%	±3.9%	±11.8%	±1.9%	±7.6%	±4.6%	±14.1%
90% or 10%	±1.2%	±4.8%	±2.9%	±8.9%	±1.4%	±5.7%	±3.5%	±10.6%
Sample Size	1,745	107 ¹	286	31	1,745	107 ¹	286	31

Note: ¹Average size of the three survey sets used to calculate precision

Another factor that should be considered is that the devices evaluated in this research study were selected because of concerns over driver understanding of the device's meaning, or some aspect of the device's meaning. This factor helps to account for the fact that only one device in the statewide survey had a correct comprehension response rate of more than 90 percent.

In many cases, the questions used in the various evaluations were intended to identify driver understanding of specific aspects of traffic control devices. As a result, the results of any specific question cannot be interpreted as the overall effectiveness of the traffic control device. In other words, the fact that only 32 percent of the drivers in the statewide survey selected the correct response for the **Curve** sign does not mean that the **Curve** sign has an effectiveness of 32 percent. The overall comprehension of a given device must be individually interpreted within the context of the question and responses and the intended purpose of the device.

DEVICES EVALUATED IN RESEARCH STUDY

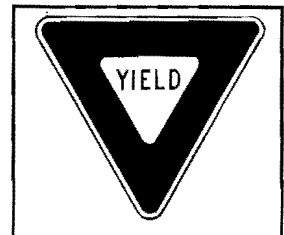
Driver understanding of 52 different traffic control devices were evaluated as part of this research study. Tables IV-3 through IV-7 indicate the specific traffic control devices that were evaluated for five different categories: regulatory signs, warning signs, other signs, pavement markings, and traffic signal indications. The category for other types of signs includes warning signs for railroad-highway grade crossings and warning signs for school areas. The tables indicate the specific evaluations that were conducted for each device and also identifies the pages of this chapter where the study results for each device are discussed.

REGULATORY SIGNS

There were a total of 13 regulatory signs evaluated in the survey. The evaluations of these signs were intended to determine whether drivers understood the regulations communicated by these signs and how they would respond to the signs.

Yield Sign

The **YIELD** sign shown in Figure IV-1 is used to control right-of-way in a manner that is less restrictive than with the use of a **STOP** sign. The sign was selected for evaluation in the study in order to determine the extent to which drivers recognize the less restrictive nature of the sign. It was evaluated only in the statewide survey.



**Figure IV-1.
R1-2 Sign**

Table IV-3. Regulatory Signs Evaluated in Research Study

Sign Label	Device Name	Evaluated In:				Alternative Designs Evaluated	In National MUTCD	Research Summary See Page:
		Statewide Survey	92 Auto Show	93 Auto Show	Focus Groups			
R1-2	YIELD	✓				No	Yes	IV-5
R2-5a	REDUCED SPEED AHEAD	✓				No	Yes	IV-11
R2-5c	SPEED ZONE AHEAD	✓				No	Yes	
R3-7	Mandatory Turn	✓				No	Yes	IV-13
R3-8	Double Turn	✓	✓			No	Yes	IV-14
R3-9b	Two-Way Left Turn Lane	✓	✓			Yes	Yes	IV-16
R3-14	HOV Restriction	✓				No	Yes	IV-18
R4-3	SLOWER TRAFFIC KEEP RIGHT	✓				No	Yes	IV-21
R4-3B	DO NOT CROSS DOUBLE WHITE LINE	✓				No	No	IV-67
R4-7	Keep Right	✓		✓		No	Yes	IV-22
R10-9	PROTECTED LEFT ON GREEN ARROW	✓				No	No	IV-24
R10-9a	PROTECTED LEFT ON GREEN	✓				No	No	
R10-12	LEFT TURN YIELD ON GREEN Ball	✓				No	Yes	

Table IV-4. Warning Signs Evaluated in Research Study

Sign Label	Device Name	Evaluated In:				Alternative Designs Evaluated	In National MUTCD	Research Summary See Page:
		Statewide Survey	92 Auto Show	93 Auto Show	Focus Groups			
W1-1	Turn	✓	✓			Yes	Yes	IV-27
W1-2	Curve	✓				No	Yes	
W1-3	Reverse Turn	✓		✓		No	Yes	
W1-5	Winding Road			✓		No	Yes	
W3-1a	Stop Ahead	✓				No	Yes	IV-33
W4-2	Lane Reduction Transition	✓			✓	Yes	Yes	IV-34
W9-1	RIGHT LANE ENDS				✓	No	Yes	
W9-2	LANE ENDS MERGE LEFT	✓		✓	✓	No	Yes	
W5-2a	Narrow Bridge	✓				No	Yes	IV-37
W6-2	Divided Highway Ends	✓				No	Yes	IV-39
W8-5	Slow Down on Wet Road*	✓	✓		✓	Yes	Yes ¹	IV-40
W8-8	ROUGH ROAD	✓				No	No	IV-43
W8-12	GROOVED PAVEMENT AHEAD	✓				No	No	
W11-10	Truck Crossing	✓				No	No	IV-45
W14-4	LIMITED SIGHT DISTANCE	✓				No	No	IV-47
W19-2	WATCH FOR ICE ON BRIDGE	✓				No	No	IV-48
W19-3	RAMP METERED WHEN FLASHING	✓		✓		No	No	IV-50

Note: *This sign is called the Slippery When Wet sign in the National MUTCD.

Table IV-5. Other Types of Signs Evaluated in Research Study

Sign Label	Device Name	Evaluated In:				Alternative Designs Evaluated	In National MUTCD	Research Summary See Page:
		Statewide Survey	92 Auto Show	93 Auto Show	Focus Groups			
---	Warning Sign Shape & Color	✓				No	Yes	IV-52
---	Guide Sign Color	✓				No	Yes	
W10-1	Railroad Advance Warning	✓				No	Yes	IV-55
W10-3	Parallel Railroad Advance Warning	✓				No	Yes	
S1-1	School Advance		✓			Yes	Yes	IV-57
S5-1	School Speed Limit	✓				No	Yes	IV-60
CW8-9a	Low Shoulder		✓			No	No	IV-61
CW21-13	Shoulder Drop-Off		✓			No	No	
CW21-14	Uneven Lanes		✓			No	No	
OM-3	Type 3 Object Marker	✓				No	Yes	IV-63

Table IV-6. Pavement Markings Evaluated in Research Study

Type of Marking	Evaluated In:				Alternative Designs Evaluated	In National MUTCD	Research Summary See Page:
	Statewide Survey	92 Auto Show	93 Auto Show	Focus Groups			
Single Broken Yellow Center Line	✓				No	Yes	IV-65
No-Passing Zone	✓				No	Yes	
Two-Way Left Turn Lane Markings	✓				No	Yes	IV-16
Single Broken White Lane Line	✓	✓			No	Yes	IV-67
Double Solid White Lane Line	✓				No	Yes	
Solid White Edge Line	✓				No	Yes	IV-69
Preferential Lane Marking	✓				No	Yes	IV-18

Table IV-7. Traffic Signal Indications Evaluated in Research Study

Device Name	Evaluated In:				Alternative Designs Evaluated	In National MUTCD	Research Summary See Page:
	Statewide Survey	92 Auto Show	93 Auto Show	Focus Groups			
Steady Yellow Arrow - Traffic Signal	✓				No	Yes	IV-71
Flashing Yellow Ball - Traffic Signal	✓				No	Yes	
Flashing Red - Intersection Beacon	✓	✓		✓	Yes	Yes	IV-73
Flashing Yellow - Intersection Beacon	✓				No	Yes	
Steady Red X - Lane-Use Control Signal	✓				No	Yes	IV-76

Statewide Survey

The statewide survey question for this sign was intended to evaluate how drivers interpret the right-of-way control provided by the **YIELD** sign. Almost 80 percent of the statewide survey participants selected the correct response to this question. Less than one percent selected the "not sure" response. As a result of the high levels of understanding, the research team determined that the **YIELD** sign was understood by most drivers and further evaluation was not necessary.

Findings and Recommendations

In evaluating the responses to the statewide survey question, the research team determined that this sign demonstrated an acceptable level of understanding. Therefore, it was decided that the **YIELD** sign did not require any further evaluation in this study. Furthermore, the research team determined that no action is necessary to change the design or use of the **YIELD** sign, nor is it necessary to change the description of the sign in the *Texas Drivers Handbook*. Table IV-8 summarizes the findings of the research study with respect to the **YIELD** sign.

Table IV-8. Research Summary for the YIELD Sign

Sign Label	R1-2
TMUTCD Section	2B-7
Evaluation Procedures	Statewide Survey - see page A-7.
Focus of Evaluation	Degree of restriction imposed by sign.
Findings	Comprehension levels of YIELD sign appear to be adequate.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	<i>"This sign tells you that the road you are on joins with another road ahead. You should slow down or stop if necessary so that you can yield the right-of-way to vehicles on the other road."</i>
Recommendations	Changes to the design, use, or education of this sign do not appear to be necessary.

Reduced Speed Ahead and Speed Zone Ahead Signs

The **REDUCED SPEED AHEAD** and **SPEED ZONE AHEAD** signs shown in Figures IV-2 and IV-3 are both used to provide the driver with advance notice of a lower speed limit. Either of these two signs can be used for this purpose. These signs are always followed by a **SPEED LIMIT** sign. Both of these signs were included in the study in order to determine if one sign was better understood than the other sign. They were only evaluated in the statewide survey.

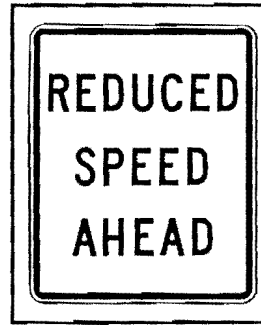


Figure IV-2.
R2-5a Sign

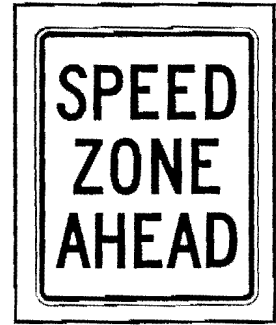


Figure IV-3.
R2-5c Sign

Statewide Survey

Identical questions and responses were asked for the **REDUCED SPEED AHEAD** and **SPEED ZONE AHEAD** signs in the statewide survey. This was done in order to allow direct comparisons to be made between the results for the two signs. These signs were included in the statewide survey in order to determine how drivers interpret the meaning of the term "*speed zone*." The use of the term can be traced back to early editions of the MUTCD (14, 15) where it was used to indicate a section of roadway where the statutory speed limits had been altered by speed limit signs. The results of the statewide survey indicate that many modern-day drivers (31 percent) associate the term "*speed zone*" with enforcement instead of a lower speed limit. This may be due to the association of enforcement with terms such as "*school zone*" and "*no parking zone*" although the evaluations did not indicate a basis for such a misunderstanding. The survey results indicate that the **REDUCED SPEED AHEAD** sign is more effective than the **SPEED ZONE AHEAD** sign at conveying the desired message. Although comprehension of the **REDUCED SPEED AHEAD** sign is higher than the **SPEED ZONE AHEAD** sign, the survey results should not be interpreted to mean that the **SPEED ZONE AHEAD** is not effective. The 31 percent of drivers who associate the sign with greater enforcement would most likely have the same response to the sign as drivers who correctly understand the sign. As a result, 86 percent of drivers will perform an appropriate response to the **SPEED ZONE AHEAD** sign.

Findings and Recommendations

At the present time, the **SPEED ZONE AHEAD** sign is used more frequently than the **REDUCED SPEED AHEAD** sign. The research results for these two signs indicate that consideration should be given to making the **REDUCED SPEED AHEAD** sign the preferred alternative. When an existing **SPEED ZONE AHEAD** sign needs to be replaced, the **REDUCED SPEED AHEAD** sign should be used. New installations should also use the **REDUCED SPEED AHEAD** sign. However, because the **SPEED ZONE AHEAD** sign also results in acceptable driver behavior, existing signs can continue to be used until the end of their service life. Because of the high levels of comprehension associated with the **REDUCED SPEED AHEAD** sign, adding the sign to education/training programs or the *Texas Drivers Handbook* does not appear to be necessary at this time. Table IV-9 summarizes the study findings and recommendations for these two signs.

Table IV-9. Research Summary for the REDUCED SPEED AHEAD and SPEED ZONE AHEAD Signs

Sign Label	R2-5a REDUCED SPEED AHEAD R2-5c SPEED ZONE AHEAD
TMUTCD Section	2B-14
Evaluation Procedures	Statewide Survey - see pages A-21 for R2-5a and A-6 for R2-5c.
Focus of Evaluation	Most effective of two signs.
Findings	The correct response rate for the REDUCED SPEED AHEAD sign was 38 percentage points higher than the correct response rate for the SPEED ZONE AHEAD sign.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	Not described.
Recommendations	The REDUCED SPEED AHEAD sign is more effective at providing drivers with advance notice of a lower speed limit. As a result, the REDUCED SPEED AHEAD sign should be used instead of the SPEED ZONE AHEAD sign whenever possible.

Mandatory Turn Sign (Right Lane Must Turn Right)

The **Mandatory Turn** sign illustrated in Figure IV-4 is used to inform the driver that the lane on the right (left) side of the road is ending a short distance ahead and any vehicles in the lane must turn right (left) at the point where the lane ends. The Texas MUTCD (13) does not indicate whether the driver must turn right at the first opportunity (such as a driveway between the sign and an intersection), or at an intersection where the lane actually ends. This sign was selected for evaluation in order to determine where drivers interpreted the turn requirement to apply. Only the statewide survey included the sign.



**Figure IV-4.
R3-7 Sign**

Statewide Survey

The in-context picture of this sign showed the sign and several driveways between the sign and the crest of a curve. There was no intersection visible in the sign. The focus of the question was whether drivers thought they had to turn right at the next driveway or intersection. The large majority of drivers (80 percent) thought the sign indicated that the lane would turn right at the next intersection. Only 14 percent indicated it applied to the next driveway.

Findings and Recommendations

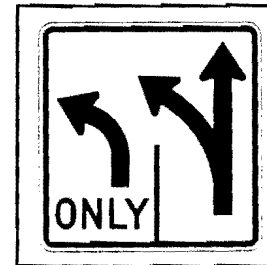
The results of the statewide survey indicated that drivers do not interpret this sign as applying to driveways between the sign and the next intersection. These results indicate that consideration should be given to providing drivers with more information if the turn restriction is intended to apply to an intermediate driveway or for those situations where the location of the turn restriction may not be apparent. This type of additional information could be provided with a supplemental distance plaque (such as **500 FEET**) located below the sign that would indicate the distance to the point where the right lane must turn right. If such a supplemental plaque is not identified for use with this sign, consideration should then be given toward adding a description of this sign to the *Texas Drivers Handbook*. Table IV-10 contains a summary of the research findings and recommendations for this sign.

Table IV-10. Research Summary for the Mandatory Turn Sign

Sign Label	R3-7
TMUTCD Section	2B-17
Evaluation Procedures	Statewide Survey - see page A-8.
Focus of Evaluation	Point where turn is required.
Findings	Almost 80 percent interpret the sign as applying to the next intersection as compared to 14 percent who thought it applied to a driveway.
Alternative Designs Evaluated	None
Texas Drivers Handbook Description	Not described.
Recommendations	In those situations where it may not be clear where the turn restriction exists, consideration should be given to the use of a supplemental distance plaque below the sign to indicate the location where the driver must turn. If such a plaque is not used, consideration should be given to adding a description of the sign to the TDH.

Double Turn Sign

The **Double Turn** sign illustrated in Figure IV-5 is intended for use at intersections where a left turn is permitted from either of the two left lanes. Vehicles in the leftmost lane can make only a left turn, while vehicles in the second left lane can make a left turn or go straight. A mirror image of this sign can be used for right turns. This sign was included in the study because previous TTI studies of the sign (5, 6) indicated that drivers did not fully understand which movements were permitted from each lane. It was evaluated in both the statewide survey and the 1992 Auto Show survey.



**Figure IV-5.
R3-8 Sign**

Statewide Survey

This question was intended to evaluate driver understanding of the message the sign conveys about the movements that are permitted/restricted for each lane. About two-thirds of the drivers selected the response that indicated a straight movement from the right lane. However, about one-third of the drivers selected responses which indicated movements that were not indicated by the sign. The research team felt that some of the driver confusion about this sign could be attributed to the format and wording of the question itself, rather than confusion over the actual

meaning of the sign. Therefore, this sign was selected for additional evaluation in the 1992 Auto Show survey.

1992 Auto Show Survey

The **Double Turn** sign was evaluated again in the 1992 Auto Show survey. The intent of the evaluation remained the same, that is, driver understanding of the movements that were permitted/restricted from each lane. In order to assess driver understanding for several movements from each of the two lanes, a true/false (T/F) question format was utilized. The results of the 1992 Auto Show survey indicate that a large majority of drivers understood the intended meaning of this sign for all movements from both lanes. Over 90 percent of the drivers selected the proper response for all but one of the eight statements.

Findings and Recommendations

The findings from the 1992 Auto Show survey indicate that this sign is understood by most drivers. As a result, the current design, use, and education for this sign appear to be adequate. Table IV-11 contains a summary of the study findings and recommendations for this sign.

Table IV-11. Research Summary for the Double Turn Sign

Sign Label	R3-8
TMUTCD Section	2B-17
Evaluation Procedures	Statewide Survey - see page A-42. 1992 Auto Show - see page B-4.
Focus of Evaluation	Driver understanding of the movements which can be made from each lane.
Findings	Most drivers understand this sign.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	<i>"This sign indicates that two lanes of traffic are permitted to turn left. The traffic in the left lane must turn left, traffic in the other lane has a choice."</i>
Recommendations	Changes to the design, use, or education of this sign do not appear to be necessary.

Two-Way Left Turn Lane Sign and Markings

Two-way left turn lanes are often used in urban areas to provide continual left-turn access to adjacent properties and as a flush median to separate opposing traffic. The two-way left turn

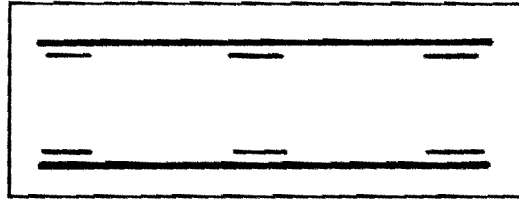


Figure IV-6.
Two-Way Left Turn Lane Markings

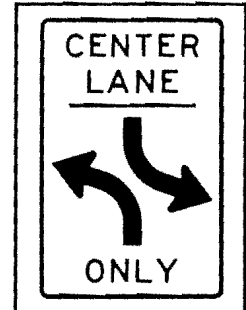


Figure IV-7.
R3-9b Sign

lane is indicated with pavement markings shown in Figure IV-6 and is typically accompanied by the **Two-Way Left Turn Only** sign shown in Figure IV-7. This is the post mounted version of the sign. An overhead version can also be used. Both the sign and the markings were selected for evaluation in this study due to concern over driver understanding and use of two-way left turn lanes. Both devices were evaluated in the statewide survey and the sign was further evaluated in the 1992 Auto Show survey.

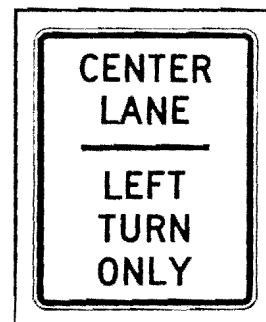
Statewide Survey

The focus of these questions was to determine how drivers used the center lane. In the question on the sign, drivers tended to select two primary responses. Each response was selected by about 45 percent. One response was the correct one, which indicated the lane was for left turns only. The other response that was most commonly selected was that the lane could be used for left or right turns. The inappropriateness of this response led the research team to include this sign in the 1992 Auto Show survey.

The question on the two-way left turn lane markings was intended to determine when drivers entered the lane for a left turn (before or after slowing down) and if drivers used the lane as a refuge area when crossing or turning onto the street. The refuge issue was included due to a lack of information indicating whether such a use is legal. Over half of the drivers indicated they would enter the lane and then slow down before making a left turn, while about one-fourth indicated they would slow in the through lanes and then enter the left turn lane. These responses indicated that it may be appropriate to provide drivers with more information about the use of a left turn lane.

1992 Auto Show Survey

The 1992 Auto Show survey evaluated the standard sign shown in Figure IV-7 and an alternative version of the sign, which is shown in Figure IV-8. The alternative design was a word message sign which was the original version of this sign as it appeared in the 1971 MUTCD (10). The response choices were revised in order to prevent the type of confusion exhibited in the statewide survey. The survey results indicate that 10 percent more drivers selected the correct response for the word message version of the sign. However, this difference is not statistically significant at a level of confidence of 90 percent. Therefore, it is inappropriate to state that the word message alternative is better understood than the symbol sign.



**Figure IV-8.
Alternative Sign**

Findings and Recommendations

The results of the study with respect to two-way left turn lanes indicate that drivers do not have a thorough understanding of how two-way left turn lanes should be used. The comparison of the symbolic and word message versions of the signs did not indicate that one sign was any more effective than the other sign. Additional evaluations should be conducted to evaluate other alternative designs to determine if a more effective sign design could better convey the desired message.

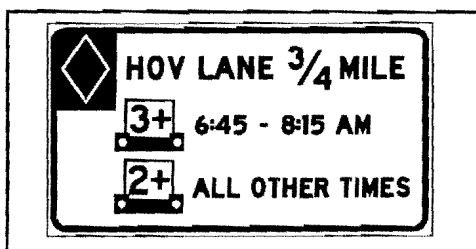
Once any additional evaluations have been conducted, it may be appropriate to review treatment of two-way left turn lanes in driver education/training programs and the *Texas Drivers Handbook*. Consideration should be given to expanding the descriptions of two-way left turn lanes in the *Texas Drivers Handbook* to mention that drivers should use the lane for slowing down and clarify the use of the lane as a refuge area when making a left turn onto the street. Table IV-12 summarizes the findings and recommendations resulting from the evaluation of these two traffic control devices.

Table IV-12. Research Summary for the Two-Way Left Turn Lane Sign and Pavement Marking

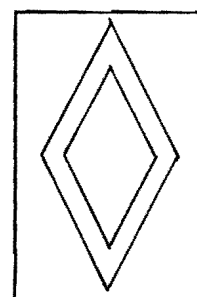
Sign Label	R3-9b
TMUTCD Section	2B-19 Sign 3B-1 Pavement Marking
Evaluation Procedures	Statewide Survey - see page A-36 for the sign and page A-9 for the pavement marking. 1992 Auto Show - see page B-5 for the standard sign and 1 alternative.
Focus of Evaluation	Driver understanding and use of two-way left turn lanes.
Findings	Drivers do not have a complete understanding of how the lane should be used.
Alternative Designs Evaluated	Word message sign.
Texas Drivers Handbook Description	Sign - <i>"The center lane of a highway is reserved for the exclusive use of left turning vehicles in either direction and not used for passing or overtaking."</i> Marking - <i>"The only time a vehicle should enter the center lane is at a point where the vehicle will have time to slow down or stop in order to make a safe left turn maneuver. The center lane should never be used for passing or as a through traffic lane."</i>
Recommendations	Conduct additional evaluations of alternative sign designs. Consider increasing the emphasis in driver education/training on the use of a two-way left-turn lane and expand the description in the TDH to include how the lane should be used.

HOV Sign and Marking

High-occupancy vehicle (HOV) facilities are used in congested urban areas to encourage people to use carpools or to ride buses. Typically, use of these HOV facilities is limited to vehicles with more than one occupant. The concept is not widely used in Texas, as only Houston and Dallas currently have HOV lanes. However, several other urban areas are beginning to consider implementing HOV facilities and they will become more common as congestion on urban freeways becomes worse. The current limited use of HOV lanes was one of the primary reasons for including two HOV traffic control devices in the research study. The two devices, which are shown in Figures IV-9 and IV-10, included a sign indicating occupancy requirements that vary by time, and the other was the diamond pavement marking, which is widely used to signify an HOV facility. They were evaluated in the statewide survey only.



**Figure IV-9.
HOV Restriction Sign**



**Figure IV-10.
Diamond
Marking**

Statewide Survey

The sign used in the question indicated that different occupancy requirements applied at different times of the day. The focus of the sign question was to determine if drivers recognized that the occupancy requirement changed with the time. Slightly less than half of the drivers selected the correct response. One-third of the drivers were not sure of the occupancy requirement.

The question on the diamond pavement marking asked drivers to indicate the purpose of the marking. About two-thirds of the drivers recognized that only certain types of vehicles could use the lane. Over one-fourth were not sure of the purpose of the marking. The "not sure" responses for these two devices were the highest of any of the devices in the statewide survey.

One of the concerns about these devices was that drivers outside the major urban areas would not be familiar with the devices. Therefore, the survey results for each of these two devices were evaluated in greater detail for the two urban areas where the statewide survey was administered and HOV lanes are currently used, Houston and Dallas. The Houston and Dallas response percentages for these two devices are shown in Tables IV-13 and IV-14. A statistical comparison of the results for these areas and the statewide results provides the following findings:

- HOV Sign
 - ▶ Statewide and Houston results are statistically different at a level of confidence of 99 percent, except for the third response.
 - ▶ Statewide and Dallas results are **not** statistically different at a level of confidence of 99 percent.
- HOV Marking
 - ▶ The second and fourth responses of the statewide and Houston results are **not** statistically different at a level of confidence of 90 percent. The first and third responses are statistically different at a level of confidence of 90 percent.
 - ▶ Statewide and Dallas results are **not** statistically different at a level of confidence of 99 percent.

Table IV-13. Comprehension of HOV Sign in Dallas and Houston

<i>It is 7:30 AM, what vehicles are allowed to enter the HOV lane?</i>			
Statewide Response Rate	Houston Response Rate	Dallas Response Rate	Response
9.9%	17.6%	8.6%	Carpools with 2 or more people.
*45.7%	*63.3%	*43.5%	<i>Carpools with 3 or more people.</i>
11.2%	8.5%	13.4%	Carpools with more than 3 people.
33.2%	10.6%	34.5%	Not sure.

Note: *Indicates correct response.

Table IV-14. Comprehension of HOV Pavement Marking in Dallas and Houston

<i>Why is the white diamond painted on the pavement?</i>			
Statewide Response Rate	Houston Response Rate	Dallas Response Rate	Response
4.3%	4.1%	5.8%	This is a symbol used for aircraft speed control.
*65.3%	*79.6%	*62.9%	<i>This lane is to be used only by certain vehicles.</i>
2.5%	2.4%	1.9%	This is a two-way road.
27.9%	13.9%	29.4%	Not sure.

Note: *Indicates correct response.

These results generally indicate that the Dallas drivers demonstrated about the same level of understanding of these devices as those in the rest of the state. The Houston drivers appear to be more familiar with these devices and have a better understanding of the meaning and use of these devices than the drivers in the rest of the state. The results for the Houston drivers tend to suggest that drivers will become more familiar with these devices when they are used in an urban area over a period of time.

Findings and Recommendations

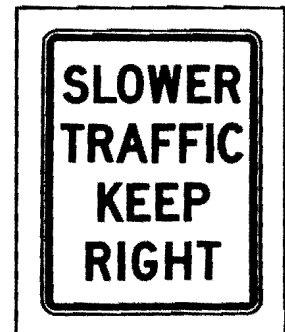
The findings of the statewide survey indicate that drivers throughout the state are not sure of the intended meanings and uses of signs and markings that relate to HOV facilities. The lack of familiarity with the HOV traffic control devices appears to be a function of a lack of familiarity with HOV facilities rather than an indication of ineffective traffic control devices. As a result, it is probably more appropriate to emphasize education and enforcement for these devices rather than a change in the devices. The study findings and recommendations for these two traffic control devices are summarized in Table IV-15.

Table IV-15. Research Summary for the HOV Restriction Sign and Diamond Pavement Marking

Sign Label	R3-14
TMUTCD Section	2B-20 Sign 3B-22 Pavement Marking
Evaluation Procedures	Statewide Survey - see page A-47 for the sign and A-44 for the pavement marking.
Focus of Evaluation	Driver understanding of and familiarity with HOV facilities.
Findings	Many drivers are not familiar with the devices used with HOV facilities.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	Not described.
Recommendations	Increase education of devices through driver education/training and the TDH.

Slower Traffic Keep Right Sign

The **SLOWER TRAFFIC KEEP RIGHT** sign shown in Figure IV-11 is intended for use on multilane roadways to reduce weaving resulting from faster traffic changing lanes to pass slower traffic. The Texas MUTCD states that the sign may be used "*where there is a tendency on the part of the motorist to drive in the left-hand lane (or lanes) below the normal speed of traffic.*" The sign was included in the study in order to assess driver understanding of the term "slower traffic." The sign was evaluated only in the statewide survey.



**Figure IV-11.
R4-3 Sign**

Statewide Survey

Most of the drivers (71 percent) selected the "slower than traffic" response, while 27 percent selected the "slower than the speed limit" response. These results indicate that about one-fourth of the drivers would continue to use the left lane if they are driving the speed limit, even if the other traffic was faster. Contrary to expectation, driver age was not a factor in the selection of responses.

Findings and Recommendations

The survey results indicate that over 95 percent of drivers recognize the "slower traffic keep right" message of this sign, although there are some differences in how they interpret the word "slower." A more detailed legend (i.e., more words) probably would not improve understanding of the sign and would decrease legibility and/or increase the time needed to read the sign. The emphasis should be on improving driver understanding of the "slower traffic" concept and the fact that "slower traffic" refers to vehicles that are slower than other vehicles on the roadway, irrespective of the speed limit on the roadway. The *Texas Drivers Handbook* should be revised to reflect this concept and the concept should be addressed in driver education/training programs. The study results and recommendations for this sign are summarized in Table IV-16.

Table IV-16. Research Summary for the SLOWER TRAFFIC KEEP RIGHT Sign

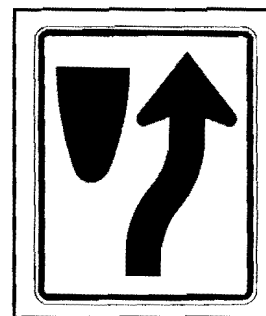
Sign Label	R4-3
TMUTCD Section	2B-23
Evaluation Procedures	Statewide Survey - see page A-13.
Focus of Evaluation	Driver interpretation of the term "slower traffic."
Findings	Over two-thirds interpret it as slower than traffic and one-fourth interprets it as slower than the speed limit.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	<i>"If you are driving slower than the normal stream of traffic keep in the righthand lane."</i>
Recommendations	Improve driver understanding of the "slower traffic" concept through driver education and revising the TDH.

Keep Right Sign

The **Keep Right** symbol sign shown in Figure IV-12 is intended for use at the beginning of islands, divided roadways, piers, and other locations where traffic is required to stay to the right of the obstruction. Word message alternatives can be used instead of the symbol sign. The sign was selected for evaluation in this study in order to assess driver understanding of this sign. It was evaluated in the statewide survey and in the 1993 Auto Show survey.

Statewide Survey

The focus of the question was whether drivers thought the sign indicated that the driver should stay to the right of the obstruction, or move to the far right-hand lane. Many drivers (70 percent) demonstrated the correct understanding of the sign, but about one-fourth of the drivers selected the response that indicated they should stay in the far right lane. The research team felt that most of these drivers understood the intended meaning of the sign, but selected the "far right lane" choice because of lane position or other interpretation of the specific situation. Therefore, this sign was selected for further study in the 1993 Auto Show survey, where drivers provided an open-ended response to questions about the sign.



**Figure IV-12.
R4-7 Sign**

1993 Auto Show Survey

In the 1993 Auto Show survey, drivers were asked several questions about the **Keep Right** sign, with responses in an open-ended format. About three-fourths of the survey participants provided an essentially correct meaning of the sign. These responses included various interpretations of the proper driving response to the sign, including "keep right," "slow down," "follow the arrow," and "merge right." About one-fourth of the drivers selected responses other than essentially correct responses.

Findings and Recommendations

The results of the two surveys indicate the need to improve understanding of the sign among some drivers through greater emphasis in driver education/training programs. The *Texas Drivers Handbook* should be revised to indicate that a lane change is not required. Table IV-17 summarizes the study activities, findings, and recommendations for this sign.

Table IV-17. Research Summary for the Keep Right Sign

Sign Label	R4-7
TMUTCD Section	2B-25
Evaluation Procedures	Statewide Survey - see page A-12. 1993 Auto Show Survey - see page C-5.
Focus of Evaluation	Driver understanding of sign meaning.
Findings	Most drivers understand the meaning and use of the sign.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	<i>"Drive to the right of this sign. This sign is used in advance of islands and medians."</i>
Recommendations	Increase understanding of this sign through driver education/training. Revise the description of this sign in the TDH.

Left Turn Signal Signs

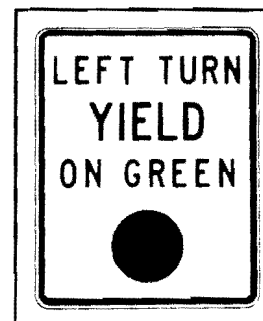
Left turn lanes and left turn signal phasing are commonly used for traffic control at signalized intersections. However, there are several different combinations of phasing and control for left turns and, in some situations, it is necessary to provide drivers with specific information about left turn signal operation at an intersection. The three signs shown in Figures IV-13, IV-14, and IV-15 have been used in Texas to inform the driver of the type of left turn signal operation. Table IV-18 describes the intended purposes of these signs. All three signs were selected for evaluation in order to assess driver understanding of the signs and their relationship to left turn signal operation. Each of the signs was evaluated only in the statewide survey.



**Figure IV-13.
R10-9 Sign**



**Figure IV-14.
R10-9a Sign**



**Figure IV-15.
R10-12 Sign**

Table IV-18. Uses of Left Turn Signal Signs

Sign	Intended Use
PROTECTED LEFT ON GREEN ARROW	The left turn is protected when a green arrow is displayed and permitted when the green ball is displayed.
PROTECTED LEFT ON GREEN	The left turn is protected when the green ball is displayed.
LEFT TURN YIELD ON Green Ball	The left turn is permitted when the green ball is displayed.

In describing left turn operation associated with these signs, the term "protected" is used to describe signal phasing where left turning traffic can make the left turn without yielding to opposing traffic. "Permitted" or "permissive" are used to indicate signal phasing where the left turning traffic must yield the right-of-way to opposing traffic and turn left only when adequate gaps are available.

Statewide Survey

For each of the questions, the focus was on whether the driver understood that the left turn was protected or permitted. It should be noted that the close-up image for the **PROTECTED LEFT ON GREEN ARROW** sign included a signal head displaying a green arrow and green ball. Table IV-19 summarizes the statewide survey results for each of the signs. The responses shown in Table IV-19 are paraphrased from the actual responses used in the individual questions.

Table IV-19. Summary of Statewide Survey Results for Left Turn Signal Signs

R10-9	R10-9a	R10-12	Paraphrase of Response Choices
27.0	47.5	13.6	Turn left only with green arrow (protected left turn).
16.6	*15.5	4.3	Protected left turn with green ball.
*53.0	34.7	*74.5	Permitted left turn with green ball.
3.3	2.3	7.6	Not sure.

Note: *Indicates correct response.

The survey results indicated that drivers do not have a full understanding of the R10-9 and R10-9a signs. The **PROTECTED LEFT ON GREEN** sign had the lowest correct response rate of any device in the survey, with only 16 percent selecting the correct response. However, over 80 percent of the drivers responding to this sign indicated that they would wait for an arrow or adequate gap in opposing traffic before making a left turn. Both of these responses are conservative responses that do not necessarily create an unsafe condition. Slightly over half of the respondents to the **PROTECTED LEFT ON GREEN ARROW** sign recognized that the sign indicated a permitted left turn. Slightly more than one-fourth of the drivers thought the sign indicated that left turns were protected only. Another 17 percent thought the sign indicated a protected left turn at all times, even when only the green ball was displayed. The percentage of drivers selecting this last response indicates a need to better inform drivers of the permissive nature of left turns in protected/permitted signal operation.

The results for the **LEFT TURN YIELD ON Green Ball** sign indicated that this sign was more effective at informing drivers of the permissive nature of the left turn. Three-fourths of drivers recognized that they had to wait for a gap in traffic. Another 14 percent would wait for a green arrow. These results indicate that this sign is more effective than the other signs at indicating the permissive nature of protected/permitted left turn operation.

Findings and Recommendations

The results of the statewide survey indicate that drivers may not have a complete understanding of the signs used to identify left turn operation at signalized intersections. The **LEFT TURN YIELD ON Green Ball** sign appears to be better understood at indicating the permissive nature of a left turn. As a result, it may reduce the potential for left turn accidents at an intersection. On the other hand, the **PROTECTED LEFT ON GREEN ARROW** does not provide a direct indication that left turns are permitted when the green ball is displayed. These findings indicate that consideration should be given to making the **LEFT TURN YIELD ON Green Ball** sign the primary sign for protected/permitted left turn signal operation. The same sign was also recommended as the preferred sign in a separate TxDOT-sponsored research study of left-turn signal operations (16). An added benefit of making this sign the primary one is that it is the only one of the three that is included in the national MUTCD (17). Consideration should also be given to adding a description of this sign to the *Texas Drivers Handbook*, as it is not currently included in the handbook. The findings and recommendations for this group of signs are summarized in Table IV-20.

One of the limitations of the statewide survey was the inability to evaluate a wide variety of conditions for each traffic control device. This limitation is especially critical as it applies to left turn signing, due to the many combinations of signs, phasing, signal heads, and geometrics that could be present at any given intersection. However, another TxDOT-sponsored research study (16) evaluated driver understanding and many other factors for several of these combinations. The findings of that study should be considered together with those of this study before making any changes to the design, use, and/or education of these signs.

Table IV-20. Research Summary for the Left Turn Signal Signs

Sign Labels	R10-9 PROTECTED LEFT ON GREEN ARROW Sign R10-9a PROTECTED LEFT ON GREEN Sign R10-12 LEFT TURN YIELD ON Green Ball Sign
TMUTCD Section	2B-37
Evaluation Procedures	Statewide Survey - see pages A-37 for R10-9, A-33 for R10-9a, and A-43 for R10-12 signs.
Focus of Evaluation	Driver understanding of left turn operation for each sign.
Findings	R10-12 sign is the most effective at indicating the permitted nature of protected/permitted left turn phasing.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	R10-9 - <i>"Sign used with traffic signal and advises that left turns are protected only when the green arrow is illuminated and that left turns are permitted on a full green light but are not protected."</i> R10-9a - Not described. R10-12 - Not described.
Recommendations	Consideration should be given to making the R10-12 sign the primary sign for protected/permitted left turn operations. Consideration should also be given to adding a description of this sign to the TDH.

WARNING SIGNS

Warning signs are intended to provide drivers with advance notice of a potentially hazardous condition which may be located in or adjacent to the roadway. These signs are used to warn of a variety of different conditions, some of which may be present at all times (such as a curve in the roadway alignment) and others which may exist only at certain times (such as wet pavement surface). A total of 17 warning signs were evaluated in this research study, and the findings are described in this section. In addition, some of the signs which are classified in the "other" category include warning signs. These signs include the shape and color of a warning sign, railroad-highway grade crossing warning signs, and school warning signs. These signs are discussed in the next section of this chapter.

Horizontal Alignment Warning Signs

Several different signs are used to provide drivers with advance warning of a change in horizontal alignment. These signs are used to indicate the direction, severity (speed), and number of changes in horizontal alignment. Table IV-21 indicates the five different signs that

are used to provide advance warning of a change in horizontal alignment. There are three other signs that are used within the change in horizontal alignment to provide additional emphasis for the alignment change. These signs are rectangular in shape. The four signs shown in Figures IV-16 through IV-19 were selected for evaluation in this research study. The **Turn**, **Curve**, and **Reverse Turn** signs were evaluated in the statewide survey. The **Turn** sign with and without an **Advisory Speed Plate** (W13-1) was evaluated in the 1992 Auto Show survey. The **Reverse Turn** and **Winding Road** signs were evaluated in the 1993 Auto Show survey. The signs were selected for evaluation in order to assess driver understanding of the severity (speed) and number messages conveyed by these signs.

Table IV-21. Advance Warning Signs for Changes in Horizontal Alignment

Recommended Speed ¹	Number of Alignment Changes		
	One	Two	Three or More
30 mph (50 km/h) or Less	Turn Sign W1-1R or W1-1L ²	Reverse Turn W1-3R or W1-3L ²	Winding Road W1-5R or W1-5L ²
Greater than 30 mph (50 km/h)	Curve W1-2R or W1-2L ²	Reverse Curve W1-4R or W1-4L ²	

Notes: ¹An Advisory Speed Plate may be used to indicate the recommended speed.
²An R or L is used to indicate the direction of the first (or only) change in horizontal alignment. The R and L signs are mirror images of one another.

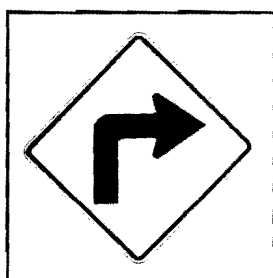


Figure IV-16.
W1-1 Sign

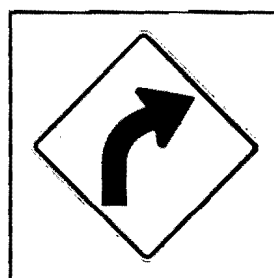


Figure IV-17.
W1-2 Sign

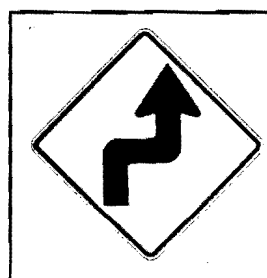


Figure IV-18.
W1-3 Sign

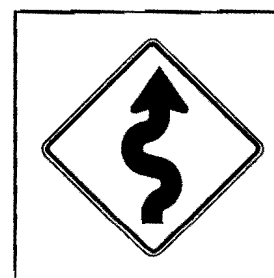


Figure IV-19.
W1-5 Sign

Statewide Survey

Part of the reason that the **Turn** and **Curve** signs were included in the statewide survey was because the *Texas Drivers Handbook* indicates that drivers should slow down in response to these signs. The question for the **Turn** sign was intended to evaluate whether drivers recognized that this sign is used when the recommended speed is 30 mph or less. Less than one-third of the

drivers selected this response. Almost half of the drivers selected the response which indicates a right turn at the next intersection. These results indicate that drivers do not recognize the speed message of the **Turn** sign.

The question on the **Curve** sign was also intended to evaluate driver understanding of the speed message conveyed by this sign. The sign was shown alone, without an **Advisory Speed Plate**. When given a choice between slowing down and driving the curve at the speed limit, two-thirds selected the "slow down" choice and one-third selected the "speed limit" choice. These findings indicate that drivers also do not fully understand the speed message of the **Curve** sign.

The **Reverse Curve** sign was included in the survey in order to evaluate the number and directional messages of the sign. Although two-thirds of the drivers selected the "left turn then right turn" response, another one-fourth of the drivers selected the "winding road" response. The 26 percent of the drivers that selected the "winding road" response do not appear to associate this sign with the presence of two changes in horizontal alignment.

1992 Auto Show Survey

The **Turn** sign was selected for additional evaluation in the 1992 Auto Show survey. Two different signs were evaluated, a **Turn** sign without an **Advisory Speed Plate** and a **Turn** sign with an **Advisory Speed Plate** indicating a recommended speed of 30 mph. The question and response choices for each alternative were identical to those of the statewide survey. The response percentages for the **Turn** sign without the **Advisory Speed Plate** are almost identical to those of the statewide survey. Table IV-22 summarizes the response percentage for the two surveys and indicates that the responses are not statistically different at a level of confidence of 99 percent. When the 30 mph **Advisory Speed Plate** was shown with the **Turn** sign, driver understanding of the speed message improved to 95 percent, as compared to the 32 and 36 percent for the **Turn** sign without the **Advisory Speed Plate**.

Table IV-22. Survey Results for the Turn Sign

Question:		<i>What does this sign mean?</i>	
Statewide Survey	1992 Auto Show Survey		Responses
Turn sign without Speed Plate	Turn sign without Speed Plate	Turn sign with 30 mph Speed Plate	
10.7%	11.7%	1.8%	There is an intersecting road to the right ahead.
*31.9%	*35.9%	*94.7%	<i>You should drive 30 miles per hour or less to make the next turn.</i>
45.2%	49.5%	3.5%	You should turn right at the next intersection.
12.2%	2.9%	0%	Not sure.

Note: *Indicates correct response.

1993 Auto Show Survey

The 1993 Auto Show survey used an open-ended response format to evaluate the **Reverse Turn** and **Winding Road** signs. These signs were selected for evaluation in order to identify the number of alignment changes that drivers associated with each type of sign. The results of the open-ended response question indicated the following:

- 83 and 74 percent would slow down for the **Winding Road** and **Reverse Turn** signs, respectively.
- 47 percent thought the **Reverse Turn** sign indicates 90 degree changes in alignment and the **Winding Road** sign indicates less severe alignment changes.
- 34 percent thought the **Reverse Turn** indicated two changes in horizontal alignment.
- 29 percent thought the **Reverse Turn** sign indicates sharper, more severe changes in horizontal alignment than the **Winding Road** sign.
- 8 percent thought the **Winding Road** sign indicates more alignment changes than the **Reverse Turn** sign.

These results indicate that drivers do not recognize the speed or severity messages conveyed by these two signs. In particular, it appears that drivers do not understand that the **Winding Road** sign is used for alignment changes of all severities. Only a small percent appear to recognize that the **Winding Road** sign is used for multiple alignment changes.

The results also indicate that many drivers associate the **Reverse Turn** sign with 90 degree changes in alignment, as is shown in the sign legend. These findings are similar to those of another study (18) which found that approximately 90 percent of the drivers surveyed associated the **Turn** sign with a 90 degree or near 90 degree change in horizontal alignment. The results of these two studies appear to indicate that drivers are associating the shape of the **Turn** and **Reverse Turn** sign legend with the shape of the roadway.

Findings and Recommendations

The findings of this study indicate that while drivers appear to understand the primary message conveyed by warning signs for changes in horizontal alignment, some drivers are not understanding the secondary messages conveyed by these signs, such as the severity (speed), shape, and number of alignment changes. However, since the primary purpose of a warning sign is to alert the driver to the presence of a potentially hazardous condition and indicate the recommended speed for the condition, a lack of understanding of the secondary messages is not necessarily significant. The use of a **Turn** or **Curve** warning sign with an **Advisory Speed Plate** provides the driver with all of the information necessary to negotiate the alignment change.

The study findings lead to several possible recommendations that could improve driver understanding of the secondary messages of signs in this series. The recommendations include revising the *Texas Drivers Handbook*, changing TxDOT practices, and conducting additional research. The findings and recommendations for the signs in this series are summarized in Table IV-23.

Four of these five warning signs are included in the *Texas Drivers Handbook*. All four descriptions indicate the need to slow down and not to pass. These descriptions should be revised to reflect the intended purpose of these signs, including the secondary messages conveyed by the signs. Consideration should also be given to adding the **Reverse Turn** sign to the handbook.

Table IV-23. Research Summary for Horizontal Alignment Signs

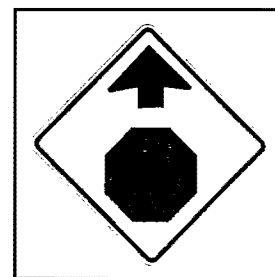
Sign Label	W1-1 Turn W1-2 Curve W1-3 Reverse Turn W1-5 Winding Road
TMUTCD Section	W1-1 2C-4 W1-2 2C-5 W1-3 2C-6 W1-5 2C-8
Evaluation Procedures	Statewide Survey - see pages A-29 for W1-1, A-11 for W1-2, and A-24 for W1-3. 1992 Auto Show Survey - see page B-6 for W1-1. 1993 Auto Show Survey - see page C-6 for W1-3 and W1-5.
Focus of Evaluation	Driver understanding of speed and number messages conveyed by these signs.
Findings	Drivers do not recognize the speed or number messages these signs are intended to convey.
Alternative Designs Evaluated	W1-1 - Standard sign with Advisory Speed Plate (W13-1).
Texas Drivers Handbook Description	Turn - <i>"Road ahead makes a sharp turn in the direction of the arrow. Slow down, keep right, and do not pass."</i> Curve - <i>"Road ahead makes a gradual curve in the direction of the arrow. Slow down, keep right, and do not pass."</i> Reverse Curve - Not described. However, the TDH does contain the following description for the Reverse Curve sign: <i>"The road curves one way and then the other. Slow down, keep right, and do not pass."</i> Winding Road - <i>"There is a winding road ahead. Drive carefully and do not pass."</i>
Recommendations	Consider developing guidelines which indicate the need to use an Advisory Speed Plate with these signs whenever the recommended speed is less than the speed limit. Revise the TDH to indicate that a speed reduction is not always necessary and that passing is not prohibited by these signs. Conduct additional research to evaluate the basis for using these signs and more effective means of conveying the intended message.

With respect to the speed message of these signs, the research findings indicate that consideration should be given to the use of an **Advisory Speed Plate** with all of these signs anytime the recommended speed is less than the posted speed. Furthermore, consideration should be given to always using the **Advisory Speed Plate** with the **Turn** sign due to the fact that drivers do not recognize the speed of 30 mph or less for this sign. Consideration should also be given to always using an **Advisory Speed Plate** with the **Winding Road** sign due to the fact that drivers tended to associate this sign with the **Curve** signs and the higher speed indicated by **Curve** signs.

Consideration should also be given to conducting future research on this subject on a nationwide basis. The future research should evaluate the basis for differentiating between the **Turn** and **Curve** signs, the effectiveness of **Advisory Speed Plates**, the methods for establishing recommended speeds, and more effective means of conveying the number of alignment changes and the length of roadway with alignment changes. Future research should also consider how drivers associate the sign legend with the expected shape of the alignment change and the development of new signs to distinguish between the direction, number, speed, and shape messages of the warning signs. The findings of this type of research could lead to fundamental changes in the way in which these warning signs are used throughout the United States. Therefore, future research on warning signs for changes in horizontal alignment should be sponsored by NCHRP or FHWA and be conducted on a nationwide basis.

Stop Ahead Sign

The **Stop Ahead** sign shown in Figure IV-20 is intended for use on approaches to an intersection when the **STOP** sign is not visible for a sufficient distance to allow the driver to stop at the sign. The **Stop Ahead** sign can also be used to emphasize the **STOP** sign at those locations where compliance with the **STOP** sign is low. This sign was selected for study because the 1981 TTI study of the sign (6), which was conducted at a time when this sign was relatively new, found that many drivers did not fully understand the intended meaning of the sign. This sign was evaluated only in the statewide survey.



**Figure IV-20.
W3-1a Sign**

Statewide Survey

The survey question was intended to evaluate whether drivers confused this sign with the actual **STOP** sign or with a sign providing directional information. The results for this question indicate that a large majority of drivers understand the intended meaning of this sign.

Findings and Recommendations

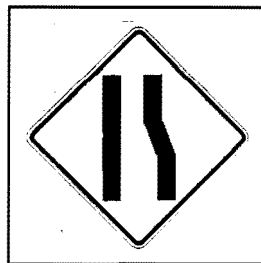
The study results indicate that almost 90 percent of the drivers understand the intended meaning of this sign. These findings indicate that changes to the design or use of this sign are not necessary. However, this sign is not described in the *Texas Drivers Handbook*. Due to the importance of this sign in a situation when adequate sight distance is not available, consideration should be given to adding a description of the sign to the handbook. The study findings and recommendations for this sign are summarized in Table IV-24.

Table IV-24. Research Summary for the Stop Ahead Sign

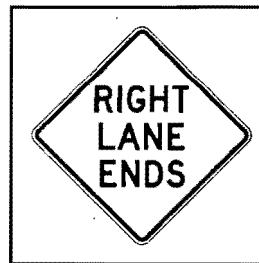
Sign Label	W3-1a
TMUTCD Section	2C-15
Evaluation Procedures	Statewide Survey - see page A-19.
Focus of Evaluation	Driver understanding of sign meaning.
Findings	Large majority of drivers understand the sign.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	Not described.
Recommendations	Changes to the design or use of this sign do not appear to be necessary. A description of the sign should be added to the TDH.

Lane Reduction Transition Signs

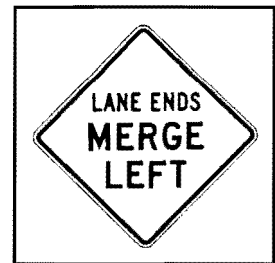
There are three different signs that are used to indicate a reduction in the number of lanes in the direction of travel. These signs are illustrated in Figures IV-21, IV-22, and



**Figure IV-21.
W4-2 Sign**



**Figure IV-22.
W9-1 Sign**



**Figure IV-23.
W9-2 Sign**

IV-23. The W4-2 symbol sign is the primary sign for the intended use. The word message signs are used to supplement the symbol sign. All three signs were evaluated in this study. The symbol sign was selected due to several previous studies which have indicated that drivers do not understand the sign. The word message signs were selected for evaluation due to a lack of previous research on these signs and their role in supplementing the symbol sign. The Lane

Reduction Transition symbol sign and the **LANE ENDS MERGE LEFT** signs were evaluated in the statewide survey. The **LANE ENDS MERGE LEFT** sign was also evaluated in the 1993 Auto Show survey. All three signs and some alternative designs for the symbol sign were evaluated in the focus groups.

Statewide Survey

The question on the symbol sign focused upon driver understanding, and the response choices included the two most common forms of misunderstandings for the sign identified in previous studies (3, 5, 6, 9, 19). The picture for the **LANE ENDS MERGE LEFT** sign showed the vehicle to be in the left lane. The question was intended to determine if drivers recognized that vehicles would be merging into their lane.

The results of the statewide survey confirmed the findings of previous studies with respect to the **Lane Reduction Transition** sign. Less than two-thirds of the drivers selected the correct response of "*fewer lanes ahead*". Slightly less than one-fourth selected the "one-lane road" choice and another one-tenth selected the "narrow lanes" response. It should be pointed out that in selecting the "one-lane road" response, some drivers may have been referring to the number of lanes in the direction of travel, and not the total number of lanes in both directions, as the research team intended.

The results for the **LANE ENDS MERGE LEFT** sign indicated that about the same percentage of drivers selected the correct response (slightly less than two-thirds). The other one-third of the drivers selected responses that indicated some level of uncertainty about maneuvering the vehicle from the lane they were in. This uncertainty over driving response as a function of lane position led the research team to include this sign in the 1993 Auto Show survey.

1993 Auto Show Survey

Using an open-ended response format, drivers were asked to indicate the proper driving response to the **LANE ENDS MERGE LEFT** sign from both right and left lane positions. Less than six percent gave incorrect responses when positioned in the right (merging) lane. When positioned in the left lane, about 13 percent gave incorrect responses, with about six percent of those being responses exactly opposite of the desired response.

One of the concerns related to this sign was driver understanding of the word "merge." Therefore, as part of the 1993 Auto Show survey, drivers were asked to describe the meaning of the word "merge." The results of this question indicated that this concern was unfounded, as 90 percent of the drivers correctly described the meaning of the word.

Focus Groups

One of the objectives of the focus groups was to evaluate the placement order for the three signs in this series. Another objective was to obtain an indication of driver preference for the alternative designs for the **Lane Reduction Transition** symbol sign illustrated in Figures IV-24 and IV-25. Previous research (18) found both of these alternatives to be as effective as the standard symbol sign.

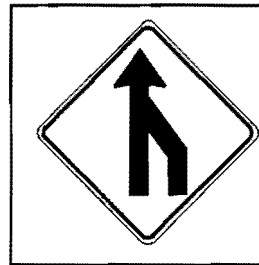


Figure IV-24.
First Alternative

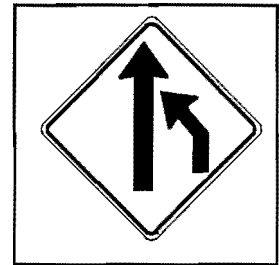


Figure IV-25.
Second Alternative

Members of the focus groups indicated a preference for the standard symbol sign over the alternative symbol signs when shown all three signs together. Preference for the standard sign was indicated despite a lack of understanding of many participants of the meaning of the standard sign.

Findings and Recommendations

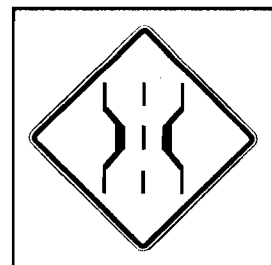
The survey findings indicate that many drivers do not understand the meaning of the **Lane Reduction Transition** symbol sign, while the word message signs used to supplement the symbol sign appear to be better understood. When shown two alternative symbol signs with the standard sign, focus group participants indicated a preference for the standard sign. The study findings indicate that driver understanding of the symbol sign needs to be improved, but the alternatives evaluated in the focus groups may not provide the most effective alternatives. Additional research should be conducted to evaluate other possibilities. The study findings and recommendations for these signs are summarized in Table IV-25.

Table IV-25. Research Summary for the Lane Reduction Transition Signs

Sign Label	W4-2 Lane Reduction Transition W9-1 RIGHT LANE ENDS W9-2 LANE ENDS MERGE LEFT
TMUTCD Section	2C-19
Evaluation Procedures	Statewide Survey - see pages A-22 for W4-2 sign and A-31 for the W9-2 sign. 1993 Auto Show - see page C-7 for W9-2 sign. Focus Groups - see page D-6.
Focus of Evaluation	W4-2 - potential driver confusion with the number of lanes and the lane width. W9-2 - driving response as a function of the lane position. Focus Groups - order of sign placement and effectiveness of alternative designs for W4-2.
Findings	Many drivers do not understand the intended meaning of these signs, particularly the W4-2. The alternative designs were not preferred in the focus groups.
Alternative Designs Evaluated	Two alternatives for W4-2: a) Two lines joining together. b) One line angling toward another line.
Texas Drivers Handbook Description	W4-2 - <i>"Gives advance notice of a reduction in the number of lanes of pavement ahead."</i> W9-1 - Not described. W9-2 - Not described.
Recommendations	Changes to the design or use of the word message signs do not appear to be necessary. Descriptions of the W9 signs should be added to the TDH. Additional research should be conducted to determine if driver understanding of the symbol sign can be improved through alternative designs or better education.

Narrow Bridge Sign

The **Narrow Bridge** symbol sign shown in Figure IV-26 is intended for use when a bridge or culvert has a clear roadway width between 4.9 and 5.5 meters (16 to 18 feet) or when the width of the roadway at the bridge or culvert is less than the width of the approach pavement. There is also a word message version of this sign (W2-5) which contains the legend **NARROW BRIDGE**. The symbol sign was selected for evaluation in order to assess driver interpretation of the number of lanes and passing restrictions on the bridge. The concern was that the stripes in the symbol implied that passing was permitted on the bridge. The symbol sign was evaluated only in the statewide survey.



**Figure IV-26.
W5-2a Sign**

The *Texas Drivers Handbook* contains the following description for this sign: "*The bridge or culvert ahead has room for only two lanes of traffic. Approach with caution.*" This description is not completely accurate. The description implies that this sign is used only when there are two lanes on the bridge. This is not accurate due to the fact that it is possible that a **Narrow Bridge** sign may be used for a bridge with four lanes if the total pavement width on the bridge is less than the total width of the approach pavement.

Statewide Survey

Over 80 percent of the drivers selected the correct response for this sign. About ten percent of the drivers selected the one-lane bridge response. These findings did not indicate any major sources of driver confusion about this sign, although it should be noted that all of the response choices included some mention of a bridge. It should also be noted that the question did not evaluate driver understanding of the relationship between the width of the lanes and the width of the shoulder at the bridge.

Findings and Recommendations

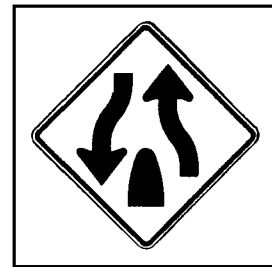
The findings for the symbolic **Narrow Bridge** sign did not identify any major sources of driver confusion for this sign with respect to passing restrictions or the presence of a one-lane bridge. However, the question did not evaluate comprehension of several other aspects of potential driver confusion related to this sign. Several of these other comprehension issues have been described in other research studies (9, 18, 19, 20). Some of these other issues should be studied in future research of this sign, particularly before any changes are made to the design of this sign. Based on the findings of this research study, no changes are recommended to the design or use of the sign. However, additional research should be conducted to evaluate other aspects of driver understanding of the sign. The description of the sign in the *Texas Drivers Handbook* should be revised to reflect all of the possible uses of the sign. Table IV-26 summarizes the study findings and recommendations for this sign.

Table IV-26. Research Summary for the Narrow Bridge Sign

Sign Label	W5-2a
TMUTCD Section	2C-21
Evaluation Procedures	Statewide Survey - see page A-18.
Focus of Evaluation	Driver understanding of number of lanes and passing restrictions at the bridge.
Findings	Most drivers understand that the sign does not indicate the presence of passing restrictions and that the sign is not used to indicate a one-lane bridge.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	<i>"The bridge or culvert ahead has room for only two lanes of traffic. Approach with caution."</i>
Recommendations	Changes to the design or use of this sign do not appear to be necessary. The TDH description should be revised to reflect the actual use of the sign with bridges that have more than two lanes. Additional research of driver comprehension of other aspects of this sign should be conducted.

Divided Highway Ends Sign

The **Divided Highway Ends** sign shown in Figure IV-27 is intended for use where a divided roadway changes to a two-way roadway. This sign uses the same legend as the **Divided Highway** sign (W6-1), except that the sign is rotated 180 degrees. It was selected for evaluation in this study because of potential driver confusion between this sign and the **Divided Highway** sign. It was evaluated only in the statewide survey.



**Figure IV-27.
W6-2 Sign**

Statewide Survey

The responses to this question included one response that represented the **Divided Highway** sign, which is often confused with this sign. Half of the drivers selected the correct answer for the **Divided Highway Ends** sign. Over one-third of the drivers selected the "divided highway ahead" sign, indicating some degree of confusion between these two signs.

Findings and Recommendations

The findings of the statewide survey indicate that there is a tendency for drivers to confuse these two signs. Both signs are properly described in the *Texas Drivers Handbook*. This leaves the use of supporting signs to reduce driver confusion, or a redesign of the existing signs. Alternative designs for these signs were not evaluated in this study. Future evaluations of these signs should consider developing an alternative design for each sign that is easily distinguishable from the other sign. Consideration should be given to using the **Two-Way Traffic** sign (W6-3) to supplement the **Divided Highway Ends** sign. The additional sign would help to reduce possible driver confusion over the presence of two-way traffic at the end of the divided highway. The findings and recommendations for the **Divided Highway Ends** sign are summarized in Table IV-27.

Table IV-27. Research Summary for the Divided Highway Ends Sign

Sign Label	W6-2
TMUTCD Section	2C-24
Evaluation Procedures	Statewide Survey - see page A-26.
Focus of Evaluation	Possible confusion with Divided Highway sign (W6-1).
Findings	Over one-third of drivers confused the two signs.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	<i>"The divided highway on which you are traveling ends ahead. Be careful as you approach the point where two-way traffic begins again."</i>
Recommendations	Reinforce message of this sign by using a Two-Way Traffic sign (W6-3).

Slow Down on Wet Road Sign

The **Slow Down on Wet Road** sign shown in Figure IV-28 is "intended for use to warn of a condition where the highway surface is extraordinarily slippery" (13). This sign was selected for evaluation in this study due to the findings of previous research (3, 5, 6, 9, 18) which indicated that some drivers associate this sign with the presence of curves on the road, and other studies (6, 9, 18, 19) which found that some



**Figure IV-28.
W8-5 Sign**

drivers think the slippery condition is present at all times. This sign and several alternative designs were evaluated in the statewide survey, the 1992 Auto Show survey, and the focus groups.

Statewide Survey

This sign was addressed in the first question of the statewide survey. The focus of the question was to determine if drivers associated this sign with a winding road or out-of-control vehicles. Less than two-thirds of the drivers selected the correct response. One-third incorrectly interpreted the sign as a warning of a winding road. The percentage that selected this response was large enough that the sign and two alternative designs were included in the 1992 Auto Show survey.

1992 Auto Show Survey

Both the symbol sign and word message alternatives were evaluated in the 1992 Auto Show survey in order to assess the comprehension differences between the symbol and word messages. The question and response choices in the 1992 Auto Show survey were identical to those in the statewide survey. However, the question was asked about three different signs in the survey. One sign was the standard **Slow Down on Wet Road** symbol sign (W8-5) illustrated in Figure IV-28; another sign was the standard symbol sign with a **SLOW DOWN ON WET ROAD** educational plaque; and the third sign was a word message sign with the legend **SLOW DOWN ON WET ROAD**. The word message sign is currently used in Texas as an alternative to the symbol sign. Figures IV-29 and IV-30 illustrate these alternative versions of the sign.

The results of the 1992 Auto Show survey indicate that the word message sign had the highest comprehension with a correct response rate of 97.2 percent. The symbol sign with an educational plaque was almost as effective, with 90.3 percent selecting the correct response for this sign combination. These two responses are not statistically the same at a level of confidence of 90 percent.



Figure IV-29.
Std. Sign with
Educational Plaque

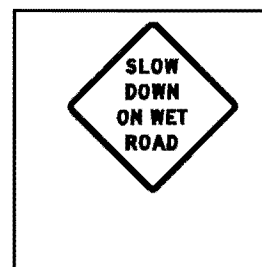


Figure IV-30.
Word Message
Alternative Sign

Focus Groups

The standard symbol sign, the word message sign, and the new alternative symbol sign shown in Figure IV-31 were discussed in the focus groups. The alternative sign was developed by adding raindrops and a horizontal line to the standard symbol sign. The raindrops were intended to reinforce the wet weather message of the sign and the horizontal line was intended to eliminate confusion with a "winding road" situation. The participants indicated a preference for the standard symbol sign over the other two signs. They indicated that the word message sign had too many words on it and the raindrops on the alternative design did not clarify the meaning of the symbol sign.



Figure IV-31.
Symbol Alternative
Sign

Findings and Recommendations

The results of the evaluations for the standard symbol sign and alternative designs indicate that many drivers do not fully comprehend the meaning of the standard sign. Some drivers associate the sign with changes in horizontal alignment or fail to recognize the wet weather connotation of the sign. The word message sign was better understood, but the language issues associated with the word message sign have not been fully evaluated. Focus group participants indicated a preference for the standard symbol sign over the other two signs.

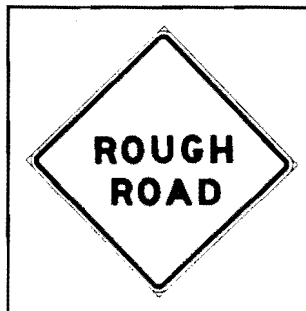
The study findings indicate that more research should be conducted for this sign to evaluate the effectiveness of alternative sign legends and the effectiveness of the word message sign among various demographic groups in Texas. The association of the sign with wet weather conditions should also be emphasized in driver training curriculums. The study findings and recommendations for this sign are summarized in Table IV-28.

Table IV-28. Research Summary for the Slow Down on Wet Road Sign

Sign Label	W8-5
TMUTCD Section	2C-30
Evaluation Procedures	Statewide Survey - see page A-4. 1992 Auto Show - see page B-6. Focus Groups - see page D-6.
Focus of Evaluation	Driver association of the sign with a winding road or a slippery pavement during all weather conditions.
Findings	Drivers are less likely to confuse the word message sign with a winding road.
Alternative Designs Evaluated	1992 Auto Show: a) Std sign with educational plaque. b) Word message sign. Focus Groups: a) Word message sign. b) Std sign with raindrops and pavement.
Texas Drivers Handbook Description	<i>"Slow down on wet road. Do not suddenly turn, speed up, or stop."</i>
Recommendations	Additional research should be conducted to determine if driver understanding of the sign can be improved through alternative symbol designs and the effectiveness of a word message legend. The wet weather message of the sign should receive greater emphasis in driver training curriculums.

Pavement Surface Condition Signs

The two word message signs shown in Figures IV-32 and IV-33 are used to warn drivers of atypical pavement surface conditions. The **ROUGH ROAD** sign shown in Figure IV-32 is intended for use when the pavement surface is extraordinarily rough. This sign should be removed when the rough pavement



**Figure IV-32.
W8-8 Sign**



**Figure IV-33.
W8-12 Sign**

condition is corrected. The **GROOVED PAVEMENT AHEAD** sign shown in Figure IV-33 is intended to warn motorcyclists that there are grooves in the road. These signs were included in the research effort in order to evaluate the extent to which drivers distinguish between the two signs and to determine if the motorcyclist portion of the **GROOVED PAVEMENT AHEAD** sign was being understood by drivers. Both signs were included only in the statewide survey.

Statewide Survey

The results for the **ROUGH ROAD** sign indicate that almost 90 percent of drivers understand that this sign indicates that the pavement is in poor condition. Less than 10 percent thought the sign was intended to warn motorcyclists. The results of the statewide survey for the **GROOVED PAVEMENT AHEAD** sign indicate that less than 30 percent of the drivers correctly realize that the sign is intended primarily for the benefit of motorcyclist. Many of those that selected the correct response were young and had a motorcycle license. None of the response choices was selected by more than 40 percent of the drivers, although the choice which indicated a noisier road was the most frequent choice, with 40 percent of the drivers choosing it. This sign was one of ten signs with a "not sure" response greater than 10 percent.

Findings and Recommendations

The results for these signs indicate that most drivers understand the intended meaning of the **ROUGH ROAD** sign and less than one-third of drivers recognize that the **GROOVED PAVEMENT AHEAD** sign is intended for motorcyclists. More drivers selected the noisy pavement response for the **GROOVED PAVEMENT AHEAD** sign than any of the other response choices provided in the survey. Another factor affecting the use of the **GROOVED PAVEMENT AHEAD** sign is that TxDOT typically no longer cuts grooves into the road surface to improve the wet weather traction of the pavement. Therefore, opportunities where this sign can be properly used are somewhat limited. The study activities, findings, and recommendations for these two signs are summarized in Table IV-29.

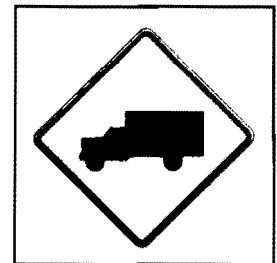
These results, combined with the limited use of pavement grooving in current practice, indicate that consideration should be given to dropping the **GROOVED PAVEMENT AHEAD** sign from the Texas MUTCD and the *Texas Drivers Handbook*. The **ROUGH ROAD** sign could then be used in those situations where the **GROOVED PAVEMENT AHEAD** sign would otherwise have been used. If the **GROOVED PAVEMENT AHEAD** sign is retained, consideration should be given to adding the sign to the motorcycle license handbook and including it in motorcycle training and the motorcycle license examination. The description of the sign in the handbook should also be revised to reflect the intended audience for the sign.

Table IV-29. Research Summary for Pavement Surface Condition Signs

Sign Label	W8-8 ROUGH ROAD W8-12 GROOVED PAVEMENT AHEAD
TMUTCD Section	2C-30.2 - ROUGH ROAD 2C-30.5 - GROOVED PAVEMENT AHEAD
Evaluation Procedures	Statewide Survey - see page A-41 for the ROUGH ROAD sign and page A-30 for the GROOVED PAVEMENT AHEAD sign.
Focus of Evaluation	ROUGH ROAD - Driver understanding of the meaning of the sign. GROOVED PAVEMENT AHEAD - Understanding that this sign is primarily intended for motorcyclists. Both Signs - Ability of drivers to distinguish the differences between the two signs.
Findings	ROUGH ROAD - Most drivers understand the intended meaning of the sign. GROOVED PAVEMENT AHEAD - Less than 30 percent of drivers recognize that the sign is intended for motorcyclists.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	ROUGH ROAD - Not described. GROOVED PAVEMENT AHEAD - " <i>The pavement has been grooved to lessen the possibility of slippery pavement in wet weather.</i> "
Recommendations	Consideration should be given to using the ROUGH ROAD sign (W8-8) instead of the GROOVED PAVEMENT AHEAD (W8-12) sign and dropping the GROOVED PAVEMENT AHEAD sign from the TMUTCD. If sign is retained, consider including this sign in motorcycle training and the motorcycle license exam. If retained, the description of the GROOVED PAVEMENT AHEAD sign in the TDH should be revised to indicate that it is intended for motorcyclists.

Truck Crossing Sign

The **Truck Crossing** symbol sign shown in Figure IV-34 is one of several signs included in the Advance Crossing series (W11) of warning signs. This particular sign is intended to warn drivers of unexpected entries into the roadway by trucks. This sign was selected for evaluation in this study in order to determine how drivers interpret the message conveyed by the symbol sign. It was evaluated only in the statewide survey.



**Figure IV-34.
W11-10 Sign**

Statewide Survey

Over 90 percent of the drivers associate this sign with the presence of trucks. However, almost 30 percent of the drivers thought the sign indicated heavy use of the road by trucks, and

not the presence of a truck crossing or entrance. Although some drivers may not be aware of the fact that trucks could enter the roadway from driveways or side streets, their awareness that trucks may be on the roadway reduce the significance of any misunderstanding of this sign.

Findings and Recommendations

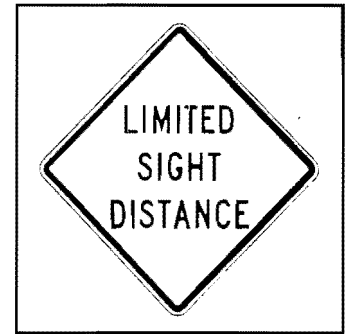
The evaluations of the **Truck Crossing** sign conducted as part of this research study indicate that the sign is communicating the major message of the sign, to be aware of trucks, but that the message of a truck crossing is not fully communicated to drivers. The description of the sign in the *Texas Drivers Handbook* already describes the crossing message conveyed by the sign. The word message version of the sign, with the legend **TRUCK CROSSING**, is unlikely to significantly increase comprehension of the situation. Furthermore, word message signs typically have recognized deficiencies compared to symbol signs, such as a lower legibility distance, increased response and reaction time, and limited value to non-English speaking drivers. The use of a supplemental plaque, such as **NEXT 5 MILES**, may help to better communicate the intended message. Additional research should be conducted to determine if the supplemental plaque would improve comprehension. The research activities, findings, and recommendations for this sign are summarized in Table IV-30.

Table IV-30. Research Summary for the Truck Crossing Sign

Sign Label	W11-10
TMUTCD Section	2C-31
Evaluation Procedures	Statewide Survey - see page A-38.
Focus of Evaluation	Driver understanding of sign message.
Findings	Over 90 percent associate sign with trucks, although almost 30 percent do not recognize the crossing or entrance message of the sign.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	<i>"Slow your speed and watch for trucks entering or crossing the highway."</i>
Recommendations	Additional research should be conducted to determine if alternative signs or supplemental plaques would better convey the intended meaning.

Limited Sight Distance Sign

The **LIMITED SIGHT DISTANCE** sign shown in Figure IV-35 is used where adequate sight distance is not available through vertical curves. This is the only warning sign in the MUTCD for which an **Advisory Speed Plate (W13-1)** is required. This sign was deleted from the national MUTCD in 1988. It was included in the statewide survey in order to determine whether it should remain in the Texas MUTCD. The statewide survey was the only evaluation in which it was included.



**Figure IV-35.
W14-4 Sign**

Statewide Survey

The question was intended to evaluate driver understanding of the meaning of the sign. The responses clearly indicate that most drivers do not understand the meaning. Less than half of the survey participants selected the correct response. This sign was one of the ten signs that had more than 10 percent of the drivers selecting the "not sure" response.

Findings and Recommendations

The results of the statewide survey indicate that the intended message of the **LIMITED SIGHT DISTANCE** sign is not effectively communicated to most drivers. This same conclusion was also reached in a FHWA study of the same sign (21). The FHWA study also evaluated the effectiveness of alternative designs for this sign, but was unable to find a sign design which effectively communicated the intended message to drivers. As a result of the FHWA study, the **LIMITED SIGHT DISTANCE** sign was dropped from the national MUTCD. The findings of the statewide survey, when combined with those of the FHWA study, indicate that consideration also should be given to dropping this sign from the Texas MUTCD. The study findings and recommendations for this sign are summarized in Table IV-31.

Table IV-31. Research Summary for the LIMITED SIGHT DISTANCE Sign

Sign Label	W14-4
TMUTCD Section	2C-39
Evaluation Procedures	Statewide Survey - see page A-15.
Focus of Evaluation	Driver understanding of the purpose of this sign.
Findings	Less than half of the drivers recognize the intended purpose of the sign.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	Not described.
Recommendations	None. Consideration should be given to dropping the sign from the Texas MUTCD.

Watch for Ice on Bridge Sign

The **WATCH FOR ICE ON BRIDGE** sign shown in Figure IV-36 is the sign that is used in Texas to warn drivers about the possible presence of ice on the roadway. At the time the statewide survey was administered, these signs were hidden from view except when conditions were favorable for the formation of ice on bridges. TxDOT practice has since changed to the constant display of the signs throughout the wintertime. The national MUTCD does not contain an icy road warning sign. Therefore, it should come as no surprise that there are several alternatives of this sign in use throughout the country. Several states use the same sign that is used in Texas. Some of the other versions of this sign used in other states have the legends: **BRIDGE ICES BEFORE ROAD**, **ICE ON BRIDGE**, **BRIDGE MAY ICE IN COLD WEATHER**, **WATCH FOR ICE**, **ICE FORMS ON BRIDGE BEFORE PAVEMENT**, and **ICY PAVEMENT ZONE**. This sign was selected for study in order to assess driver understanding of the sign used in Texas. It was evaluated only in the statewide survey.



**Figure IV-36.
W19-2 Sign**

Statewide Survey

The question was intended to determine how drivers respond to this sign. The large majority of drivers selected the desirable driving response to this sign. However, a significant

percentage (12 percent) selected the response which included applying the brakes while on the bridge. Those drivers selecting this incorrect response demonstrated a lack of knowledge of driving in icy conditions. The only realistic treatment for this lack of knowledge is increased educational effort.

Findings and Recommendations

The statewide survey findings indicate that a large majority of drivers recognize the proper driving response to this sign. However, some drivers demonstrated driving behavior completely opposite of the desired action. This lack of understanding may be attributed in part to the fact that many parts of Texas rarely experience icy road conditions. A change in the design or use of the subject sign is not likely to lead to a change in driving behavior of these drivers. Instead, increased educational effort should be focused upon providing drivers with information about winter driving behavior.

The *Texas Drivers Handbook* should be revised to reflect current TxDOT practice regarding the display of these signs. Consideration should also be given to including a statement in the part of the handbook which describes this sign that states the driver should not apply the brakes while on a bridge which may be covered with ice. Table IV-32 summarizes the findings and recommendations resulting from the evaluation of this sign.

Table IV-32. Research Summary for the WATCH FOR ICE ON BRIDGE Sign

Sign Label	W19-2
TMUTCD Section	2C-41
Evaluation Procedures	Statewide Survey - see page A-10.
Focus of Evaluation	Driver response to sign.
Findings	Most drivers understand the sign, but a significant percentage would apply the brakes while on the bridge.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	<i>"Warns of hazardous condition on bridge caused by ice. This sign will be displayed only during the time that the hazard exists."</i>
Recommendations	Increase emphasis in driver training programs on the hazards associated with braking on an icy road. Revise TDH description of the display of this sign to reflect current TxDOT practice.

Ramp Metered When Flashing Sign

The sign shown in Figure IV-37 is used in advance of a freeway entrance ramp which uses a traffic signal to control the traffic entering the freeway. One or two flashing beacons are erected with the sign. The flashing beacons are operated only when the ramp signals are operating. The flashing beacons are dark when the ramp signal is dark. This sign is typically used when ramp metering is first installed or in areas where drivers may not be familiar with ramp metering. This sign was selected for evaluation in order to assess the familiarity of drivers statewide with the ramp metering concept. The sign was included in the statewide survey and the 1993 Auto Show survey.

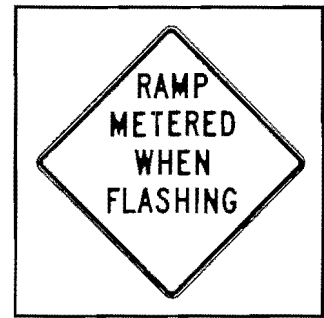


Figure IV-37.
W19-3 Sign

Statewide Survey

The question was intended to ascertain whether drivers understood the meaning of the sign and the flashing light which is used with the sign. Less than half of the participants selected the correct response. This question had the third highest "not sure" response in the statewide survey. Those drivers that selected the correct response tended to be from urban areas and had commercial or motorcycle licenses. These findings indicate that the sign is not widely understood across the state. Therefore, the research team decided to evaluate the results of the question for those major metropolitan areas where ramp metering is currently in use.

A comparison of the statewide responses and those of drivers in Houston and Dallas is found in Table IV-33. A statistical comparison of these results indicate that the statewide and Dallas response are not statistically different at a level of confidence of 99 percent. A statistical comparison of the statewide and Houston responses indicates that the "correct" (first) response and the "not sure" response are statistically different at a level of confidence of 95 percent. The other responses are statistically the same at a 95 percent level of confidence.

Table IV-33. Comprehension of Ramp Meter Sign in Dallas and Houston

Statewide Response Rate	Houston Response Rate	Dallas Response Rate	Response
*45.7%	*52.3	*49.5	When the yellow lights are flashing, a traffic signal at the entrance to the freeway is in use.
19.9%	22.8	17.6	Only a certain number of cars are allowed on the ramp when the yellow light is flashing.
7.6%	6.5	7.7	You must pay a toll to use the freeway entrance ramp.
26.8%	18.4	25.2	Not sure.

Note: *Indicates correct response.

1993 Auto Show Survey

The **RAMP METERED WHEN FLASHING** sign was also included in the open-ended 1993 Auto Show survey. Drivers were shown the sign and asked to describe its meaning. An almost identical percentage (24.7 percent for the Auto Show survey versus 26.8 percent in the statewide survey) stated they did not know. The only other response with a percentage greater than 10 percent fell in the category "light controls ahead." The responses to the sign in the 1993 Auto Show survey confirm that many drivers do not fully comprehend the meaning of the sign, and possibly the concept of ramp metering. This was despite the fact that the Auto Show survey was administered in Houston, where ramp metering is used on several freeways.

Findings and Recommendations

In general, the study findings for the **RAMP METERED WHEN FLASHING** sign indicate that drivers are not familiar with the message conveyed by the sign. Drivers in Houston are only slightly more familiar with the sign than drivers statewide. As a result, efforts to better educate drivers about ramp metering may be appropriate. Consideration should be given to adding a description of ramp metering to the *Texas Drivers Handbook* and placing more emphasis on ramp metering in driver education curriculums. The study findings and recommendations associated with this sign are summarized in Table IV-34.

Table IV-34. Research Summary for the RAMP METERED WHEN FLASHING Sign

Sign Label	W19-3
TMUTCD Section	2C-41
Evaluation Procedures	Statewide Survey - see page A-40. 1993 Auto Show - see page C-8.
Focus of Evaluation	Meaning of sign.
Findings	Drivers do not understand the concept of ramp metering.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	Not described.
Recommendations	Educate drivers about the use of ramp metering. Consider adding a description of ramp metering to the TDH.

OTHER TYPES OF SIGNS

The large majority of the signs evaluated in this research study were regulatory or warning signs. However, there were ten signs that are classified in the MUTCD into other categories or special applications. These types of signs include sign shape and color, railroad-highway grade crossing warning signs, school signs, construction signs, and an object marker.

Sign Shape and Color Principles

The use of standard shapes and colors in traffic signs is one of the basic tenets of the MUTCD. Each category of sign uses shape and color combinations which are generally unique to that category. Standard sign shapes and colors are intended to help drivers recognize the general type of sign from a greater distance than the sign legend can be recognized. Despite the important role that sign shape and color is assumed to play in communicating with the driver, there has been little research on the subject. Previous studies evaluating sign shape and/or color have found driver comprehension of these design elements to be less than 75 percent in some cases. The lack of previous research on driver understanding of shape and color led to the decision to include two questions in the statewide survey on sign shape and color.

The last two questions of the statewide survey addressed sign shape and color. One question presented the survey participant with a yellow diamond and asked the driver to indicate the meaning of a sign with this shape and color. The last survey question presented the driver with

a green rectangle and asked the driver to indicate the purpose of a green sign. The results of the two questions indicate that drivers have not learned the meaning of the sign shapes and colors. When shown a yellow diamond, only 58 percent of the drivers knew the shape and color were used in a warning sign. Comprehension of a green sign was much better, as 75 percent were able to indicate the meaning of the sign. However, 14 percent of the drivers were not sure about the use of a green sign. This percentage was the eighth highest "not sure" response in the statewide survey.

Table IV-35 indicates driver comprehension of sign shape and/or color in this study and other previous studies. In all of the studies except for the 1981 TTI study, the driver was shown a shape, color, or shape and color and was then asked to indicate the meaning of the stimulus. In the 1981 TTI study, the driver was asked to provide the proper shape or color for a specific sign message. It is worth noting that the comprehension levels for a given shape and/or color combination are almost identical in the different studies.

The results of the statewide study confirm the findings of previous research efforts with respect to driver understanding of sign shapes and colors. These findings, which are summarized in Table IV-36, indicate that many drivers do not have a fundamental understanding of the shapes and colors used in traffic signs. The only effective action that can be taken to improve this lack of understanding is to increase the emphasis that is given in driver training programs to the meaning of shapes and colors in traffic control devices. The *Texas Drivers Handbook* should also be revised to provide examples which combine sign shape and color together.

Table IV-35. Comprehension of Sign Shape and Color

Sign Class	Shape	Color	Correct Comprehension Level (percent)			
			Virginia Study	Maryland Study	1981 TTI Study	Statewide Survey
Regulatory Signs	Octagon	Red	93	N/T	78	N/T
	None	Red	85	84	87	N/T
	Octagon	None	89	89	56 ¹ /88 ²	N/T
	Triangle	None	85	84	N/T	N/T
	Vert Rectangle	None	N/T	73	N/T	N/T
	None	White	48	54	N/T	N/T
Warning Signs	Diamond	Yellow	59	N/T	N/T	58
	None	Yellow	86	76	N/T	N/T
	Diamond	None	71	70	N/T	N/T
	Circle	Yellow	64	N/T	N/T	N/T
	Circle	None	67	N/T	N/T	N/T
	None	Orange	N/T	32	N/T	N/T
	Pentagon	None	N/T	38	N/T	N/T
Guide Signs	None	Green	24	49	N/T	75
	Horz Rectangle	None	N/T	73	N/T	N/T
	None	Blue	26	54	N/T	N/T
Sample Size			Color = 1,163 Shape = 1,197 Color/Shape = 671	37	94	1,745
Year of Study			1967	1987	1981	1992
Reference			(22)	(23)	(6)	---

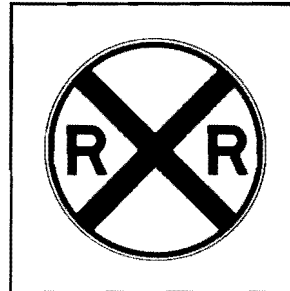
Notes: N/T - not tested.
¹Drew an octagon
²Drew an octagon, hexagon, or circle

Table IV-36. Research Summary for Sign Shape and Color

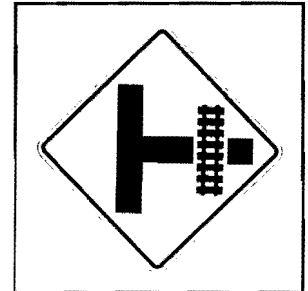
TMUTCD Sections	2A-10 Shape 2A-11 Color
Evaluation Procedures	Statewide Survey - see pages A-48 and A-49.
Focus of Evaluation	Understanding of sign shape and color principles.
Findings	Drivers do not have a fundamental understanding of the shapes and colors used in traffic signs.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	Diamond - <i>"Exclusively to warn of existing or possible hazards on roadways or adjacent areas."</i> Yellow - <i>"General warning."</i> Green - <i>"Direction or guidance."</i>
Recommendations	Greater emphasis on sign shape and color in driver education curriculum. Improve education by emphasizing in driver education.

Railroad Warning Signs

There are two basic types of warning signs which are used to provide the driver with advance warning of a railroad-highway grade crossing. The circular sign shown in Figure IV-38 is used when the crossing is located on the same roadway as the driver is on. The diamond sign shown in Figure IV-39 is used when the railroad tracks are parallel to the main road and the crossing is on a roadway intersecting the main road. There are three different versions of the diamond sign which are used to indicate different types of intersection configurations. The circular sign was selected for evaluation in this research due to the findings of previous research which indicate that drivers do not distinguish between the circular advance sign and the **Crossbuck** sign (R15-1) used at the crossing. The diamond sign was included in the study because of a lack of previous research on driver understanding of the sign. Both signs were evaluated only in the statewide survey.



**Figure IV-38.
W10-1 Sign**



**Figure IV-39.
W10-3 Sign**

Statewide Survey

The primary focus of the question on the circular sign was to determine if drivers confuse the sign message with the intended message of the **Crossbuck** sign. The survey results indicate that about one in six drivers demonstrated this type of confusion. The focus of the question on the diamond sign was to determine if drivers associated this sign with a railroad crossing on a parallel road. Over 90 percent of the drivers selected one of the two responses which included a railroad crossing in the response. However, slightly over one-fifth of the drivers demonstrated some confusion related to the orientation of the sign and the crossing.

Findings and Recommendations

The findings of the statewide survey on the circular railroad warning sign indicate that most drivers associate this sign with an advance warning of a railroad crossing. Slightly over 15 percent demonstrated some confusion between the warning and **Crossbuck** signs. The circular sign is correctly described in the *Texas Drivers Handbook* as an advance warning sign; therefore, no changes are recommended for this description. The results for the **Parallel Railroad Advance Warning** sign indicate that drivers exhibited some confusion over the orientation associated with the sign message. These results, combined with the lack of previous research on the diamond sign, indicate the need to further evaluate this sign and determine if alternative legends could more effectively communicate the desired message. The parallel sign is not described in the handbook; therefore, the addition of the sign to the handbook may help to improve driver understanding of the intended location message of the sign. Any changes to the design, use, or application of these railroad crossing warning signs should be coordinated with other research studies evaluating the use of traffic control devices at railroad-highway grade crossings. Table IV-37 summarizes the study activities for these two signs.

Table IV-37. Research Summary for the Railroad Warning Signs

Sign Label	W10-1 Railroad Advance Warning Sign W10-3 Parallel Railroad Advance Warning Sign
TMUTCD Section	8B-3
Evaluation Procedures	Statewide survey - see page A-5 for W10-1 and page A-28 for W10-3.
Focus of Evaluation	W10-1 - Driver confusion of sign with Crossbuck sign. W10-3 - Driver understanding of sign meaning.
Findings	Drivers associate both these signs with the presence of a railroad crossing, although some drivers are not certain of the relative location between the sign and the crossing.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	W10-1 - <i>"You are within a few hundred feet of a railroad crossing. You should slow down and be prepared to stop. If you see a train coming - STOP - never try to beat it."</i> W10-3 - Not described.
Recommendations	Additional evaluations of the Parallel Advance Railroad Warning sign should be considered to determine if other legends better communicate the intended meaning. Changes to the design, use, or placement of the circular sign do not appear to be necessary. Any changes in the design or use of these signs should consider the findings of a related TxDOT research study on passive grade crossing protection.

School Advance Sign

The **School Advance** sign shown in Figure IV-40 can be used for three different purposes. It is required (a shall condition) in advance of any **School Crossing** (S2-1) sign. This is one of the few conditions in the MUTCD where the use of a warning sign is required. The other two purposes for this sign are in advance of any established school crossing and where school areas are adjacent to the highway. The **School Advance** sign is one of only two signs in the MUTCD which use a pentagon shape with parallel vertical sides (a different pentagon shape is used for the county road marker). This sign was selected for evaluation because of previous research efforts which indicated driver comprehension difficulties. Similarities between the **School Advance** and **School Crossing** signs have been identified as one source of driver confusion for these signs (5, 6, 7, 9). Drivers also have difficulty distinguishing between the school children in these signs and the pedestrian in the **Advance Crossing** and **Crossing** signs (6, 7, 9, 19, 20). One study (9) stated that the use of schoolbooks or the pentagon shape to identify school areas is too subtle



Figure IV-40.
S1-1 Sign

a distinction for most drivers to notice. Another source of potential confusion is the multiple messages that the sign communicates. The actual message communicated by the sign depends upon the circumstances in which it is used. Due to the well-documented lack of driver understanding of the more subtle messages of this sign, it was not included in the statewide survey. Instead, the 1992 Auto Show survey was used to evaluate the effectiveness of an alternative design for the sign.

1992 Auto Show Survey

This survey question was intended to determine if the alternative sign shown in Figure IV-41 is more effective than the standard S1-1 sign at communicating the advance warning of a school crossing. The question results confirmed the findings of previous research relative to driver confusion over the meaning of the standard S1-1 sign. In comparison, the alternative sign was more effective in providing the driver with advance warning of a school crossing at a statistically significant level of confidence of 99 percent. These findings were conclusive enough that additional evaluation in the 1993 Auto Show survey was not necessary.



**Figure IV-41.
Alternative Sign**

Findings and Recommendations

The results of the evaluation of the standard **School Advance** sign and the alternative sign design shown in Figure IV-41 indicate that the alternative design is more effective at providing the driver with advance warning of a school crossing. Therefore, consideration should be given to the use of the alternative design in advance of established school crossings. The existing standard S1-1 sign can then be used in advance of school areas. The use of these two different signs would eliminate the dual message which the current S1-1 sign conveys. Additional evaluation of these signs may be necessary, due to the fact that the evaluation did not address driver confusion of the school crossing signs with pedestrian crossing signs or the effectiveness of other alternative designs. Key aspects of the evaluation procedure, along with the findings and recommendations for this sign are shown in Table IV-38.

Table IV-38. Research Summary for the School Advance Sign

Sign Label	S1-1
TMUTCD Section	7B-9
Evaluation Procedures	1992 Auto Show - see page B-7.
Focus of Evaluation	Effectiveness of alternative design at indicating advance warning of a school crossing.
Findings	Alternative design is more effective.
Alternative Designs Evaluated	Standard S2-1 with an arrow at the top of the sign.
Texas Drivers Handbook Description	<i>"You are near a school. Slow down, and prepare to stop suddenly if necessary. Watch for children."</i>
Recommendations	Consider adding alternative design to the Texas MUTCD. Revise language in the TDH to reflect actual use of the sign, including possible dual messages. Conduct additional evaluations to determine if driver confusion between school and pedestrian signs can be reduced.

In addition to the possible implementation of the alternative design, the language in the *Texas Drivers Handbook* should be modified. If the alternative design is not implemented, the language should be expanded to mention that the sign may be used in advance of a school crossing. If the alternative design is implemented, then both signs should be described in the handbook.

The effectiveness of the alternative design may also be applied to the **Advance Pedestrian Crossing (W11-2)** sign. The findings of previous research (9) has shown that drivers do not understand the distinctions between the **Advance Pedestrian Crossing (W11-2)** sign and the **Pedestrian Crossing (W11A-2)** sign. The concept of placing an arrow at the top of the advance crossing sign also would be effective. A recent research study (18) found the pedestrian sign with an arrow to be significantly more effective than the standard design.

It should be noted that this research effort did not attempt to resolve driver confusion between the school crossing and pedestrian crossing signs. Additional research should be conducted to determine if alternative designs could reduce driver confusion between these two groups of signs.

School Speed Limit Sign

Speed limit signs such as the one shown in Figure IV-42 are used in the vicinity of schools to reduce vehicular speeds at times when children may be present in or near the roadway. School speed zones are typically located on roadways adjacent to a school or at established school crossings. The end of a school zone can be indicated by a standard **SPEED LIMIT** sign or an **END SCHOOL ZONE** sign. Driver understanding of the end of a school speed zone was the subject evaluated in the statewide survey.



Figure IV-42.
S5-1 Sign

Statewide Survey

The question in the statewide survey asked drivers to identify the point where they could speed back up after passing the sign shown in Figure IV-42. The results of this question indicate that about one in five drivers does not know that a standard **SPEED LIMIT** sign marks the end of the school speed zone.

Findings and Recommendations

The statewide survey results for the **SCHOOL SPEED LIMIT** sign indicate that consideration should be given to the use of a different sign to indicate the end of the school speed zone. One possible alternative is to use the **END SCHOOL ZONE** sign. An illustration of this sign was added to the Texas MUTCD in Revision 5 to go with the text describing its use. Consideration should be given making the **END SCHOOL ZONE** sign the preferred alternative for indicating the end of a school speed zone or using both the **END SCHOOL ZONE** and **SPEED LIMIT** signs together in the same assembly. Before establishing this sign as the preferred alternative, additional evaluations should be conducted to determine that the **END SCHOOL ZONE** sign is more effective than the standard **SPEED LIMIT** sign. The study findings and recommendations for this sign are summarized in Table IV-39.

Table IV-39. Research Summary for the SCHOOL SPEED LIMIT Sign

Sign Label	S5-1
TMUTCD Section	7B-12
Evaluation Procedures	Statewide Survey - see page A-32.
Focus of Evaluation	End of school speed zone.
Findings	Over 20 percent of drivers do not know where the end of the school speed zone is located.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	<i>"The speed shown is in effect when the yellow light is flashing. Be extremely careful for school children."</i>
Recommendations	Consider making the END SCHOOL ZONE sign the preferred alternative for indicating the end of a school zone. Conduct evaluations of the effectiveness of the END SCHOOL ZONE sign.

Uneven Pavement Construction Signs

Construction signing was not included in the statewide survey due to another TTI research study that was evaluating construction signing (11). However, even after that study was completed, there were still some comprehension related issues that had not been resolved. One of these was the ability to distinguish between the different meanings of construction signs which are used to warn of an uneven roadway surface in a construction or maintenance zone. The Texas MUTCD indicates that the **Low Shoulder**, **Shoulder Drop-Off**, and **Uneven Lanes**, illustrated in Figure IV-43, are used for this purpose. All three of these construction signs use a black legend on an orange background. Table IV-40 describes the intended use of these signs. As Table IV-40 indicates, the only differences between the applications of these signs is the location of the drop-off or low area and the height of the drop-off or low area. It should also be noted that the **Low Shoulder** sign is the only one of the three that can be used as a standard yellow warning sign. These signs were not described in the national MUTCD until the revision to Part VI was issued (24). In the revision, these signs appear as word message signs.

The previously mentioned TTI study of work zone traffic control (11) was completed after the statewide driver comprehension study had been concluded. During the analysis of the statewide survey results, the research team recognized the need to further evaluate driver comprehension of these three construction signs. Therefore, these three signs were included in the 1992 Auto Show survey.

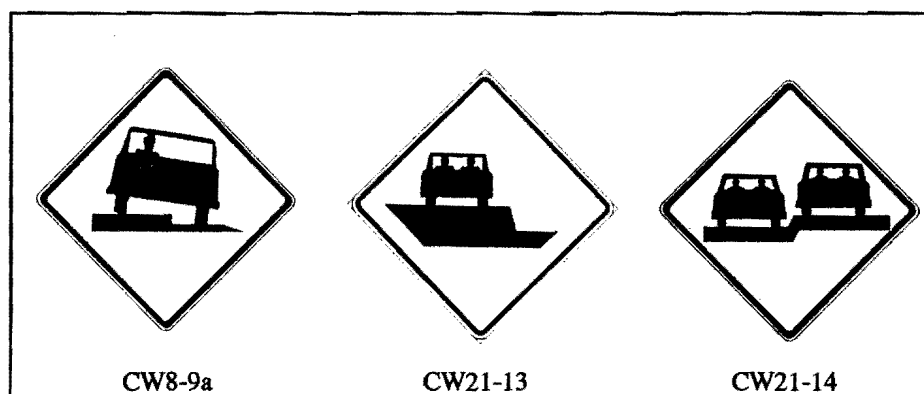


Figure IV-43. Uneven Pavement Construction Warning Signs

Table IV-40. Intended Applications of Uneven Pavement Construction Signs

Sign Name	Label	TMUTCD Section	Intended Application
Low Shoulder	CW8-9a	2C-30.3	<i>"Intended for use to warn of a three-inch or greater drop from the pavement edge to the shoulder which presents a hazard to vehicles that might get off the pavement."</i>
Shoulder Drop-Off	CW21-13	6B-28.3	<i>"Intended for use when a shoulder drop-off exceeds three inches in height and is not protected by a positive protective barrier."</i>
Uneven Lanes	CW21-14	6B-28.4	<i>"Intended to be used during resurfacing operations which create a difference in elevation between adjacent lanes greater than 1-inch."</i>

1992 Auto Show Survey

The 1992 Auto Show survey included a question for each of these three signs. The intent of the questions was to determine if drivers could distinguish the differences between the three signs. The question and response choices for each sign were identical, the only difference between the questions was the sign image that was presented with the question. One of the four response choices was "not sure." The other three responses identified the location of the drop-off for each one of the three signs. The height of the drop-off was not addressed.

The results for these questions indicate that about half of the drivers cannot distinguish between the meanings of the **Low Shoulder** and **Shoulder Drop-Off** signs. A sizable (more than 15 percent) percentage of drivers selected each of the three possible response choices (not including the "not sure") for these two signs. However, drivers do appear to understand the meaning of the **Uneven Lanes** sign.

Findings and Recommendations

The results of the 1992 Auto Show survey indicate that the different meanings conveyed by the **Low Shoulder** and the **Shoulder Drop-Off** symbol signs are not being effectively conveyed to drivers. The symbol signs should be replaced with the word message signs described in the Part VI revision to the national MUTCD (24). It may also be appropriate to add descriptions of the word message signs to the *Texas Drivers Handbook* so that drivers can better understand the differences between the signs. Table IV-41 summarizes the study findings and recommendations for these signs.

Table IV-41. Research Summary for the Uneven Pavement Construction Signs

Sign Label	CW8-9a Low Shoulder CW21-13 Shoulder Drop-Off CW21-14 Uneven Lanes
TMUTCD Section	2C-30.3 Low Shoulder 6B-28.3 Shoulder Drop-Off 6B-28.4 Uneven Lanes
Evaluation Procedures	1992 Auto Show - see page B-7.
Focus of Evaluation	Driver understanding of the differences between the signs.
Findings	Drivers do not differentiate between the meanings of the Low Shoulder and Shoulder Drop-Off signs.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	Low Shoulder - <i>"There is an appreciable drop from the pavement edge to the shoulder. If you leave the pavement -- slow down and steer firmly."</i> Shoulder Drop-Off - not described. Uneven Lanes - not described.
Recommendations	The word message signs described in the Part VI revision to the national MUTCD should be adopted for use in Texas. Consideration should also be given to adding all three of these signs to the TDH.

Object Marker

Object markers are used to mark obstructions located in or along the roadway. There are three different types of object markers. One of the most visible of the markers is the Type 3 shown in Figure IV-44, which is used to provide additional emphasis for objects such as bridge piers and columns. Although the Type 3 Object Marker looks like a sign, it is described in the Markings chapter of the Texas MUTCD. One of the primary concerns related to comprehension

of this device is the directional cue provided by the diagonal stripes. Vehicles should pass to the lower side of the diagonal stripes. Previous research on comprehension of diagonal stripes has shown that drivers do not understand this message. Therefore, the research team decided not to focus on this aspect of comprehension. Instead, the survey question was intended to determine whether drivers recognize the manner in which the device is used. This device was evaluated only in the statewide survey.

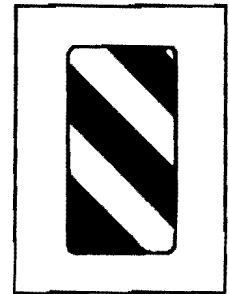


Figure IV-44.
Type 3
Object Marker

Statewide Survey

Only 62 percent of the survey participants selected the correct meaning of the marker. The 19 percent that selected the "not sure" response was the fifth highest in the statewide survey. The relatively large percent that did not select the correct response indicates that drivers may not be completely aware of this traffic control device and how it is used. Although the correct response rate for this device was relatively low, the research team felt that further evaluation of the marker would not reveal additional useful information.

Findings and Recommendations

The findings of the statewide survey indicate that the Type 3 Object Marker is not completely understood by drivers. This study did not investigate alternative designs for the sign because there is a current FHWA research study evaluating the use of markers for older drivers which may develop new or revised markers. The Type 3 Object Marker is already described in the *Texas Drivers Handbook*. Therefore, the only remaining treatment is increased emphasis in driver education curriculums. Table IV-42 summarizes the study findings and recommendations for this device.

PAVEMENT MARKINGS

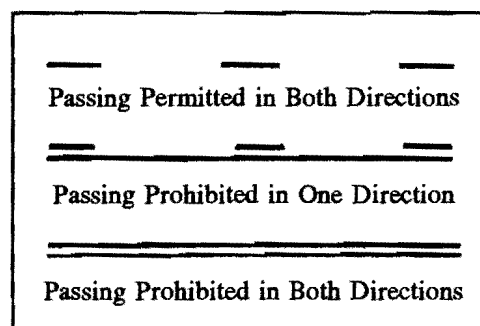
Pavement markings are used to help drivers distinguish the travel way and to convey information about lane position, direction of travel, and permitted or prohibited maneuvers. This research study included evaluations of seven different pavement markings. Two of these (two-way left turn lane and HOV lane markings) have been previously discussed in the regulatory sign section of this chapter.

Table IV-42. Research Summary for a Type 3 Object Marker

Label	OM-3
TMUTCD Section	3C-1
Evaluation Procedures	Statewide Survey - see page A-17.
Focus of Evaluation	Meaning of marker.
Findings	Less than two-thirds of drivers selected the correct response.
Alternative Designs Evaluated	None tested (current FHWA study is evaluating marker designs).
Texas Drivers Handbook Description	<i>"This sign is used to mark the ends of the side rails of narrow bridges and other obstructions so that they may be easily seen."</i>
Recommendations	Increase emphasis in driver education curriculums.

Center Line Pavement Markings

Center line pavement markings are used to separate opposing directions of traffic. They may or may not be in the geometric center of the roadway. Center lines are always yellow. Three different patterns of center lines are used to indicate where passing is permitted or prohibited as shown in Figure IV-45. A single broken center line indicates that passing is permitted in both directions. A double solid centerline indicates that passing is prohibited in both directions. When a single solid center line is located next to a single broken center line, passing is prohibited for vehicles traveling on the side with the solid line.



**Figure IV-45.
Center Line Patterns**

The single broken center line and the no-passing zone pavement markings were selected for evaluation in order to assess driver understanding of the color code for pavement markings and driver understanding of restrictions on passing maneuvers. They were evaluated only in the statewide survey.

Statewide Survey

The statewide survey contained one question each for the two types of center line markings. The question for the single broken yellow center line addressed two issues: 1) whether the road

was one-way or two-way, and 2) whether passing was permitted or prohibited. Three-fourths of the participants understood the intended meaning of the marking. Another twelve percent recognized the directional message of the marking, but failed to recognize that passing was permitted. However, eight percent thought that the marking separated vehicles traveling in the same direction. Although this eight percent would probably have a better understanding of the two-way nature of a roadway if they were actually driving on it, this incorrect interpretation indicates that some drivers lack a fundamental understanding of the color and shape code used in pavement markings.

The question on the no-passing zone marking was intended to address the same issues as the other center line marking. As a result, the question and responses to the no-passing zone markings were identical to those of the single broken center line. Although a higher percentage selected the correct response to this question (88 percent), six percent did not understand the passing restrictions imposed by the solid line in their lane. Another three percent thought the markings indicated a one-way road.

Findings and Recommendations

A large majority of the survey participants selected the correct response to these markings. However, a relatively small percentage (8 and 9 percent) of the drivers selected the responses which were opposite of the desired driving behavior. The study results for the center line markings indicate that 23 and 12 percent of the survey participants did not recognize the entire message conveyed by the single broken center line and no-passing zone markings, respectively.

The study findings for center line markings indicate that drivers do not fully comprehend the color and shape codes used in pavement markings. One possible explanation for the lack of understanding of these two markings is that the MUTCD principles for center line markings have changed several times over the years as the color and shape codes for pavement markings have changed. The use of yellow for pavement markings has had variations in every edition of the Texas MUTCD. As a result, many Texas drivers have experienced at least four changes in the basic principles for centerline pavement markings.

In considering possible actions to improve driver comprehension of center line pavement markings, the research team determined that it was not appropriate to make additional changes to the principles for pavement markings. These principles have remained basically unchanged for over ten years, and additional changes would probably reduce comprehension instead of improve it. Instead, the research team determined that comprehension of center line pavement markings should be improved by increasing the emphasis in driver education programs on the use of color and shapes in pavement markings. The emphasis of this effort should be on the use of yellow to separate opposing traffic, as the barrier line indicating a no-passing zone is fairly well understood. The study findings for these two traffic control devices are summarized in Table IV-43, along with a summary of the recommendations for these markings.

Table IV-43. Research Summary for Center Line Pavement Markings

TMUTCD Section	3A-7 Single Broken Center Line Marking 3A-7 No-Passing Zone Marking
Evaluation Procedures	Statewide Survey - see page A-23 for the single broken center line marking and page A-27 for the no-passing zone marking.
Focus of Evaluation	Meaning of pavement marking color code (one-way versus two-way) and passing restrictions indicated by markings.
Findings	Some drivers do not recognize the color and shape codes used in pavement markings.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	Single Broken Center Line Marking - <i>"Keep to the right of the yellow center line. You may cross the broken line when passing another vehicle or when the right half of the roadway is closed to traffic. DO NOT CROSS THE LINE IF IT IS NOT SAFE TO DO SO."</i> No-Passing Zone Marking - <i>"A solid yellow line on your side of the road marks a 'no-passing zone.'"</i>
Recommendations	Increase emphasis in driver education curriculums on the meaning of color and shape in pavement markings.

Lane Line Markings and Signing

Lane lines are used to separate traffic traveling in the same direction. Lane lines are white and are typically a broken line. Other patterns which are used in lane lines include a solid white line and a double solid white lane line. A single solid line discourages crossing and a double solid line prohibits crossing. Two types of lane lines were selected for evaluation in the study, a single broken white line and a double solid white line. The study also included a sign which

is typically displayed with the double solid white line. The lane line markings evaluated in the study are shown in Figure IV-46, and the sign is shown in Figure IV-47. All three devices were evaluated in the statewide survey, and one was evaluated in the 1992 Auto Show survey.

Statewide Survey

A different question was asked about each of the three devices. The question for the single broken lane line asked the driver to identify the directional movements and ability to change lanes. The correct response was selected by

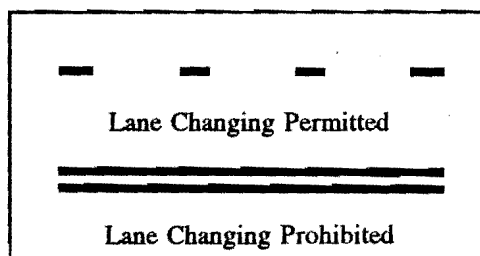


Figure IV-46.
Lane Line Patterns

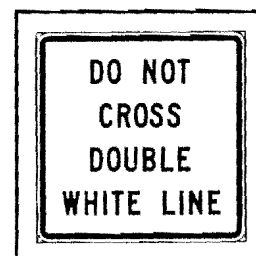


Figure IV-47.
R4-3b Sign

only half of the respondents. Over 40 percent thought the broken white line indicated a two-way road. The large percentage selecting the incorrect response could indicate a lack of knowledge about the color code for pavement markings. However, in reviewing the survey instrument, the research team concluded that some of the drivers may not have been able to clearly distinguish the color of the lane line as it appeared in the video. Therefore, the single broken lane line was selected for further evaluation in the 1992 Auto Show survey.

The intent of the questions for the double solid white lane line marking and sign were to establish driver comprehension of the prohibitory nature of the marking. Only 61 percent of the drivers knew the correct response for the marking. Twenty-nine percent selected the responses which indicated that lane changing was permissible, and ten percent were not sure what the marking meant. The double solid lane line marking was one of ten devices in the statewide survey that had "not sure" response choices of ten percent or more. When the sign was shown to drivers, 84 percent selected a response which indicated lane changing was prohibited. Ten percent appeared to confuse the double white markings with double yellow markings indicating a two-way road.

1992 Auto Show Survey

Driver understanding of the use of pavement marking color to distinguish between one-way and two-way traffic flow was evaluated in the 1992 Auto Show survey. When shown a **ONE-WAY** sign, almost 80 percent of the drivers knew that the pavement markings would be white. These results indicate that drivers do appear to understand the color code for pavement markings.

Findings and Recommendations

The results of the evaluations of the single white lane marking indicate that drivers appear to understand the use of this marking to separate lanes of traffic traveling in the same direction. Changes to the design, use, or education of this marking do not appear to be needed. Consideration should be given to the use of a **ONE-WAY** sign at intersections with one-way streets in order to improve driver recognition of the one-way situation.

The results of the two questions addressing the double solid white lane line indicate that drivers do not have a complete understanding of the intended meaning of the marking when viewed in isolation. Comprehension of the markings was much better when the sign was shown to drivers. These findings indicate that the **DO NOT CROSS DOUBLE WHITE LINE** sign should be used with the double solid white lane line pavement marking. Consideration should also be given to adding the sign and double line marking to the *Texas Drivers Handbook*. The findings and recommendations for these devices are summarized in Table IV-44.

Solid White Edge Line Marking

Edge lines are used to indicate the right edge of roadways. They are normally used on rural highways and not in urban areas. An edge line was included in the study in order to determine if drivers recognized that the edge line indicated the edge of the travel lanes. The marking was evaluated only in the statewide survey.

Table IV-44. Research Summary for Lane Line Markings and Signing

Sign Label	R4-3b
TMUTCD Section	3A-7 Single Broken Lane Line 3A-7 Double Solid Lane Line 2B-23.2 Sign
Evaluation Procedures	Statewide Survey - see pages A-34, A-20, and A-39. 1992 Auto Show - see page B-5.
Focus of Evaluation	Statewide Survey - Directional cues of lines and ability to change lanes. 1992 Auto Show - color of markings on a one-way road.
Findings	Drivers appear to understand the meaning of the single white lane line, but not the double white lane line.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	Single Broken Lane Line - <i>"On a one-way roadway, each lane is marked with a broken white line, you may drive in either lane. When turning from a one-way road, be sure to move into the proper lane well in advance of your turn."</i> Double Solid Lane Line - <i>"Solid white lines are used for pavement edge lines, shoulder markings, channelizing, transitions, and lane use control. Crossing a solid white line should be avoided if possible."</i> Sign - Not described.
Recommendations	Single Broken Lane Line - Changes to the design, use, or education of this marking do not appear to be necessary. Consider use of a ONE-WAY sign at intersections with a one-way street. Double Solid Lane Line - Consideration should be given to using the sign wherever the marking is used. Consideration should also be given to adding this pavement marking and sign to the TDH.

Statewide Survey

Three-fourths of the drivers in the statewide survey selected the proper response for this marking. The remaining 25 percent of the drivers indicated some degree of uncertainty over the correct meaning of the marking.

Findings and Recommendations

Although 25 percent of the drivers did not fully understand the meaning of an edge line, there is little that can be done with the design or use of the marking to improve comprehension of it. As with the other pavement markings, the primary treatment to improve comprehension is to place greater emphasis on the appearance and meaning of pavement markings in driver

training curriculums. Table IV-45 summarizes the findings and recommendations for this type of pavement marking.

Table IV-45. Research Summary for the Solid White Edge Line Marking

TMUTCD Section	3B-6
Evaluation Procedures	Statewide Survey - see page A-16.
Focus of Evaluation	Meaning of marking.
Findings	One-fourth of drivers do not have a complete understanding of the meaning of the marking.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	<i>"Solid white lines are used for pavement edge lines, shoulder markings, channelizing, transitions, and lane use control. Crossing a solid white line should be avoided if possible."</i>
Recommendations	Increase emphasis in driver training curriculums.

SIGNAL INDICATIONS

Traffic signals are used to assign right-of-way at intersections and on roadways and to provide motorists with other information about the use of the roadway. The evaluation of a traffic signal indication is inherently difficult in a survey which uses still images, due to the dynamic operation of a traffic signal. Therefore, only five different traffic signal indications were evaluated in the research study.

Yellow Traffic Signal Indications

The yellow indication in a conventional traffic signal is a vital aspect of traffic signal operation. A steady yellow indication in a conventional traffic signal informs the driver that movements into the intersection are ending and a red indication is about to be displayed. Although drivers can legally enter the intersection under a steady yellow indication, the general message conveyed by the indication is to stop, if a stop is possible. On the other hand, when a conventional traffic signal uses flashing operation, vehicular right-of-way is assigned in the same manner that it is with intersecting beacons. When a flashing yellow ball is illuminated, drivers approaching the indication are not required to stop. Instead, they may proceed through

the intersection with caution. As a result, the *"stop if possible"* message of the steady yellow indication is somewhat contradictory to the *"proceed"* message of the flashing yellow indication. This inconsistency was reinforced by informal observations of the research team of drivers stopping for a flashing yellow traffic signal indication. Therefore, steady and flashing yellow signal indications were included in the statewide survey in order to evaluate how drivers interpret yellow signal indications.

Statewide Survey

One question in the statewide survey asked drivers to select the meaning of a steady yellow arrow indication. The question was intended to determine if drivers recognize that it is legal to enter the intersection during a steady yellow indication. Four-fifths of the respondents selected the correct response. Six percent of the drivers indicated that it was illegal to enter the intersection during a yellow indication.

The other question in the statewide survey asked how drivers would respond to a flashing yellow indication. Although 81 percent of the respondents would execute the correct response, 18 percent would stop or treat the intersection as if it had a stop sign. This means that almost one in five drivers might stop at the intersection. Although this is a conservative error which is not unsafe, it can reduce the overall capacity of the intersection.

Findings and Recommendations

The findings of the statewide survey indicate that about the same percentage (80 percent) correctly understand the steady and flashing yellow indications. The results indicate that some drivers believe that a flashing yellow traffic signal conveys a stop related message. Although such behavior errs on the side of safety, it can create operational constraints. However, there are not any traffic control device related treatments which can improve driver understanding of either indication. Instead, driver training curriculums should emphasize the difference between the flashing yellow and steady yellow traffic signal indications. The results of this research with respect to yellow traffic signal indications are summarized in Table IV-46.

Table IV-46. Research Summary for the Yellow Traffic Signal Indications

TMUTCD Section	4B-5
Evaluation Procedures	Statewide Survey - see page A-45 for the steady arrow indication and A-35 for flashing indication.
Focus of Evaluation	Meaning of steady yellow indication. Whether flashing yellow indication means stop.
Findings	Almost 1/5 of drivers might stop for a flashing yellow indication.
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	Flashing yellow - " <i>Caution - Slow down and proceed with caution.</i> " Steady yellow - " <i>Caution - red light coming up! You must STOP before entering the nearest crosswalk at the intersection, if you can do so safely. If a stop cannot be made safely, you may proceed cautiously through the intersection before the light changes to red.</i> "
Recommendations	Increase emphasis in driver training curriculums.

Intersection Beacon Indications

Intersection control beacons are "*intended for use at intersections where traffic or physical conditions do not justify conventional traffic signals, but where accident rates indicate a special hazard*" (13). One of the primary concerns with flashing signals (both intersection beacons and flashing conventional signals) is driver understanding of the right-of-way assignments. A driver approaching a flashing red indication is not provided with any direct evidence of the flashing indication displayed to the intersecting roadway. This is not a critical situation if a flashing red indication is displayed to the intersecting traffic. However, if a flashing yellow indication is displayed to the intersecting traffic and the driver assumes a flashing red indication is being displayed, then there is the potential for a driver to enter the intersection and possibly cause an accident. Concern over the accident potential of this situation led to it being evaluated in the statewide survey, the 1992 Auto Show survey, and the focus groups.

Statewide Survey

The statewide survey included questions about both the flashing red and the flashing yellow intersection beacon indications. Both survey questions asked the driver to select the signal indication that intersecting traffic would observe. The results of the statewide survey indicate that drivers do not fully understand the relationship between the indication they see on the approach and the indication displayed to conflicting traffic.

1992 Auto Show Survey

The degree of driver uncertainty identified in the statewide survey indicated a need for the evaluation of possible alternative treatments. The 1992 Auto Show survey included a standard intersection and two alternative treatments. The first alternative added a 2-WAY supplemental plaque below the STOP sign, while the second alternative treatment added a 2-WAY supplemental plaque below both the STOP sign and the intersection beacon. It should be noted that the 2-WAY supplemental plaque is a new sign which is not described in the TMUTCD.

Focus Group Evaluations

The alternative treatments evaluated in the Auto Show survey were included in the focus groups, along with three additional alternative treatments for the intersection. These alternatives were included in the focus groups to determine if the two-way stop control situation could be more effectively conveyed to drivers. The consensus of all three focus groups was that a 2-WAY supplemental plaque located below the STOP sign was sufficient to convey the message that intersecting traffic would not stop.

Findings and Recommendations

The study findings for intersection beacon indications indicate that drivers do not fully understand the manner in which the beacons are used. The use of a 2-WAY supplemental plaque below the STOP sign was found to improve driver understanding of right-of-way assignments at the intersection. However, the 2-WAY plaque is not currently included in the Texas MUTCD. The study findings indicate that consideration should be given to further evaluation of the 2-WAY plaque for possible inclusion in the MUTCD. Such evaluations should also include evaluation of other alternative treatments for communicating right-of-way assignments at 2-way stop controlled intersections.

The limitations on driver understanding of the indications shown to intersecting traffic indicate a need to emphasize this situation in driver education curriculums. The description of a flashing red indication in the *Texas Drivers Handbook* should be expanded to include a statement that the conflicting traffic may or may not have to stop at the intersection. The

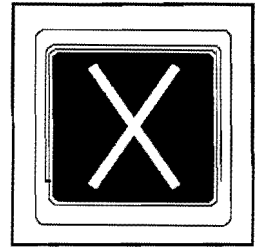
findings and recommendations of this study for intersecting beacon indications are summarized in Table IV-47.

Table IV-47. Research Summary for the Flashing Intersection Beacon Indications

TMUTCD Section	4E-3
Evaluation Procedures	Statewide Survey - see page A-25 for flashing red and page A-14 for flashing yellow. 1992 Auto Show - see pages B-8 and 9. Focus Groups - see page D-1.
Focus of Evaluation	1992 Auto Show - alternative treatments to distinguish between 2-way and 4-way stop intersections. Focus Groups - alternative treatments to distinguish between 2-way and 4-way stop intersections.
Findings	Statewide Survey - drivers do not have a complete understanding of intersection beacon indications. 1992 Auto Show - 2-WAY supplemental plaque improves driver understanding of the right-of-way assignment at a two-way stop controlled intersection. Focus Groups - drivers prefer the use of a 2-WAY supplemental plaque below the STOP sign to indicate two-way stop control.
Alternative Designs Evaluated	1992 Auto Show <ol style="list-style-type: none"> 1. Flashing red beacon with STOP sign. 2. Flashing red beacon with STOP sign and a 2-WAY supplemental plaque below the sign. 3. Flashing red beacon with a 2-WAY supplemental plaque below the signal and a STOP sign with a 2-WAY supplemental plaque below the sign. Focus Groups <ol style="list-style-type: none"> 1. Flashing red beacon with a STOP sign. 2. Flashing red beacon with a STOP sign and a 2-WAY supplemental plaque below the sign. 3. Flashing red beacon with a STOP sign and a 2-WAY supplemental plaque below the beacon. 4. Flashing red beacon with a STOP sign and a 2-WAY supplemental plaque below both the signal and the sign. 5. Flashing red beacon with yellow STOP sign. 6. Flashing red beacon with purple STOP sign.
Texas Drivers Handbook Description	Flashing red beacon - " <i>Stop completely before entering the crosswalk or intersection, then proceed when you can do so safely.</i> " Flashing yellow beacon - " <i>Caution - Slow down and proceed with caution.</i> "
Recommendations	Consideration should be given to the use of a 2-WAY supplemental plaque below the STOP sign to indicate a two-way stop controlled intersection. Further evaluations of the use of a 2-WAY plaque should be conducted before it is implemented. Increase the emphasis in driver training curriculums on right-of-way assignments at intersections controlled by flashing signals. Expand description of flashing red indication in the TDH.

Steady Red X Lane-Use Control Signal Indication

Lane-use control signals (LCS) are used to inform drivers of the availability of the lane below the signal for travel. The steady red X shown in Figure IV-48 is used to indicate that the lane is closed to traffic. This signal indication was included in the statewide survey because lane-use control signals are becoming more common on streets, freeways, and HOV facilities, but driver understanding of the indications has not been widely evaluated in the past. In particular, driver understanding of LCS will become more crucial as they are more widely utilized as part of freeway traffic management systems.



**Figure IV-48.
Steady Red X
LCS Indication**

Statewide Survey

Only one question in the statewide survey evaluated driver understanding of lane-use control signal indications. Three-fourths of the survey participants selected the correct response, but 19 percent selected the "not sure" response. The 19 percent that were not sure was the fourth highest "not sure" response in the survey.

Findings and Recommendations

In evaluating the study findings for this traffic control device, the research team concluded that driver unfamiliarity with the device can be partly attributed to the fact that the use of this type of signal is limited to some of the major metropolitan areas of the state. Therefore, most drivers have not been exposed to this type of signal.

The study recommendation relative to the steady red X and other lane-use control signal indications is that these indications be added to the *Texas Drivers Handbook*. Consideration should also be given toward the development of a sign describing the meanings of the indications. This sign could then be erected in areas where the signal is used. Furthermore, any treatment actions related to lane-use control signals should be coordinated with the findings of TxDOT study 1498, *Design, Installation, and Operation of Freeway Lane Control Signals* (25). The study findings for this traffic control device are summarized in Table IV-48.

Table IV-48. Research Summary for the Steady Red X Lane-Use Control Indication

TMUTCD Section	4E-9
Evaluation Procedures	Statewide Survey - see page A-47.
Focus of Evaluation	Meaning of LCS indication.
Findings	Correct response rate of 75 percent. Fourth highest "not sure" response rate (19 percent).
Alternative Designs Evaluated	None.
Texas Drivers Handbook Description	Not described.
Recommendations	Add descriptions of the meaning of lane-use control signal indications to the TDH. Consider development of sign which describes the meaning of the indications for lane-use control signals. Coordinate treatment actions with related TxDOT research studies (25).

CHAPTER V

IMPLEMENTATION ACTIVITIES

From the beginning of this study, the implementation of the study results was an important element of the overall research plan. In addition to the evaluations of motorist understanding of traffic control devices and recommendations for improving understanding, the research plan included efforts for implementing the study results into actual practice. Four basic implementation activities are being used to realize the recommendations described in Chapter IV. The **No Action** activity is appropriate for those devices which were found to be adequate. **Changes to TxDOT Practices** revises the manner in which some devices are used in order to improve their effectiveness. For some traffic control devices, the most appropriate activity is to improve driver understanding by increasing their awareness of the meaning and uses of traffic control devices. Driver awareness of specific traffic control devices can be improved through various **Driver Education/Training programs**. These programs include *driver education courses*, *defensive driving/driver safety courses*, the *Texas Drivers Handbook*, and *public information campaigns*. Finally, for several devices, the researchers believe that a change in the design of the device may be the best alternative for improving motorist understanding. Therefore, **Additional Research** will be conducted in the fifth year of this study to evaluate alternative designs for selected traffic control devices. It should be noted that it is possible for a device to be included in more than one implementation activity.

NO ACTION

In conducting this research, the researchers wanted to limit the evaluation to those devices which had the greatest potential for improving driver understanding. Therefore, the procedure used to select devices for evaluation in this study (2) eliminated devices with high levels of understanding. Despite this fact, the evaluation results indicated that three of the devices have adequate levels of understanding and require no changes to the design, use, or education of the devices. The devices for which no further action is recommended include:

- **Yield Sign (R1-2)** - Drivers appear to have an adequate understanding of the restrictions imposed by this device.

- **Double Turn Sign (R3-8)** - Drivers appear to understand the permitted and restricted movements indicated by this sign.
- **Advance Railroad Warning Sign (W10-1)** - Although some drivers appear to confuse this sign with the **Crossbuck** sign, the association of this sign with a railroad crossing is sufficient to alert drivers to the presence of a crossing.

CHANGES TO TxDOT PRACTICES

For many of the devices, the recommendations indicate that a change in the selection or placement was appropriate. These types of recommendations are being implemented through changes in TxDOT practices regarding the selection of devices, placement of devices, or combination of multiple devices. TxDOT practices are being revised through memorandums to the districts, revisions of the Texas MUTCD, the adoption of a new Part VI and the associated construction signing, and additional future efforts.

Memorandum to Districts

In July 1994, the Traffic Operations Division distributed a memorandum to each TxDOT district which described changes in the use of several traffic control devices. A copy of the directive is included in Appendix E. The devices included in this directive are listed below along with a brief description of the change in practice.

- **SPEED ZONE AHEAD and REDUCED SPEED AHEAD Signs (R2-5c and R2-5a)** - The **REDUCED SPEED AHEAD** sign (R2-5c) has been established as the preferred alternative of these two signs.
- **Turn Sign (W1-2)** - An **Advisory Speed Plate (W13-1)** should be used with these signs when the recommended speed shown in the plate is 30 mph or less.
- **Curve Sign (W1-1)** - An **Advisory Speed Plate (W13-1)** should be used with this sign in accordance with the TxDOT manual *Procedure for Establishing Speed Zones Manual*.
- **Divided Highway Ends Sign (W6-2)** - The **Two-Way Traffic** sign (W6-3) should follow the use of the **Divided Highway Ends** sign (W6-2).

- **ROUGH ROAD and GROOVED PAVEMENT AHEAD Signs (W8-8 and W8-12)** - The **ROUGH ROAD** sign (W8-8) replaces the **GROOVED PAVEMENT AHEAD** sign (W8-12).
- **DO NOT CROSS DOUBLE WHITE LINE Sign (R3-4b)** - The sign will be used whenever double solid white lane lines are used.

Changes to Texas MUTCD

In March 1994, TxDOT issued Revision 5 to the 1980 Texas MUTCD. This revision affected the use of three of the devices evaluated in this study. A list of the devices and the impact of the revision is given below.

- **Mandatory Turn Sign (R3-7)** - Revision describes the use of a supplemental distance plaque below the sign to indicate the distance to the restriction.
- **PROTECTED LEFT ON GREEN Sign (R10-9a)** - This sign has been dropped from the *Manual*. Dropping the sign became necessary due to changes in the national MUTCD which eliminated the ability to use a green ball to indicate protected left turn phasing.
- **LIMITED SIGHT DISTANCE Sign (W14-4)** - This sign has been dropped from the *Manual*.

Adoption of New Part VI

FHWA recently revised the 1988 national MUTCD with the publication of a new Part VI addressing traffic control for construction, maintenance, utility, and incident management operations (24). By January 1996, each state must revise their state manual to substantially conform with the new Part VI standards and guidelines. The devices affected by the adoption of the new Part VI are described below.

- **Uneven Pavement Construction Signs (CW8-9a, CW21-13, and CW21-14)** - The Texas MUTCD specifies the use of symbol signs for indicating uneven pavement conditions. Until the recent revision to Part VI of the national MUTCD, the national MUTCD had not contained any construction warning signs for these types of

conditions. When the recently revised Part VI of the national MUTCD is adopted by Texas, the word message signs will replace the symbol signs as the preferred versions of these signs.

Future Changes to TxDOT Practices

Several other devices are under consideration for being addressed in future changes in TxDOT practices. These changes may be through additional memorandums to districts or future revisions to the Texas MUTCD. These devices include:

- **LEFT TURN YIELD ON Green Ball and PROTECTED LEFT ON GREEN ARROW Signs (R10-12 and R10-9)** - The **LEFT TURN YIELD ON Green Ball** sign (R10-12) is the preferred alternative of these two signs for use with permissive/protected left turn phasing.
- **Single Broken White Lane Line Marking** - A **ONE-WAY** sign should be used at intersections with one-way streets.
- **Steady Red X Lane-Use Control Signal** - A supplemental sign should be developed that can be used with the LCS to explain the meaning of the indications. Development of such a sign should be coordinated with a related TTI/TxDOT study on LCS for freeways.

DRIVER TRAINING PROGRAMS

A major finding of this research is that many drivers do not understand basic fundamentals of traffic control devices such as the color and shapes associated with signs and pavement markings. For the majority of the devices in this study, the researchers recommend that efforts to educate or train drivers about the meaning of these devices would be more effective than any of the other implementation activities. The implementation activities in this area can be divided into three areas: 1) changes in the driver education/driver safety course curriculums, 2) revisions to the *Texas Drivers Handbook*, and 3) development of a public information campaign.

Driver Education/Driver Safety Course Curriculums

Driving is a learned process. The driver must possess a minimum level of knowledge and skill in order to safely operate a vehicle. The driver licensing process provides the means of confirming the competency of a driver. However, there are additional avenues for training and retraining drivers. Driver education (DE) courses provide a means of training potential drivers between the ages of 16 and 18. Driver safety courses (DS), which have also been known as defensive driving courses, are taken by currently licensed drivers. DS courses are often taken in order to remove a traffic violation from a driver's record or to obtain discounts on automobile insurance. The results of this research identified several devices where increased emphasis in DE/DS courses are the most effective means of improving driver understanding of the traffic control devices.

- **Two-Way Left Turn Lane Sign (R3-9b) and Markings** - Emphasize the purpose of the lane, permissible methods of using the lane, and methods of signing and marking. Descriptions of the permitted uses of the lane should address whether the lane can be used for deceleration prior to making a left turn, for storage halfway through a turn onto the street with the lane, and for accelerating after turning onto the street.
- **HOV Restriction Sign (R3-14) and Preferential Lane Marking** - Describe HOV concepts, applications in urban areas, and the traffic control devices used on this type of facility.
- **SLOWER TRAFFIC KEEP RIGHT Sign (R4-3)** - Emphasize the "slower traffic" concept as vehicles that are slower than other vehicles on the roadway.
- **Keep Right Sign (R4-7)** - Emphasize the use and meaning of the sign, particularly lane changing behavior.
- **LEFT TURN YIELD ON GREEN Ball Sign (R10-12)** - Emphasize the various possibilities for providing left-turn control at signalized intersections and the signs that can be used to explain left-turn signal operation. Include descriptions of the permitted/protected left turn phasing pattern.
- **Slow Down on Wet Road** - Emphasize the wet pavement message of the sign.
- **WATCH FOR ICE ON BRIDGE (W19-2)** - Emphasize the proper driving actions for driving on bridges which may have ice on them.

- **RAMP METERED WHEN FLASHING Sign (W19-3)** - Describe the ramp metering concept and the traffic controls which are used with ramp metering.
- **Sign Shape & Color** - Emphasize the shapes and colors, both separately and together, that are used with traffic signs.
- **Type 3 Object Marker** - Describe the use of markers and the types of potential hazards they warn of.
- **Center Line and Lane Markings** - Emphasize the difference between yellow and white markings and the restrictions indicated by different marking patterns.
- **Edge Line Marking** - Emphasize the use of edge lines and the differences between edge lines and other types of pavement markings.
- **Yellow Traffic Signal Indications** - Emphasize that a flashing yellow traffic signal does not require a stop. Indicate the difference between a steady and flashing traffic signal indication.
- **Flashing Red Intersection Beacon Indication** - Emphasize that a driver facing a flashing red indication should not expect traffic on the cross street to stop. Intersecting traffic may be facing a flashing yellow or flashing red indication.
- **Lane-Use Control Signals** - Describe how these signals are used on streets, freeways, and HOV lanes.

Texas Drivers Handbook

The *Texas Drivers Handbook* (TDH) is the primary document used by the Texas Department of Public Safety (DPS) to inform drivers of the rules of the road and the meaning of traffic control devices. Many of the devices evaluated in this study are not described in the TDH, or, if they are described, the description is not consistent with the actual use of the sign. The research findings identify two types of changes to the TDH that should be considered: 1) adding new descriptions of devices which are not in the current TDH, and 2) revising descriptions which are in the TDH, but which may not accurately reflect the meaning and/or use of devices. The devices and recommended changes for each type are described below.

Adding New Descriptions

The descriptions of the following devices should be added to the TDH.

- **HOV Restriction Sign (R3-14) and Preferential Lane Marking** - Describe the HOV concept, application in urban areas, and illustrations of two or three HOV signs.
- **DO NOT CROSS DOUBLE WHITE LINE Sign (R4-3b) and Double Solid White Lane Line** - Add description indicating the prohibitory nature of this marking and the sign.
- **LEFT TURN YIELD ON GREEN Ball Sign (R10-12)** - Describe the permissive/protected message of this sign and its use for identifying left-turn signal operation. Descriptions of permissive phasing should indicate that drivers have to wait for a safe gap in the opposing traffic to make their turn.
- **Reverse Turn Sign (W1-3)** - This sign should be added so that all of the signs warning of a change in horizontal alignment are included in the handbook. The description should be consistent with the revised descriptions of the other warning signs for changes in horizontal alignment.
- **Stop Ahead Sign (W3-1a)** - Add a description of the meaning of this sign.
- **RIGHT LANE ENDS Sign (W9-1)** - Add a description of the meaning of this sign.
- **LANE ENDS MERGE LEFT Sign (W9-2)** - Add a description of the meaning of this sign.
- **ROUGH ROAD Sign (W8-8)** - Add a description of the meaning of this sign.
- **RAMP METERED WHEN FLASHING Sign (W19-3)** - Add a description of the traffic controls for ramp metering.
- **Lane-Use Control Signal Indications** - Add a description indicating how these signals are used and the different meanings of the indications.

Revising Existing Descriptions

The existing descriptions for the following devices which are contained in the current TDH should be revised to more accurately reflect the meanings or uses of the devices.

- **Two-Way Left Turn Lane Sign (R3-9b) and Markings** - Revise sign to show post mounted version, as it is the more common of the two signs. Show sign and pavement marking together in the same illustration. Revise description of lane to address use of lane for deceleration prior to making a left turn, for storage during turning maneuver, and for accelerating after turning onto street.
- **SLOWER TRAFFIC KEEP RIGHT Sign (R4-3)** - Revise description to "Stay in the righthand lane if you are driving slower than other vehicles on the roadway."
- **Keep Right Sign (R4-7)** - Revise the description to indicate that changing lanes is not necessary.
- **PROTECTED LEFT ON GREEN ARROW Sign (R10-9)** - Revise the description to indicate that permissive left turns require the driver to wait for a safe gap in the opposing traffic to make their turn.
- **Sign Shape & Color** - In addition to the separate treatment of shape and color currently in the handbook, consider presenting the information together (i.e., a yellow diamond, a red octagon, etc.)
- **Turn, Curve, Reverse Curve, and Winding Road Signs (W1-1, W1-2, W1-4, and W1-5)** - Revise the descriptions to indicate that a speed reduction is not necessary unless an **Advisory Speed Plate** indicates a speed less than the speed limit. The "do not pass" statements should be deleted from the descriptions of these signs as they do not convey a restriction on passing.
- **Narrow Bridge Sign (W5-2a)** - The description should be revised to delete the reference to a two-lane bridge. The description should reflect all the circumstances under which the sign may be used.
- **GROOVED PAVEMENT AHEAD Sign (W8-12)** - Delete the description if the sign is discontinued from service. If the sign continues in service, revise the description to indicate that drivers should pay attention to steering and prepare for an increase in roadway noise. The description should also reflect that the sign is intended for motorcyclists.
- **WATCH FOR ICE ON BRIDGE Sign (W19-2)** - Revise the description to reflect that current TxDOT practice is to display the sign continuously during wintertime periods. Add that drivers should not apply their brakes while on the bridge.
- **Flashing Red Intersection Beacon Indication** - Revise description to indicate that vehicles on the intersecting roadway may not have to stop.

Public Information Campaign

Implementation activities associated with driver education/driver safety courses and the *Texas Drivers Handbook* will not reach all segments of the driving population. Therefore, the implementation activities associated with driver education/training include an effort to reach other portions of the driving population through a public information campaign.

A framework for an initial public information campaign has been jointly developed by the researchers and the Technical Panel. The framework has three key elements. It identifies the target audiences for which a public information campaign would be most effective. It identifies the tools or actions which are envisioned to be the most effective methods of conveying the desired information to the target audiences. Finally, the framework focuses on those devices of greatest interest and need to the target audience. Table V-1 identifies the key elements of a potential public information campaign.

It should be noted that the actual conduct of a public information campaign will require support, both financial and otherwise, from various agencies and organizations. Such a campaign is beyond the scope and resources of this research study. However, the framework contained in Table V-1 can be used as a starting point for such a long-term effort.

ADDITIONAL RESEARCH

For a few of the devices, the study recommendations indicate that an alternative version may have a higher level of driver understanding than the existing version. The alternative versions may be modifications to existing sign designs or the development of new sign designs. However, the statewide survey was limited to only existing devices, and the follow-up evaluations of alternative sign designs was limited in size and geographic representation. Therefore, for those signs for which an alternative version may be better understood by drivers, it will be necessary to conduct additional research to assess driver understanding of the alternative designs. The intent of the additional evaluations is to develop the information needed to request a change in the national MUTCD for those alternative versions found to be more effective. These evaluations will be conducted in the fifth year of this study. The devices which are being considered for additional evaluations include:

Table V-1. Possible Public Information Campaigns for Implementation of Study Findings

TARGET AUDIENCE	IMPLEMENTATION TOOL	DEVICES TO BE ADDRESSED
Driver Education and Driver Safety Course Instructors	<ul style="list-style-type: none"> • Direct mailouts • Speakers at meetings • Professional journal articles • Curriculum enrichments 	<ul style="list-style-type: none"> • Flashing intersection beacons • Left turn signal indications and signing • Color/shapes of signs and markings • Two-Way Left Turn Lane signs and markings • School speed limit signs • Pedestrian/School Crossing and Advance Crossing signs • Speed message of Turn and Curve signs
Driver License Station Patrons	<ul style="list-style-type: none"> • Posters • Pamphlets • Electronic/video displays 	<ul style="list-style-type: none"> • Flashing intersection beacons • Left turn signal indications and signing • Color/shapes of signs and markings • Two-Way Left Turn Lane signs and markings • School speed limit signs • Pedestrian/School Crossing and Advance Crossing signs • Speed message of Turn and Curve signs
Mature Drivers	<ul style="list-style-type: none"> • Magazine articles (Modern Maturity, Readers Digest, etc) • Newspaper articles • Pamphlet • AARP publications • Presentations to AARP chapters 	<ul style="list-style-type: none"> • Flashing intersection beacons • Left turn signal indications and signing • Two-Way Left Turn Lane signs and markings • Speed message of Turn and Curve signs

- **Two-Way Left Turn Lane Sign (R3-9b) and Markings** - Effectiveness of alternative sign designs.
- **Lane Reduction Transition Sign (W4-2)** - Effectiveness of alternative sign designs.
- **Narrow Bridge Sign (W5-2a)** - Effectiveness of alternative sign designs.
- **Slow Down on Wet Road (W8-5)** - Effectiveness of alternative symbol legends and understanding of the word message among various demographic populations.
- **Truck Crossing (W11-10)** - Effectiveness of alternative sign designs.
- **Parallel Railroad Advance Warning Sign (W10-3)** - Effectiveness of alternative sign designs.
- **School Advance (S1-1)** - Effectiveness of alternative sign designs.
- **END SCHOOL ZONE Sign (S5-2)** - Evaluate the effectiveness of the sign alone and in combination with the **SPEED LIMIT** sign.
- **Flashing Red and Flashing Yellow Intersections Beacons** - Effectiveness of alternative treatments for distinguishing between a 2-way and 4-way stop controlled intersection.

It should be noted that once research of these devices is completed, it may be appropriate to add these devices to one or more of the other implementation activities described previously in this chapter.

SUMMARY OF IMPLEMENTATION ACTIVITIES

Tables VI-7 through VI-11 in Chapter VI summarize the implementation activities which have been initiated for each of the 52 devices evaluated in this study.

CHAPTER VI
SUMMARY OF RECOMMENDATIONS
AND IMPLEMENTATION EFFORTS

The ability to convey information to drivers through the use of traffic control devices is a very important element of the roadway environment. In an effort to improve the overall operations of the state highway system, the Texas Department of Transportation (TxDOT) sponsored a research study to assess and improve driver understanding of traffic control devices. The intent of the research was to select a number of devices, based on previous research or actual experience, which exhibited a potential for improving comprehension. These devices were then evaluated using a variety of procedures. The results of the evaluations were analyzed, and implementation activities were developed to improve driver understanding and awareness of selected traffic control devices.

Five different evaluation procedures were used to evaluate a total of 52 traffic control devices. Table VI-1 summarizes the key elements of each procedure and identifies the appendices which contain the questions and responses for each procedure. The majority of effort was devoted to the development and administration of the statewide survey. The survey instrument was a videotape which presented separate in-context and close-up images for each device. This survey was administered at driver license stations in twelve Texas cities. The response percentages to the statewide survey questions were analyzed and are described in a previous research report (3). Chapter II summarizes the methodology and Appendix A contains the question, images, and response percentages for each of the statewide survey questions.

Table VI-1. Summary of Evaluation Procedures

Evaluation Procedure	Type of Evaluation	Date of Evaluation	Number of Drivers Surveyed	Number of Devices Evaluated	Report Appendix
Statewide Survey	Multiple-choice survey	Feb-Jul 91	1,745	46	A
1992 Auto Show Survey	Multiple-choice survey	Jan-Feb 92	322	10	B
1993 Auto Show Survey	Open-ended survey	Jan-Feb 93	286	5	C
Spanish-Language Survey	Spanish language survey	Jan 92	31	46	--
Focus Groups	Opinion and discussion	Feb-May 93	30	3	D

Once the results of the statewide survey were analyzed, a series of follow-up evaluations were conducted. The Spanish-language survey was identical to the statewide survey except that Spanish was dubbed onto the audio portion of the videotape survey instrument. The results of the statewide and Spanish-language surveys were used to select a few traffic control devices for further evaluation. In addition, a few other devices which were not in the statewide survey were selected for further evaluation. The follow-up evaluations included two surveys administered at the Houston Auto Show and focus groups conducted in three Texas cities. The results of these evaluations were analyzed and are described in Chapter III of this report.

In all, a total of 52 traffic control devices were evaluated in the five evaluation procedures. The total number of drivers which participated in the evaluations was 2,414. The results from these evaluations were analyzed to determine the study findings. These findings were used to develop a series of recommendations for improving understanding of those devices which demonstrated a potential for improvement. Chapter IV describes the findings and recommendations for each of the traffic control devices evaluated in this study.

The development of implementable recommendations was a major emphasis of this research study. Four basic implementation activities were developed. They include no action, a change in TxDOT practices, possibly increasing the emphasis in driver education/training programs, or conducting additional research on the device. Changing TxDOT practices included memorandums to TxDOT districts revising the use of traffic control devices, changes in the *Texas Manual on Uniform Traffic Control Devices*, adoption of a new Part VI on construction and maintenance traffic control, and other future actions. Driver education/training actions include potential revisions to the driver education/driver safety course curriculums, potential revisions of the *Texas Drivers Handbook* issued by the Texas Department of Public Safety, and a public information campaign targeted at the general public. Chapter V of this report summarizes and categorizes the implementation activities for the study recommendations.

Tables VI-2 through VI-6 summarize the study evaluations. For each of the 52 devices, these tables indicate the evaluation procedures used for that device, briefly identify the major focus for that device, the findings of the evaluations, and the general category of implementation activities for the device. Tables VI-7 through VI-11 provide more specific information about the implementation activities for the devices.

Table VI-2. Summary of Regulatory Signs Evaluations

Label	Sign Name	Eval Proc ¹	Focus	Findings	Impl Actv ²
R1-2	YIELD	ST	Degree of restriction imposed by sign.	Comprehension levels appear to be adequate.	NA
R2-5a	REDUCED SPEED AHEAD	ST	Most effective of the two signs.	The correct response rate for the R2-5a sign was higher than the correct response rate for the R2-5c sign.	TxDOT
R2-5c	SPEED ZONE AHEAD				
R3-7	Mandatory Turn	ST	Point where turn is required.	More drivers interpret the sign as applying to the next intersection instead of the next driveway.	TxDOT
R3-8	Double Turn	ST, 92	Movements which can be made from each lane.	Most drivers understand this sign.	NA
R3-9b	Two-Way Left Turn Lane	ST, 92	Understanding and use of two-way left turn lanes.	Drivers do not have a complete understanding of how the lane should be used.	DE, AR
R3-14	HOV Restriction	ST	Understanding and familiarity with HOV facilities.	Many drivers are not familiar with the devices used with HOV facilities.	DE
R4-3	SLOWER TRAFFIC KEEP RIGHT	ST	Interpretation of the term "slower traffic."	Many drivers interpret the sign as slower than the speed limit.	DE
R4-3B	DO NOT CROSS DOUBLE WHITE LINE	ST	Restrictive message of double white line.	Drivers do not understand the meaning of the double white lane line without the sign.	TxDOT, DE
R4-7	Keep Right	ST, 93	Understanding of sign meaning.	Some drivers do not fully understand the sign.	DE
R10-9	PROTECTED LEFT ON GREEN ARROW	ST	Driver understanding of left turn operation for each sign.	Some drivers do not recognize the permissive nature of this sign.	TxDOT
R10-9a	PROTECTED LEFT ON GREEN			Most drivers do not fully understand this sign.	
R10-12	LEFT TURN YIELD ON GREEN Ball			R10-12 sign is the most effective at indicating the permitted nature of protected/permitted left turn phasing.	

Notes: ¹Evaluation procedures. Abbreviations - ST=Statewide survey, 92=1992 Auto Show survey, 93=1993 Auto Show survey, FG=Focus groups.

²Implementation activities. Abbreviations - NA=No action, TxDOT=Change in TxDOT practices, DE=Changes in driver education/training programs, AR=Additional Research. See Tables VI-7 through VI-11 for specific implementation activities.

Table VI-3. Summary of Warning Signs Evaluations

Label	Sign Name	Eval Proc ¹	Focus	Finding	Impl Actv ²
W1-1	Turn	ST, 92	Understanding of the speed message and the number of alignment changes conveyed by these signs.	Drivers do not recognize the speed or number messages these signs are intended to convey. An Advisory Speed Plate significantly improves understanding of the speed message.	TxDOT
W1-2	Curve	ST			TxDOT
W1-3	Reverse Turn	ST, 93			DE
W1-5	Winding Road	93			DE
W3-1a	Stop Ahead	ST	Understanding of sign meaning.	Majority of drivers understand the sign.	DE
W4-2	Lane Reduction Transition	ST, FG	Confusion over number of lanes and lane width. Effectiveness of alternative signs.	Many drivers do not understand the meaning of the symbol sign. The alternative symbols were not preferred in the focus groups. Word message signs are better understood than the symbol sign.	AR
W9-1	RIGHT LANE ENDS	FG	Order of sign placement and driving response as a function of the lane position.		
W9-2	LANE ENDS MERGE LEFT	ST, 93, FG			
W5-2a	Narrow Bridge	ST	Understanding of number of lanes and passing restrictions.	More research is needed to evaluate driver interpretation of the sign.	DE, AR
W6-2	Divided Highway Ends	ST	Possible confusion with Divided Highway sign.	Many drivers confuse the two signs.	TxDOT
W8-5	Slow Down on Wet Road	ST, 92 FG	Understanding of sign meaning and confusion with W1-5 sign.	Drivers are less likely to confuse the word message sign with a winding road.	DE, AR
W8-8	ROUGH ROAD	ST	Understanding of sign meaning. Confusion with W8-12 sign.	Most drivers understand the intended meaning of the sign.	TxDOT
W8-12	GROOVED PAVEMENT AHEAD	ST	Understanding of motorcycle message. Confusion with W8-8 sign.	Few drivers recognize that the sign is intended for motorcyclists.	TxDOT
W11-10	Truck Crossing	ST	Understanding of sign meaning.	High association with trucks, but low association with truck crossing or entrance.	AR
W14-4	LIMITED SIGHT DISTANCE	ST	Understanding of sign meaning.	Few drivers understand the sign.	TxDOT
W19-2	WATCH FOR ICE ON BRIDGE	ST	Driver response to sign.	Drivers understand sign, but exhibited a poor driving response.	DE
W19-3	RAMP METERED WHEN FLASHING	ST, 93	Understanding of sign meaning.	Drivers do not understand the concept of ramp metering.	DE

Notes: ¹Evaluation procedures. Abbreviations - ST=statewide survey, 92=1992 Auto Show survey, 93=1993 Auto Show survey, FG=Focus groups. ²Implementation activities. Abbreviations - NA=No action, TxDOT=Change in TxDOT practices, DE=Changes in driver education/training programs, AR=Additional Research. See Tables VI-7 through VI-11 for specific implementation activities.

Table VI-4. Summary of Other Signs Evaluations

Label	Sign Name	Eval Proc ¹	Focus	Findings	Impl Actv ²
---	Warning Sign Shape & Color	ST	Understanding of sign shape and color principles	Many drivers do not associate shapes and colors with specific types of signs.	DE
---	Guide Sign Color	ST			
W10-1	Railroad Advance Warning	ST	Confusion of sign with Crossbuck sign.	Many drivers do not recognize the location message of this sign.	NA
W10-3	Parallel Railroad Advance Warning	ST	Understanding of sign meaning.	Some drivers confused over orientation of sign message.	AR
S1-1	School Advance	92	Effectiveness of alternative design for advance school crossing.	Alternative design is more effective.	AR
S5-1	School Speed Limit	ST	Driver recognition of the end of a school speed zone.	Some drivers do not know where the school speed limit ends.	DE
CW8-9a	Low Shoulder	92	Driver understanding of the difference between the signs.	Drivers do not differentiate between the meanings of the Low Shoulder and Shoulder Drop-Off signs.	TxDOT
CW21-13	Shoulder Drop-Off	92			
CW21-14	Uneven Lanes	92		Drivers understand the meaning of the sign.	
OM-3	Type 3 Object Marker	ST	Meaning of marker.	Some drivers do not understand the marker.	DE

Notes: ¹Evaluation procedures. Abbreviations - ST=statewide survey, 92=1992 Auto Show survey, 93=1993 Auto Show survey, FG=Focus groups. ²Implementation activities. Abbreviations - NA=No action, TxDOT=Change in TxDOT practices, DE=Changes in driver education/training programs, AR=Additional Research. See Tables VI-7 through VI-11 for specific implementation activities.

Table VI-5. Summary of Markings Evaluations

Types of Marking	Eval Proc ¹	Focus	Findings	Impl Actv ²
Single Broken Yellow Center Line	ST	Use of yellow to separate opposing traffic.	Some drivers do not recognize the difference between one-way and two-way markings.	DE
No-Passing Zone	ST	Passing restrictions indicated by markings.	Most drivers recognize the passing restriction.	DE
Two-Way Left Turn Lane Markings	ST	Understanding and use of two-way left turn lanes.	Some drivers do not have a complete understanding of how the lane should be used.	DE, AR
Single Broken White Lane Line	ST, 92	Directional cues of lines, ability to change lanes, and color of markings on a one-way road.	Most drivers understand the meaning of the single white lane line.	TxDOT, DE
Double Solid White Lane Line	ST	Restrictions on lane changing.	Most drivers do not recognize the restrictions imposed by a double white lane line.	TxDOT, DE
Solid White Edge Line	ST	Understanding of marking.	Some drivers do not have a complete understanding of the meaning of the marking.	DE
Preferential Lane Marking	ST	Understanding and familiarity with HOV facilities.	Many drivers do not associate this marking with HOV facilities.	DE

Notes: ¹Evaluation procedures. Abbreviations - ST=statewide survey, 92=1992 Auto Show survey, 93=1993 Auto Show survey, FG=Focus groups.

²Implementation activities. Abbreviations - NA=No action, TxDOT=Change in TxDOT practices, DE=Changes in driver education/training programs, AR=Additional Research. See Tables VI-7 through VI-11 for specific implementation activities.

Table VI-6. Summary of Signal Indications Evaluations

Types of Signal Indications	Eval Proc¹	Focus	Findings	Impl Actv²
Steady Yellow Arrow - Traffic Signal	ST	Meaning of steady yellow indication.	Some drivers do not fully understand the indication meaning.	DE
Flashing Yellow Ball - Traffic Signal	ST	Whether flashing yellow indication means stop.	Almost 1/5 of drivers might stop for a flashing yellow indication.	DE
Flashing Red - Intersection Beacon	ST, 92, FG	Driver recognition of cross-street indications and effectiveness of alternative treatments.	Some drivers do not recognize that cross-street traffic may view a flashing yellow indication. The 2-WAY supplemental plaque improves driver understanding.	DE, AR
Flashing Yellow - Intersection Beacon	ST	Driver recognition of cross-street indication.	Drivers recognize that cross-street traffic views a flashing red indication.	DE, AR
Steady Red X - Lane-Use Control Signal	ST	Meaning of indication.	Some drivers do not recognize the meaning of the indication.	TxDOT, DE

Notes: ¹Evaluation procedures. Abbreviations - ST=statewide survey, 92=1992 Auto Show survey, 93=1993 Auto Show survey, FG=Focus groups.

²Implementation activities. Abbreviations - NA=No action, TxDOT=Change in TxDOT practices, DE=Changes in driver education/training programs, AR=Additional Research. See Tables VI-7 through VI-11 for specific implementation activities.

Table VI-7. Summary of Implementation Activities for Regulatory Signs

Label	Name	No Action	TxDOT Practice				Education &/or Training			Additional Research
			Memo	MUTCD	Part VI	Future	DE/DSC	TDH	Info	
R1-2	YIELD	✓								
R2-5a	REDUCED SPEED AHEAD		✓							
R2-5c	SPEED ZONE AHEAD		✓							
R3-7	Mandatory Turn			✓						
R3-8	Double Turn	✓								
R3-9b	Two-Way Left Turn Lane					✓	✓	✓	✓	
R3-14	HOV Restriction					✓	✓			
R4-3	SLOWER TRAFFIC KEEP RIGHT					✓	✓			
R4-3b	DO NOT CROSS DOUBLE WHITE LINE		✓				✓			
R4-7	Keep Right					✓	✓			
R10-9	PROTECTED LEFT ON GREEN ARROW					✓	✓	✓		
R10-9a	PROTECTED LEFT ON GREEN			✓						
R10-12	LEFT TURN YIELD ON GREEN Ball					✓	✓	✓	✓	

Table VI-8. Summary of Implementation Activities for Warning Signs

Label	Name	No Action	TxDOT Practice				Education &/or Training			Additional Research
			Memo	MUTCD	Part VI	Future	DE/DSC	TDH	Info	
W1-1	Turn		✓					✓	✓	
W1-2	Curve		✓					✓	✓	
W1-3	Reverse Turn							✓		
W1-5	Winding Road							✓		
W3-1a	Stop Ahead							✓		
W4-2	Lane Reduction Transition									✓
W9-1	RIGHT LANE ENDS							✓		
W9-2	LANE ENDS MERGE LEFT							✓		
W5-2a	Narrow Bridge							✓		✓
W6-2	Divided Highway Ends		✓							
W8-5	Slow Down on Wet Road						✓			✓
W8-8	ROUGH ROAD		✓					✓		
W8-12	GROOVED PAVEMENT AHEAD		✓					✓		
W10-1	Railroad Advance Warning	✓								
W10-3	Parallel Railroad Advance Warning									✓
W11-10	Truck Crossing									✓
W14-4	LIMITED SIGHT DISTANCE			✓						
W19-2	WATCH FOR ICE ON BRIDGE						✓	✓		
W19-3	RAMP METERED WHEN FLASHING						✓	✓		

Table VI-9. Summary of Implementation Activities for Other Signs

Label	Name	No Action	TxDOT Practice				Education &/or Training			Additional Research
			Memo	MUTCD	Part VI	Future	DE/DSC	TDH	Info	
---	Warning Sign Shape & Color						✓	✓	✓	
---	Guide Sign Color						✓	✓	✓	
S1-1	School Advance								✓	✓
S5-1	School Speed Limit								✓	✓
CW8-9a	Construction Low Shoulder				✓					
CW21-13	Construction Shoulder Drop-Off				✓					
CW21-14	Construction Uneven Lanes				✓					
OM-3	Type 3 Object Marker						✓			

Table VI-10. Summary of Implementation Activities for Markings

Name	No Action	TxDOT Practice				Education &/or Training			Additional Research
		Memo	MUTCD	Part VI	Future	DE/DSC	TDH	Info	
Single Broken Yellow Center Line						✓			
No-Passing Zone						✓			
Two-Way Left Turn Lane Markings						✓	✓	✓	✓
Single Broken White Lane Line					✓	✓			
Double Solid White Lane Line		✓				✓	✓		
Solid White Edge Line						✓			
Preferential Lane Marking							✓		

Table VI-11. Summary of Implementation Activities for Traffic Signal Indications

Name	No Action	TxDOT Practice				Education &/or Training			Additional Research
		Memo	MUTCD	Part VI	Future	DE/DSC	TDH	Info	
Steady Yellow Arrow - Traffic Signal						✓			
Flashing Yellow Ball - Traffic Signal						✓			
Flashing Red - Intersection Beacon						✓	✓	✓	✓
Flashing Yellow - Intersection Beacon								✓	✓
Steady Red X - Lane-Use Control Signal					✓	✓	✓		

CHAPTER VII

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TxDOT IMPLEMENTATION OF 1261 STUDY FINDINGS

REDUCED SPEED AHEAD (R2-5a) AND SPEED ZONE AHEAD (R2-5c) SIGNS

The **Reduced Speed Ahead** and **Speed Zone Ahead** signs shown in Figures E-1 and E-2 are both used to provide the driver with advance notice of a lower speed limit. The Texas MUTCD indicates that either of these signs can be used for this purpose. These signs are always followed by a **Speed Limit** sign. These signs were included in the study in order to determine if one sign was better understood than the other sign.

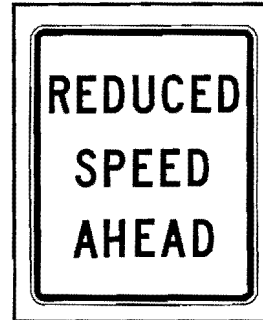


Figure E-1.
R2-5a Sign

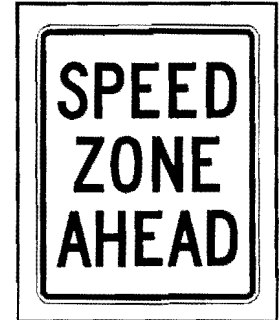


Figure E-2.
R2-5c Sign

Identical questions were asked for the **Reduced Speed Ahead** and **Speed Zone Ahead** signs in the statewide survey, along with identical responses, as shown in Table E-1. The results indicate that many drivers (31 percent) associate the term "*speed zone*" with enforcement, instead of a lower speed limit. The survey results indicate that the **Reduced Speed Ahead** sign is more effective than the **Speed Zone Ahead** sign at conveying the desired message.

Table E-1. Statewide Survey Results for Changes in Speed Limit Signs

Question:	<i>What is the meaning of this sign?</i>	
Responses	Speed Zone Ahead	Reduced Speed Ahead
The speed limit will be higher ahead.	6.2%	1.9%
The speed limit ahead will be strictly enforced by the police.	31.1%	3.7%
The speed limit will be lower ahead.	55.0% (correct)	93.2% (correct)
Not sure.	7.7%	1.1%

TURN (W1-1) AND CURVE (W1-2) SIGNS

The **Turn** and **Curve** signs shown in Figures E-3 and E-4 are used to provide drivers with advance warning of a change in horizontal alignment. The signs indicate the direction and severity (speed) of a change in horizontal alignment. Both the **Turn** and **Curve** signs were

evaluated in the research study. The focus of the evaluations were driver comprehension of the speed message of the signs.

The **Turn** sign was evaluated in the statewide and 1992 Auto Show surveys. Table E-2 summarizes the response percentages from the two surveys on the **Turn** sign. The questions were intended to evaluate whether drivers recognized that this sign is used when the recommended speed shown in the legend is 30 mph or less. Approximately one-third of the drivers selected this response when the **Turn** sign was shown alone. Almost half of the drivers selected the response which indicates a right turn at the next intersection. These results indicate that drivers do not recognize the speed message of the **Turn** sign by itself. When the 30 mph **Advisory Speed Plate** was shown with the **Turn** sign, driver understanding of the speed message improved to 95 percent, as compared to the 32 and 36 percent for the **Turn** sign without the **Advisory Speed Plate**.

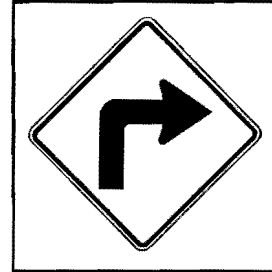


Figure E-3.
W1-1 Sign

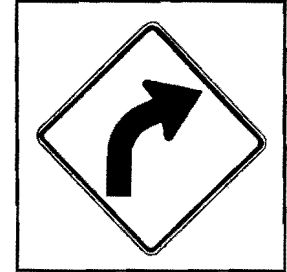


Figure E-4.
W1-2 Sign

Table E-2. Survey Results for the Turn Sign

Question:	What does this sign mean?		
Responses	Statewide Survey	1992 Auto Show Survey	
	Turn sign without Speed Plate	Turn sign without Speed Plate	Turn sign with 30 mph Speed Plate
There is an intersecting road to the right ahead.	10.7%	11.7%	1.8%
You should drive 30 miles per hour or less to make the next turn.	31.9% (correct)	35.9% (correct)	94.7% (correct)
You should turn right at the next intersection.	45.2%	49.5%	3.5%
Not sure.	12.2%	2.9%	0%

The statewide survey question on the **Curve** sign was also intended to evaluate driver understanding of the speed message conveyed by this sign. The sign was shown alone, without an **Advisory Speed Plate**. Table E-3 indicates the responses to the question. When given a choice between slowing down and driving the curve at the speed limit, two-thirds selected the

"slow down" choice and one-third selected the "speed limit" choice. These findings indicate that drivers do not understand the speed message of the Curve sign.

Table E-3. Statewide Survey Results for the Curve Sign

Question:	<i>How should you respond to this sign?</i>	
Responses	Curve sign	
The road will curve to the left a short distance ahead and you should slow down before reaching the curve.	65.0%	
The road will curve to the left a short distance ahead, but you may drive the curve at the speed limit.	32.4% (correct)	
The next mile of highway has several curves and you should slow down.	1.7%	
Not Sure	0.9%	

DIVIDED HIGHWAY ENDS (W6-2) SIGN

The Divided Highway Ends sign shown in Figure E-5 is intended for use where a divided roadway changes to a two-way roadway. It was selected for evaluation in this study because of potential driver confusion between this sign and the Divided Highway sign.

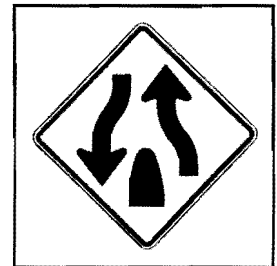


Figure E-5. W6-2 Sign

The responses to the statewide survey question are shown in Table E-4. They included one response that represented the Divided Highway sign. Half of the drivers selected the correct answer for this sign. Over one-third of the drivers selected the "divided highway ahead" response, indicating some degree of confusion between the Divided Highway Ends and the Divided Highway signs.

Table E-4. Statewide Survey Results for the Divided Highway Ends Sign

Question:	<i>What is this sign telling you?</i>	
Responses	Divided Highway Ends sign	
There is two-way traffic ahead.	50.7% (correct)	
There is one-way traffic ahead.	6.0%	
There is a divided highway ahead.	37.8%	
Not sure.	5.6%	

ROUGH ROAD (W8-8) AND GROOVED PAVEMENT AHEAD (W8-12) SIGNS

The two word message signs shown to the right are used to warn drivers of atypical pavement surface conditions. The **Rough Road** sign is intended for use when the pavement surface is extraordinarily rough. This sign should be removed when the rough pavement condition is corrected. The **Grooved Pavement Ahead** sign is intended to warn motorcyclists that there

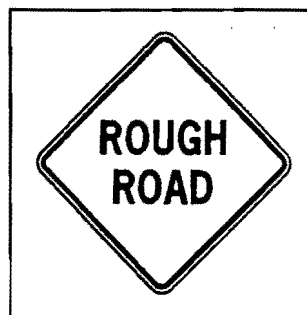


Figure E-6.
W8-8 Sign



Figure E-7.
W8-12 Sign

are grooves in the road. These signs were included in the research effort in order to evaluate the extent to which drivers distinguish between the two signs and to determine if the motorcyclist message of the **Grooved Pavement Ahead** sign was being understood by drivers.

The statewide survey results for these two signs are shown in Table E-5. Almost 90 percent of drivers understood that the **Rough Road** sign indicates that the pavement is in poor condition. Less than 10 percent thought the sign was intended to warn motorcyclists. The results for the **Grooved Pavement Ahead** sign indicate that less than 30 percent of the drivers correctly realize that the sign is intended primarily for the benefit of motorcyclist. Many of those that selected the correct response were young and had a motorcycle license. None of the response choices were selected by more than 40 percent of the drivers, although the choice which indicated a noisier road was the most frequent choice, with 40 percent of the drivers choosing it. This sign was one of ten signs in the survey with a "not sure" response greater than 10 percent.

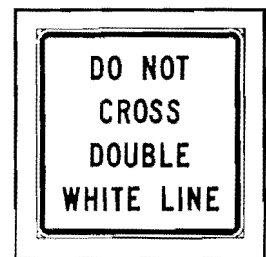
Table E-5. Statewide Survey Results for Pavement Condition Signs

Question:	<i>What is the purpose of this sign?</i>	
Responses	Rough Road	Grooved Pavement Ahead
To let motorists know the road will be slippery when wet.	---	16.5%
To let motorists know the pavement is in poor condition.	88.7% (correct)	---
To let motorists know the road will be noisier ahead.	2.5%	39.5%
To let motorcyclists know they should use caution.	7.2%	29.2% (correct)
Not Sure	1.7%	14.7%

The results for these signs indicate that most drivers understand the intended meaning of the **Rough Road** sign and less than one-third of drivers recognize that the **Grooved Pavement Ahead** sign is intended for motorcyclists. More drivers selected the noisy pavement response for the **Grooved Pavement Ahead** sign than any of the other response choices provided in the survey.

DOUBLE SOLID WHITE LANE LINE PAVEMENT MARKING AND DO NOT CROSS DOUBLE WHITE LINE (R4-3b) SIGN

The double solid white lane line pavement marking is used to indicate where travel in the same direction is permitted on both sides of the line, but crossing the line is prohibited. The **Do Not Cross Double White Line** sign shown in Figure E-8 is used as a supplement to the pavement markings to inform drivers of the restriction. Both devices were included in the survey to establish driver comprehension of the prohibitory nature of the marking and the need for the sign as a supplement to the markings.



**Figure E-8.
R4-3b Sign**

The statewide survey responses for the marking and sign are shown in Tables E-6 and E-7. Only 61 percent of the drivers knew the correct response for the marking. Twenty-nine percent selected the responses which indicated that lane changing was permissible, and ten percent were not sure what the marking meant. The double solid lane line marking was one of ten devices in the survey that had "not sure" response choices of ten percent or more. When the sign was shown to drivers, 84 percent selected a response which indicated lane changing was prohibited. Twelve percent appeared to confuse the double white markings with double yellow markings indicating a two-way road.

Table E-6. Statewide Survey Results for Double White Line Marking

Question:	<i>Which one of the following statements is true about the double white lines on the pavement?</i>	
Responses	Double Solid White Lane Line Marking	
It is illegal to change lanes across these lines.	61.0% (correct)	
You may change lanes across these lines with caution, if necessary.	22.1%	
You may change lanes across these lines from left to right, but not from right to left.	6.9%	
Not Sure	10.0%	

Table E-7. Statewide Survey Results for the Do Not Cross Double White Line Sign

Question:	<i>What does the sign on the right mean?</i>	
Responses	Do Not Cross Double White Line sign	
Do not change lanes or turn across the double white lines.	72.6% (correct)	
Do not pass. Two-way traffic.	9.6%	
Do not change lanes.	11.7%	
Not Sure	6.1%	

The results of the two questions addressing the double solid white lane line marking and sign indicate that drivers do not have a complete understanding of the intended meaning of the marking when viewed in isolation. Comprehension of the markings was much better when the sign was shown to drivers.